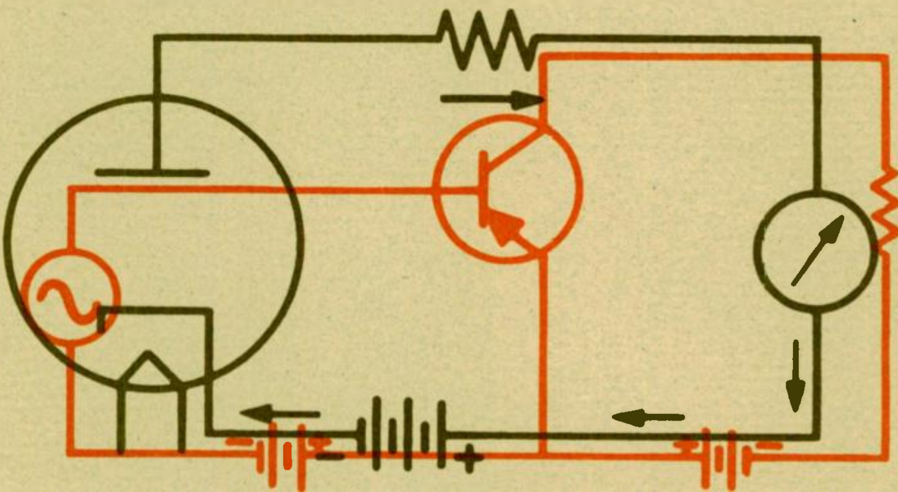
LESSON NO. 73

RECORD PLAYERS



RADIO and TELEVISION SERVICE and REPAIR

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Contents

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INTRODUCTION

Few things appear to be as complicated as the cams, levers, and slides found underneath the baseplate of a record changer. At first glance it may seem impossible to determine the function of each piece. Yet each piece is there for a purpose and, altogether, these pieces represent years of careful engineering by the changer manufacturers. These parts have to do with the change cycle. They control the acts of lifting the tone arm off a record when it has reached the end of the record, moving the arm back beyond the edge of the record, dropping the next record into playing position, then moving the arm over the beginning grooves of the new record and setting it down to play that record.

Each manufacturer has his own way of accomplishing the change cycle. Yet, the functions above the baseplate are about the same for all record changers. Credit should be given to the manufacturers for making these functions fairly standard.

WHAT RECORD CHANGERS ARE AND DO

"Record changers" or, if you prefer, 1 "automatic turntables" are devices 2 designed to accept a stack of phonograph records and play them all, one at a time, changing them automatically, going through all the mechanics of handling the tone arm, and finally shutting off automatically after the last record is played. A widely used name for these devices is "record changer." However, some manufacturers do make an unusually good quality changer, and prefer to call them "automatic turntables." (Fig. 1).

Figure 1 — The Garrard Model SL-95 automatic transcription turntable shown with manual spindle.

There are some home record changers available that will play each side of each record in sequence. They turn each record over, one at a time. This is a desirable feature but it takes a complicated and expensive mechanism to do it.

Figure 2 — A recent model V-M changer containing most of the standard features used on today's record changers.

The more popular record changers of today (Fig. 2) play a stack of records, one side of each record only, until the complete stack is finished. After the last record is played, the entire stack is turned over manually. Then the second side of each record is played in sequence. This system is satisfactory for playing 45-rpm single-song records, and 33¹/₃-rpm popular-song albums. Symphonies, operas, and musical comedies, however, usually take both sides of a 12-inch LP record and must be played manually if a continuous performance is to be heard. This is probably the main drawback of the popular record changer.

Record-Changer Features

While this lesson deals primarily with how record changers work—that is, how the records are fed to the turntable, how the tone arm works, the operation of the change cycle under the baseplate, and the functions of the motor, the cartridge, and the needle or stylus—there are certain differences in features among different record changers that are worth noting. The differences can be important depending on the user's purpose for the record changer.

Hi-Fi enthusiasts will be interested in one or more of the following features found to a greater or lesser degree on better record changers:

Plug-in Cartridges. Most record changers have a ceramic cartridge with a dual stylus. Either the cartridge or the stylus flips over for playing either the old 78-rpm records, or the modern LP microgroove records. A few come with magnetic cartridges. Some of the better changers are not supplied with a cartridge; a high-fidelity magnetic cartridge must be purchased separately. These cartridges have a single stylus for playing microgroove records only. A separate, plug-in cartridge must be purchased for playing 78-rpm records.

Adjustable Tone Arm. Because high-fidelity cartridges are critical as to stylus pressure on the record, better changers have a counterweight system of balancing the tone arm precisely.

Turntable Inertia. The heavier the turntable platter, the better the speed constancy and the lower the turntable rumble. Some changers have platters weighing as much as 6 to 7¹/₂ pounds.

Turntable Surface. Most turntable platters have a rubber mat mounted on the top surface on which the record rests while being played. This mat is used to protect the record from damage and also to provide friction so that the record will not slip on the turntable while playing. Most of the turntable mats supplied with record changers by the major manufacturers have concentric ribs over their surface to provide as much additional friction as possible. These rubber mats are relatively heavy and not cemented to the platter itself and can therefore be easily removed.

Cuing Lift. A lever on the side of some changers is used to lift the arm off the record, or place it down on a special part of the record when it is desired to play a certain selection on a 12-inch LP record.

Anti-Skating. Nearly all record changers today have anti-skating schemes for overcoming the tendency of the tone arm to be pulled in towards the center of the record as it is playing. This is important in playing stereo records. Better changers include a means for adjusting the amount of anti-skate, as this is tied in with stylus pressure and trackability.

The improvement in records, and especially the need to play stereo records, has brought about improvements in the quality of record changers. The very fine microgrooves in LP records have resulted in designs for tone arms with lighter stylus pressure on the record. This, in turn, made it necessary to develop record-changer tripping mechanisms that would respond to feather-touch movement of the tone arm. In many changers no change was made in the basic design of the mechanism but levers and other moving parts were more precisely made and better pivoted (Fig. 3).

Figure 3 — The Miracord Model PW-40 automatic turntable shown with automatic spindle.

Before the days of stereo, monophonic cartridges were made to respond only to the lateral movement of the stylus. Vertical movement was purposely stiff to reduce the response to turntable rumble. Stereo cartridges, in order to produce two-channel information from one groove, respond both to lateral and vertical movements. The two channels of information are at a 45-degree angle from the vertical (or horizontal) and 90 degrees from each other. When music comes from both channels at the same time, as it nearly always does, the stylus will sometimes move horizontally and sometimes vertically, but mostly a combination of both. Stereo, then, imposes a new requirement on record changer design—the changer must produce a minimum of rumble. This is accomplished by better resilient mounting of the motor to the baseplate, newer and better material on the idler wheel that couples the power of the motor to the turntable, and better shock mounting of the entire changer to the cabinet or base on which it rests.

Changer Manufacturers

There are a number of manufacturers of record changers, both domestic and foreign. There are more manufacturers of radio and TV consoles, and record players using changers. Many of the set and phonograph manufacturers find it more economical to contract with a well-known changer manufacturer to supply them with their changer needs. This may call for a change in appearance on top, and even a change in some of the operating features. Because these changers carry the label of the set maker, they are referred to as "private label" changers. A close look at the mechanism under the baseplate is necessary in order to identify the changer manufacturer. The set makers issue their own service instructions, and usually have their own replacement part numbers and supply centers.

Look carefully at the inner grooves of a modern record. The grooves are very closely spaced, so closely in fact that the records are called "microgroove" records. At the end of the playing grooves, the stylus enters a series of widely-spaced grooves known as "runout" grooves. It is these widely-spaced grooves that initiate the changer's tripping mechanism. This is because the tone arm moves faster across the record on the widely-spaced grooves than it does on the play grooves. The term *velocity trip* for starting the change cycle comes from the increased velocity of the movement of the tone arm on the wider-spaced grooves. In spite of the differences between changers in their methods of accomplishing the change cycle, they all depend on the same runout grooves to start the cycling. Nearly all of today's changers start their cycling sequence with velocity trip.

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Record Speeds

Power for turning the turntable and operating the change cycle comes from a small motor mounted underneath the baseplate. The motor is usually coupled to the turntable through an idler wheel that is between the pulleys on the shaft of the motor and the inner rim of the turntable. The idler wheel is rubber or neoprene rimmed, which substantially reduces the transfer of motor noise to the turntable.

Nearly all record changers today will play records at $16^2/_3$, $33^1/_3$, 45, or 78 rpm (revolutions per minute) of the turntable by merely pushing a lever or turning a knob. They are also designed to automatically change 7-inch, 10-inch or 12-inch records. The mechanism has a feedback system that "knows" whether you have a stack of 7-inch, 10-inch, or 12-inch records on the center spindle. On some changers you can intermix 10-inch and 12-inch records.

The $16^2/_3$-rpm speed is very slow and is for playing "story book" records, of which there is a rather limited selection available. Because of the slow speed, higher musical frequencies suffer, so this speed is not used for high-fidelity musical selections.

The $33^{1}/_{3}$-rpm speed is for playing 10-inch and 12-inch microgroove records called albums because they contain a complete symphony, opera, musical comedy, or a large number of individual songs. (A few 7-inch records have been made at $33^{1}/_{3}$ rpm.) This speed is slow enough to get long-play (LP) music out of a single record, since it is also coupled with closely spaced grooves, and with modern recording and pressing techniques, excellent fidelity is achieved even at this slow speed.

The 78-rpm speed was *the* standard speed of all records in years past. At that time this speed was necessary to assure some fidelity to the music, especially because the records were not made of fine plastic as they are now. The high speed and widely-spaced grooves resulted in a short playing time. There are no 78-rpm records being made today, but because so many people still have a good library of these records on hand, this speed is included on most record changers. The center holes on all except the 45-rpm record are small, ($^{1}/_{4}$-inch diameter) and are designed to fit the standard center spindle of the changer.

The 45-rpm record is 7 inches in diameter and ideal for single-song use. It has an extra large center hole, which was designed for a special record-dropping spindle. Most of today's changers are equipped with a 45-rpm spindle adapter that fits over the standard spindle, for playing 7-inch, 45-rpm records. The Zenith changer has the special 45-rpm spindle folded into the turntable. When needed, the two halves are folded out from wells in the turntable. For changers having no special 45-rpm spindle, you can purchase special discs which fit into the large center holes of the records. These discs have small center holes for use on the standard spindle.

Only records to be played at the same speed are to be stacked together for playing in one session. This is because the speed of the changer is selected manually. On some changers 10-inch and 12-inch records may be stacked intermixed for playing at the same speed, but some changers require stacking 10-inch records separately from 12-inch recrods.

The number of records that can be stacked on a changer is a function of the height of the stack. Depending on the changer, and on the thickness of the records, the number of records varies from 6 to 12.

Manual Play

Most changers permit manual play of single records. By moving the record leveler above the turntable to one side or switching to "MAN" position on the panel control knob or selector, the mechanism is set up for manual play. Most changers recycle automatically even on manual play, some bringing the tone arm to rest on its rest post and shutting off the motor, others returning the tone arm to its rest post, but allowing the motor to continue to run. On most record changers you must manually place the tone arm into the starting grooves of the record on manual play. A few will set down the tone arm at the beginning of the record automatically.

The Motor

The motors on most record changers are called 2-pole, shaded-pole, or induction motors. They develop a very small amount of power, but very little power is needed. To give you an idea of the amount of power they develop, it would take about 100 phono motors to equal the power of a 1/4-horsepower motor, such as those used in washing machines and other moderate-duty applications. Motors are largely dependent for their speed on the 60-Hz frequency of the power-line voltage. For this reason, motor speed remains fairly constant even with moderate variations of the line voltage. Better changers use a 4-pole motor, which produces less vibration as it drives the turntable rim.

The Stylus or Needle

Of course, the whole object of a record player is to turn the record at a constant speed and let a tone arm convert the variations of the record grooves into sound. This is done by mechanically vibrating a stylus (needle) by the wavy course it follows in the record grooves, transferring that motion into electrical energy through a cartridge.

Styli differ as to the radius of the tip, and the material from which the tips are made. For microgroove records the point must be sharp, and usually has a radius of from 1 mil (.001 in' to .7 mil (.0007 in.), and sometimes as small as .5 mil for stereo records. A 3-mill radius is most common for the older 78-rpm records.

Many cartridges are made with a separate stylus on each side, one for microgroove records (with a 1-mil radius), and the other for 78-rpm records (with a 3-mil radius). You manually flip the cartridge over in the tone arm for the stylus you want to put into play. On most cartridges both styli are separate points, one on each side of a revolving common shank on one side of the cartridge. Flipping a lever turns the shank on its axis and places the proper stylus into play.

Some low-cost monophonic phonograph systems use a single stylus with a compromise point radius of 2 mils, for playing both 78-rpm and microgroove records.

Better styli have a point made of diamond; others have sapphire points. A diamond point lasts longer.

The Cartridge

Most record changers are equipped with a ceramic cartridge. The cartridges for high-fidelity systems are usually magnetic, and even their quality can vary considerably. Magnetic cartridges have very low output. That is, the same stylus movement in the groove produces a much lower voltage output from a magnetic cartridge than from a ceramic cartridge. Therefore, a magnetic cartridge calls for a higher order of amplification in the amplifier.

Stereo cartridges may be of the ceramic or magnetic type, but they are quite different from the monophonic types. You might say that they consist of two cartridges in one, but are driven by a single stylus. Each cartridge section produces the voltage for one of the channels of information. Magnetic stereo cartridges are never dual stylus, as they are never intended for playing 78-rpm records. They have a single stylus with a .7- or .5-mil radius. Newer types are even more sophisticated, and are ground to an ellipse with dimensions of some from .0009 in. × .0002 in. to others at .0007 in. × .0003 in. Also they are set at a precise 15-degree angle considered optimum for stereo records. These latter cartridges are quite high priced and may or may not be supplied with the changer; they sometimes must be purchased separately. Stylus pressure for a magnetic cartridge using an elliptical stylus must be very light, usually on the order of from 1/2 to 6 grams, with the nominal pressure usually being about 1 gram.

Record Speeds

The four standard turntable speeds for record changers are 16 2/3, 33 1/3, 45, and 78.26 revolutions per minute. For the sake of simplicity, however, the fractions on the numbers are dropped, and the four speeds are shown on the speed selector as 16, 33, 45, and 78.

On many changers, the speed selector is a round knob with a pointer. Some changers make the speed-selector knob concentric (on one shaft bushing) with the function control. Others use a separate slide type control.

Turntable speed is a function of the motor speed times the ratio of the diameter of the motor shaft driving the idler wheel (a rubber-tired wheel under the plate), and the diameter of the inner surface of the turntable rim. The driving end of the motor shaft is ground to four steps, thus there are four diameters to choose from to drive the idler wheel. The action of the speed-selector knob above the baseplate moves the idler wheel up or down to engage the right step on the end of the motor shaft. The smallest diameter step will turn the turntable at the slowest speed, 16 rpm, and so on up the line of increasing step diameters to 78 rpm (Fig. 4).

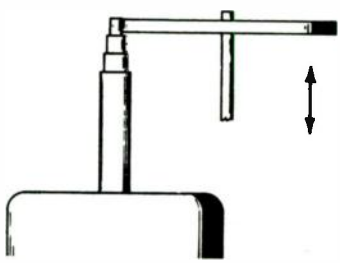


Figure 4 — Speed change is accomplished by moving the idler wheel up or down to engage the correct diameter step on the end of the motor shaft.

Off-On-Reject

The function switch may have only the three designations shown in the heading, or it may have another one called MANUAL or just MAN. The ON position of the control merely turns on the AC voltage to the motor. The REJECT position trips the cycling mechanism the same way the movement of the tone arm does when the arm is in the runoff grooves at the end of a record. The REJECT position is either spring return or mechanism return, but the switch does return to the ON position once the change cycle has been initiated. A MANUAL position on the function control merely defeats the change-cycle mechanism to permit playing records the same as on a non-changing record player. Changers without the MANUAL position accomplish the same thing in another way.

Stylus Selection

Changers supplied with a ceramic cartridge will have a means for picking the stylus tip for playing 78-rpm records, or microgroove (LP) records. Either the cartridge is two-sided, with a stylus on each side, or the stylus will have two points. In either case a turnover method is used. A lever extending out the side of the tone-arm head will carry markings such as "78" on one side and "33" on the other, or "S" on one side and "LP" on the other, or something similar to identify the 78-rpm stylus vs. the microgroove stylus. Flipping the lever down and to the other side of the tone-arm head turns the cartridge over, or turns the stylus over (Fig. 5). Some cartridges use a swing type stylus with two points, one on each end of an inverted T. The shaft protrudes up through the cartridge and out the tone-arm head. The inverted T is swung around for placing the proper stylus point into play, by pressing down slightly and turning.

Center Spindle

In the center of the turntable is a 1/4-inch diameter spindle, the top of which is offset to form a shelf. All records except the 45-rpm types have a 1/4-inch diameter hole in the center. When a stack of records is placed on the spindle, they rest on the shelf, above the turntable. The section of the spindle above the

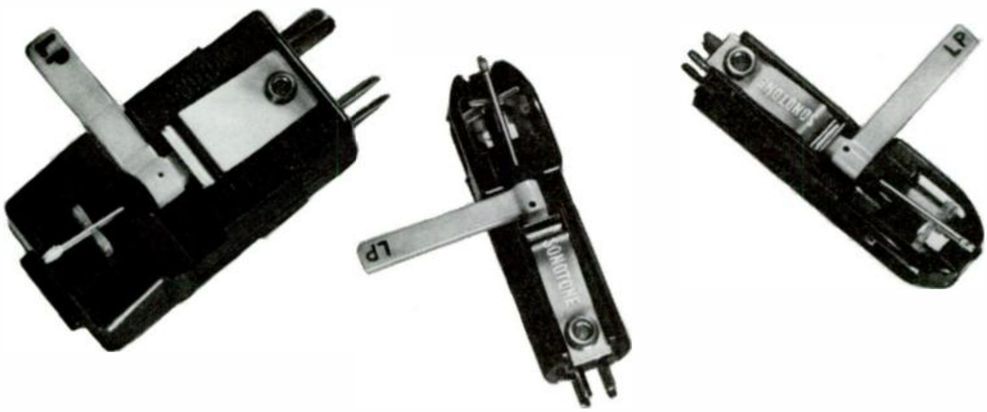


Figure 5 — Examples of ceramic cartridges with dual-point, single-shank styli.

shelf is long enough to hold from 6 to 12 records (depending on the manufacturer) at one time. Inside the spindle is a lever which is activated by the change mechanism beneath the baseplate. The lever size and offset is proportioned to move only the bottom record over slightly from beneath the stack and onto the main spindle so that the record will drop to the turntable. The rest of the stack remains offset, and on the shelf.

The center hole diameter on 45-rpm records is much larger and requires the use of a 45-rpm adapter spindle over the 1/4-inch spindle. The adapter is either supplied with the changer or may be purchased separately. In the Zenith changer, the special 45-rpm spindle splits in two and folds down into the turntable. The records are supported on ears or blades protruding out of the 45-rpm adapter. The lever in the regular spindle acts on the mechanism of the adapter to drop one record at a time. The 45-rpm records may be equipped with reducers which adapt the records for use on the regular spindle.

Record-Leveler Arm

An arm lies on top of the record stack on the spindle to hold the stack in a level position. This arm is called a record-leveler arm, a record-support arm, or a record-balance arm. The arm lifts up and swings away to clear the top of the spindle and make room to put a stack of records onto the spindle. In most models the arm lifts and swings to the right, or counterclockwise, snapping into a detent to hold the arm in position above or parallel with the tone arm while the records are being stacked. In some models, the arm swings the other way.

The number of records that may be stacked varies with different changers. Many manufacturers limit the stack to 6 records. Other manufacturers design their changers for a stack of up to 12 records. Some specify the stack in inches, such as 7/8-inch. To design a changer for higher stacks would be easy for any changer manufacturer, but the loss of good playing angle for the tone arm between the first and last records imposes a practical limit of 12 to the record stack.

Automatic Play

Once the user has selected the stylus and the speed and has operated the REJECT switch (the REJ switch starts the automatic play, whether it is used to reject a record in the middle of its play, or to start the mechanism for automatic play at the beginning), the changer handles a stack of records automatically. After the tone arm reaches the end of play, it enters the runout grooves in the record which are spaced farther apart than the regular play grooves. The movement of the tone arm during its inward travel is speeded up in the runout grooves. This increased velocity trips the change-cycle mechanism beneath the baseplate.

Tone-arm setdown on a record of any size is automatic. Feelers positioned on or near the turntable determine the presence (or absence) of records and their size, and direct the setdown mechanism for the tone arm.

Manual Play

On changers where the function switch includes a MANUAL position, switching to MAN defeats the change-cycle mechanism. In this event, the leveler must be out of the way.

Automatic Shutoff

After the last record is played, the tone arm is brought to rest off the record, and the motor is automatically shut off. Also, the idler wheel is lifted away from contact with the motor shaft and the turntable rim. This avoids the development of flat spots on the rubber or neoprene tire on the idler wheel.

THE CHANGE CYCLE

The most interesting, although the most difficult, operation to follow is the record-changing cycle. There are many similarities between changer makes in the change cycle, but each make differs from the other in many details. Each manufacturer has designed his changer to meet the operating requirements at minimum manufacturing cost, and each has a patented system different from the others, for his particular market.

Changer Similarities

All changers meet certain basic requirements, easily recognized just by looking at the top of the record changer. Each must hold a stack of records, dropping one record at a time from the bottom of the stack onto the turntable, or onto the records already dropped. Each changer synchronizes this with the movement of the tone arm, as the arm ends its play of the previous record.

All changers have a mechanism that lifts the tone arm at the end of a record, and then moves the arm out of the way while the next record drops. The mechanism then moves the arm over the starting grooves of the new record and lowers the arm into play position. At this point, the change cycle ends and the arm is free to move with the record grooves. All pressures due to the change cycle have been neutralized, which is important to the unhindered movement of the tone arm while playing the record.

In spite of what seems to be vast differences in the mechanism details of each make of changer, a few parts are similar in nearly all of them. In most changers a small gear at the hub of the turntable turns a larger gear. It is the large gear that does the work by engaging slides or levers as it rotates, and these levers in turn activate other levers.

The large gear has a small section on its outer rim that is void of teeth. This is the neutral position that allows the turntable to rotate freely while playing a record.

The way in which the large gear first engages the turntable gear is also quite similar in most changers.

The system has the name "velocity trip" and is a function of the increased speed of movement of the tone arm as the stylus leaves the regular playing grooves of a record and starts into the runoff grooves at the end of the record. The runoff grooves are more widely spaced than the regular play grooves, so the tone arm moves inward toward the hub at a faster rate.

Most velocity-trip mechanisms function approximately as follows: A small trip lever or pawl on the main drive gear is lightly touched by a finger coupled indirectly to the tone arm. The other side of the pawl rubs against a protrusion or pin on the turntable as the turntable revolves. The space between the play grooves on a record is so small that the pawl barely moves with each revolution of the record, and the protrusion on the turntable pushes the pawl aside each time it comes around. However, when the tone arm starts to move faster on the runoff grooves of the record, the pawl is able to get in front of the turntable protrusion, and is pushed by it. This action is coupled to the large gear and causes its teeth to become engaged with the teeth on the turntable hub. Thus, when an increase in the *velocity* of the tone arm, the change cycle begins.

The center spindles in most changers are quite similar. They are offset vertical spindles which depend on a shelf at the offset point to hold the record stack. A push rod in the center of the spindle is coupled to a lever inside the spindle. When the rod is pushed from underneath, it causes the lever to push the bottom record of the pile off the shelf. The record then falls down the spindle onto the turntable.

A "feedback" system is used on changers to supply information for proper setdown for the tone arm on the beginning grooves of various size records. Fingers either feel the edge of the record being played or feel the presence or absence of some record sizes.

How To Watch The Change Cycle

Nothing is as educational in learning how a change cycle performs as observing the action on your own changer. To do this best you must lift the changer out of its base or mounting board. When out, the changer must be supported on some structure that tilts slightly so you can see the bottom mechanism. Servicemen use a device called a "chassis cradle" (Fig. 6), which sells for about $7.35. These are designed to hold radio or TV chassis as well as record changers, are adjustable as to size, and permit free tilting of the changer for easy inspection. A simple, homemade device could be made by fastening three upright wood supports to a board. The back upright should be shorter than the two front uprights to provide tilt to the changer.

Slowly rotate the turntable clockwise, and operate the Reject switch on top. This starts the change cycle, the action of which can be watched while you hand-rotate the turntable.

On most changers, all the action

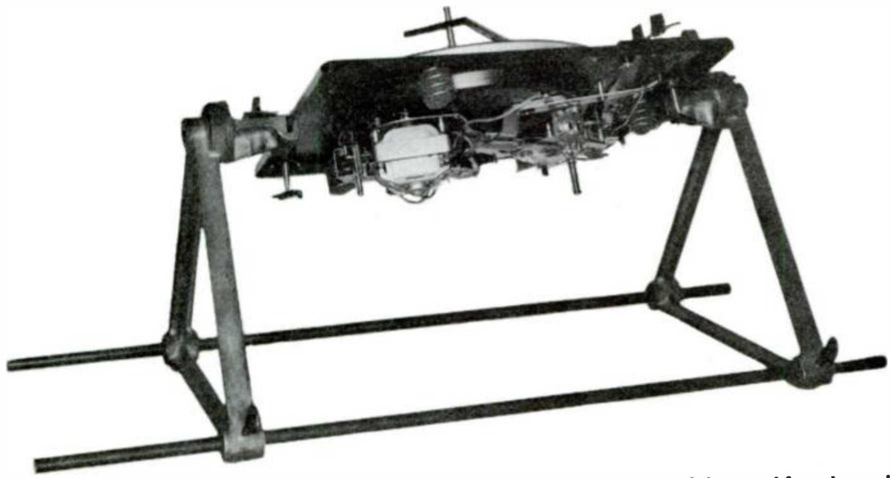


Figure 6 — A changer mechanism mounted on a "chassis cradle" for servicing and for observing the change cycle.

takes place underneath the baseplate of the changer. There are some exceptions (as for example, Admiral) in which the large gear is between the turntable and the top of the baseplate. The action can be seen only on removal of the turntable; but, removing the turntable also removes the center hub gear. You can, however, purchase a hand-rotatable center hub gear from Admiral.

The Five Basic Operations

There are five basic operations a changer goes through in the change cycle. These are generally sequential, but some actions overlap. All actions are synchronized to occur at the right time. The basic actions are as follows:

1. *Start of cycle with large gear engaging center hub gear*—This was described in the discussion on velocity trip.
2. *Lifting of tone arm and moving it aside*—The arm is fastened to a vertical rod, the bottom of which protrudes below the baseplate. The rod is lifted from below by cam action of one kind or another. A lever acts on a horizontal member of the vertical rod to move the arm aside.
3. *Dropping a record*—A cam moves a rod inside the center spindle up to operate the push-off lever.
4. *Returning arm to record starting groove*—On release, a cam working on the vertical rod of the tone arm moves the arm inward. The arm's travel is limited by the record-size feedback system. The arm is lowered by the lifting cam moving out of the way.
5. *Last record shutoff*—The lowering of the record-leveling arm on release of the last record off the spindle shelf engages a lever which, during the following cycling operation, pushes the AC switch off at the moment the cycling operation returns to neutral.

MOTORS

The pitch or frequency of a musical note must be true or the music will not sound right. Record manufacturers go to considerable expense to maintain a constant tape speed in the original recording, and constant turntable speed in transferring the tape to a master disc. To reproduce the record as it should be, the record must turn on the record-player turntable at a precise $33^1/_3$, or 45, or 78.26 revolutions per minute, depending on the record. This calls for a constant speed on the part of the turntable.

On most record changers, the speed of the turntable is a function of the motor speed, and the ratio of speed reduction between the shaft of the motor and inner rim of the turntable. (Some changers use a belt between the motor and the outside of the turntable rim.) The shaft does not engage the turntable rim directly, but indirectly through an idler wheel (Fig. 7). The idler wheel has no effect on the speed; it can be any size and the speed at the turntable will not be affected. The idler wheel acts as a buffer between the motor and the turntable to reduce the effects of motor vibration. The idler is spring-loaded, and has a rubber or neoprene rim.

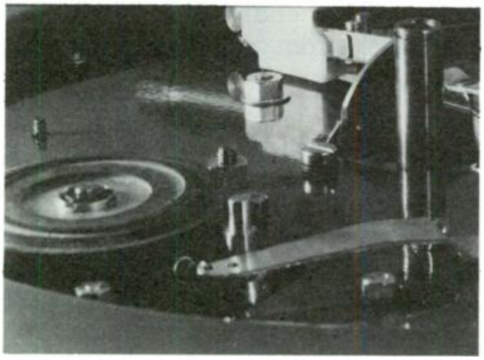


Figure 7 — Close-up view of top of changer with turntable removed. Idler wheel and stepped motor shaft are at left-center of picture.

The actual motor shaft bears on the idler wheel. The shaft has a four-step diameter at one end, and this engages the idler wheel. Each diameter of the four steps is precisely machined to have the proper ratio between the steps and the turntable rim, for the four speeds available on most record changers. The speed-change lever on top of the changer shifts the idler wheel to engage the proper step on the shaft (Fig. 8).

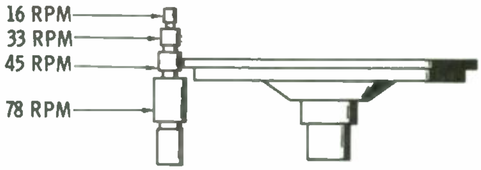


Figure 8 — Sketch showing the four different diameter steps on a motor shaft.

Having fixed the ratio of motor speed to turntable speed by manufacturing design, it is now up to the motor to maintain a constant speed.

Types Of Motors

The motors used on record changers are called AC induction motors, and are miniature cousins to the fractional horsepower motors used in washers, dryers, and many other household appliances, as well as in workshops for bench saws, lathes, etc. Record-changer motors develop only about 1/100th of the power of the $^1/_4$-horsepower motor. They differ in many other respects also, especially in the system used to start them and get them up to speed.

Like their larger cousins, the motors used in nearly all record changers have a speed a little less than synchronous, that is about 1750 rpm for a four-pole motor and about 3500 for a two-pole. There will be more details about this a little later on.

To assure exact turntable speed, the motor must be a synchronous type. Some of the higher-priced record changers use a synchronous motor, but this type of motor is found most often in non-changer record players. Synchronous motors are more expensive than non-synchronous motors and so are not in common use. A synchronous motor revolves at a locked-in speed governed by the 60-Hz frequency of the line voltage. A four-pole synchronous motor has a speed of exactly 1800 rpm.

The more standard AC induction motor also depends on the 60-Hz line voltage, but has a little slip in speed, depending on the load.

Motor Shocks

If it were not for the rubber suspension mounts used by all record changer manufacturers on their motors, the main source of noise pickup when playing records would be from the motor. Every motor, no matter how well made, will have some vibration due to the changing magnetic flux and the rotation of the rotors. If you put your hand on the outer housing of any motor used in a large home appliance you can feel the "hum" when it is operating. The hum from a phono motor could be transmitted from the mounting board to the record, which would vibrate the stylus and be heard through the speakers. This has a jerking effect on the record speed which is called "flutter."

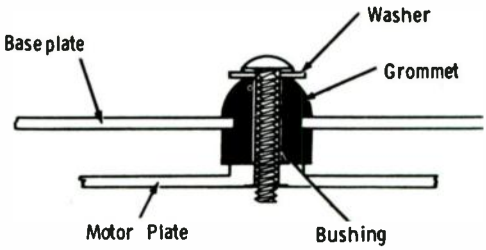


Figure 9 — Rubber shock mounts isolate the motor vibrations from the changer baseplate.

In record changers, the motor is fastened to a mounting plate, which in turn is suspended from the changer baseplate by rubber shock mounts (Fig. 9). Any transmitted vibration is lost in the rubber. For this reason, it is important that the screws through the rubber mounts should never be tightened excessively. By shock-mounting the motor and by shock-mounting the baseplate from the mounting board, the changer is very well isolated from external vibration (Fig. 10).

THE CARTRIDGE AND STYLUS

The mechanical movements of the needle (or stylus) are converted to an electrical voltage; the voltage is amplified and develops the high power necessary to operate a speaker in the output stage of the amplifier. Many years of engineering have produced record players and

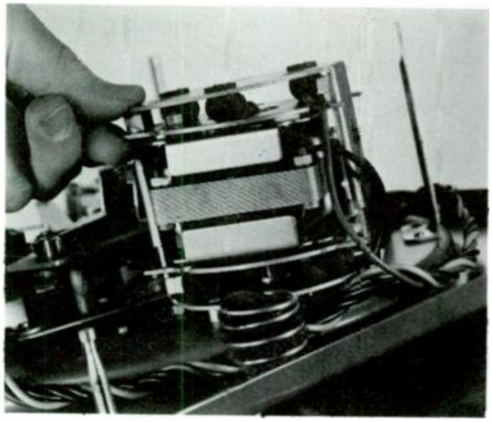


Figure 10 — Very resilient rubber is used for the motor shock mounts as this picture clearly illustrates.

records that have an amazing fidelity to the original music. Stereo has added that extra dimension of realism—you can sit back with your eyes closed while listening to a symphony on a stereo Hi-Fi system, and believe that "you are there" while a real orchestra is playing before you.

The fine grooves in a record follow a wavy course as they spiral inward. The undulations are so fine it takes a powerful magnifying glass to see even the loud passages of music. The grooves are V-shaped and, in the case of monophonic records, move from side to side, never up and down. A needle (or stylus, if you prefer) rides in the groove and "wiggles" back and forth with the waves in the groove. The stylus is coupled to a cartridge which converts the mechanical movements to an AC voltage containing all the frequency components of the original music. Cartridges are either crystal (ceramic) or magnetic.

Ceramic Cartridges

Early cartridges were made of a bimorph crystal of Rochelle salts. Some cartridges are still made of this material because their voltage output is greater. For the most part, however, crystal cartridges are made of a ceramic material, and the word ceramic has largely replaced the word crystal even though the cartridge is actually a ceramic crystal.

When a small slab of a certain ceramic material is held in a fixed position at one end and attached to a needle (or stylus) at the other end, any twisting or bending action by the stylus on the ceramic will cause a voltage to be developed in the crystal. This is known as the *piezoelectric effect.* By placing two metallic electrodes in contact with the crystal, one on each side of the crystal, the voltage will appear on the electrodes as an alternating voltage with opposite polarities on each electrode (Fig. 11). The frequency of the alternating voltage will be the same as the frequency of back-and-forth movement of the stylus in the record groove. The frequencies will correspond to the frequencies of the music impressed on the record. The actual voltage at the output is a result of the distance the stylus swings back and forth, the final result of this being how loud you hear the music from the speaker.

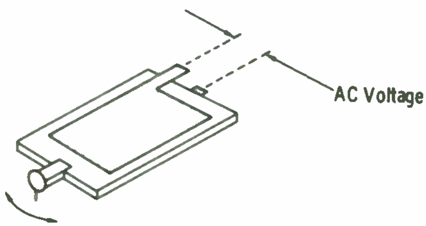


Figure 11 — Sketch illustrating the piezoelectric effect in a ceramic crystal.

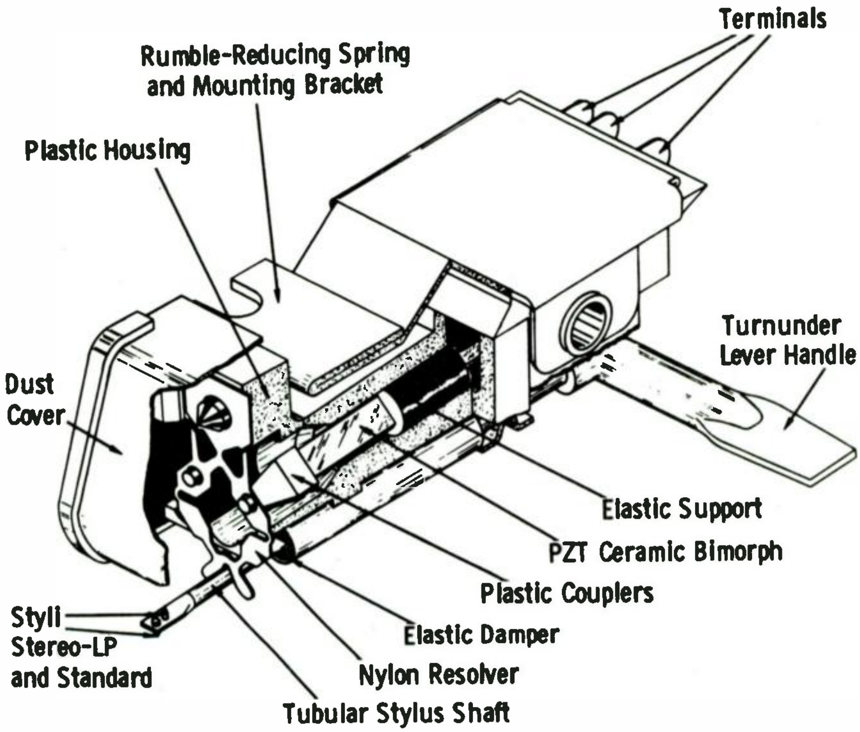


Figure 12 — Cutaway drawing of a stereo ceramic cartridge.

The actual construction of a ceramic cartridge is somewhat more complex than the simple explanation just given, especially for a stereophonic cartridge. Figure 12 is a cutaway view of a typical stereophonic cartridge. A stereo cartridge employs two crystals, one for each channel of information. For simplicity, only one crystal element is shown here. The other element is located horizontally to the left of the one shown. Two needle points, or styli, are affixed to opposite sides of a tubular shaft. The shaft rests between the forked contour of what is known as a resolver. One end of each ceramic element is coupled to the resolver, and the other end is in a fixed position. As the groove of the record moves the stylus, the action is transferred to the ceramic elements and a voltage appears at the output terminals. The illustration shows three terminals. One terminal is common to both ceramic elements, while the other two are connected to each of the opposite electrodes of the two ceramic elements. How two-channel or stereo music is obtained from this cartridge will be explained later.

Even in the best modern cartridges there is some load on the stylus. Anything that moves has mass. The ceramic elements have stiffness. The energy used to move the mass of the stylus, the shank, and the plastic couplers is part of the load. The stiffness of the ceramic element is part of the load. Through good engineering and careful production, the load is kept very low.

Magnetic Cartridges

A ceramic cartridge develops a voltage when the element is twisted or bent, while on the other hand, a magnetic cartridge develops a current of electricity. Although this is a basic difference, the final results are the same since the current of a magnetic cartridge is converted to a voltage before it is magnified. A magnetic cartridge works somewhat like a generator. An electric generator has a rotating armature and a stationary field. When the armature rotates inside the field coils, the magnetic action between the two produces electric currents in the wires of the coils. In a magnetic cartridge there is no continuous rotation of an armature in a stator, but only a slight movement back and forth. This is enough to develop the electric current needed.

When a coil of wire moves across a magnetic field, an electric current is induced in the wires of the coil. The coil may be moved across a stationary field, or the coil may be stationary and the magnetic field moved across the coil. The relative effect is the same. As the coil cuts across the magnetic field in one direction, the current induced in the coil flows in one direction. As the coil is moved in the opposite direction, the current induced reverses direction in the wires of the coil. This also happens with the movement of a magnetic field across a stationary coil. Therefore, if the coil is moved back and forth, an alternating current will be developed in the wires of the coil (Fig. 13). When this alternating current is impressed across the terminals of a resistor, an alternating voltage appears across the resistor.

In a magnetic cartridge, the magnetic field is always created by a tiny permanent magnet. Although small, this magnet is very powerful because of the special materials from which it is made. Modern magnets used in speakers, microphones, phono cartridges, etc., are made of special alloys such as Alnico 5 which produce very strong magnetic fields for their size. Magnetic cartridges are made in either of two ways: (1) either the stylus is coupled to a coil, and wiggles the coil in the magnetic field, or (2) the stylus is coupled to the permanent magnet, and wiggles the magnet in the presence of a coil. Either way, the magnetic flux is cutting across the turns of wire in the coil and a current is produced. In the case of stereophonic magnetic cartridges, there are two coils.

As with ceramic cartridges, the moving parts of magnetic cartridges have mass, and energy is required to move them. The current in the wires of the coil as the coil cuts across the flux of the permanent magnet, develops a magnetic

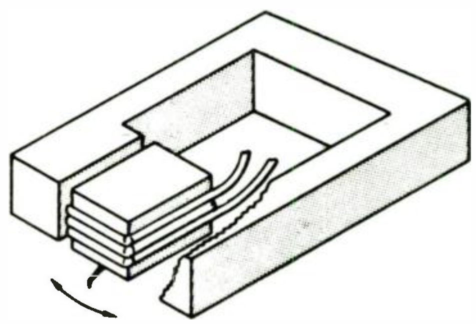


Figure 13 — Simplified drawing of a moving-coil magnetic cartridge.

field which is in opposition to the field of the permanent magnet. This opposing magnetic flux acts like a brake on the movement of the coil, and this, too, is a load on the movement of the stylus. The loading due to this braking action may be likened to the load due to the stiffness of a ceramic cartridge. The magnetic cartridge load, however, is much less than that of a ceramic cartridge.

Ceramic cartridges have considerably higher voltage output for the same amount of stylus swing than magnetic cartridges do. The older bimorph crystal cartridges have outputs of around $1/2$ to 1 volt. Ceramic cartridges have outputs averaging around $1/5$ of a volt. The output of a magnetic cartridge is frequently between 5 and 10 millivolts (thousandths of a volt). The amplifier that follows must have higher gain (or amplification) for a magnetic cartridge than for a ceramic cartridge.

Equalization

Another big difference between a ceramic cartridge and a magnetic cartridge is the factor on which the amount of output voltage depends. The output voltage of a ceramic cartridge is in direct proportion to the swing of the stylus as it follows the groove of the record. The higher the amplitude of movement of the stylus in the groove, the higher the output voltage. In a well-designed cartridge, the output relationship is a linear one; that is, the output is an exact pattern of the stylus swing. The output is independent of the frequency. It does not matter how fast the stylus swings, only how far.

A magnetic cartridge is like an electric generator. The faster the magnetic flux field is cut, the higher the output will be. In an electric generator, increasing the speed of the rotating armature increases the output voltage. In a like manner, increasing the speed with which the magnetic-cartridge coil cuts across the magnetic field increases the output. This, of course, is related to the frequency of the tone being played. The higher the frequency of the note or notes, the faster the coil will move back and forth across the magnetic field, and the higher will be the output. To state it another way, the output of a ceramic cartridge is amplitude dependent, whereas the output of a magnetic cartridge is velocity dependent.

A magnetic cartridge must always be followed by a compensating network to correct for the velocity dependency of the cartridge. A combination of resistors and capacitors is used to make the magnetic cartridge appear to be amplitude dependent above 500 Hz. This compensation network introduces additional losses, and requires still more amplification to build up the remaining feeble voltages.

Monophonic vs Stereophonic Recording

The construction of stereo cartridges was mentioned previously. Whether the cartridge is ceramic or magnetic, two sets of voltage- or current-producing elements are required for stereo, as compared to only one for monophonic play. One element produces the left channel of information, and the other element produces the right channel. It follows, of course, that for stereo, separate amplifier channels are needed to amplify each channel and drive two speakers, each with separate information. All this is not very difficult to understand since it is basic and straightforward. What may be revealing, however, is how separate channels are obtained from a single groove in a record and reproduced by a single stylus.

As mentioned before, the groove in a monophonic record waves back and forth laterally, like a winding river. The stylus follows the lateral undulations of the winding groove, and this motion is transferred to action on the cartridge. Monophonic cartridges are designed to respond only to lateral movement of the stylus. Furthermore, these cartridges are intentionally designed not to respond to vertical movements of the stylus. Turntable rumble and dirt flecks in the record groove can cause some vertical movement of the stylus. If the stylus reproduces that movement as a signal, it will add noise to the music, which is undesirable. Therefore, monophonic-cartridge design includes minimum response to vertical movements of the stylus.

Imagine now that another voltage-producing element is added to the cartridge construction so that vertical movements of the stylus result in an output from that element, but the element would be immune from the effects of lateral movements of the stylus. By recording the left-channel information into horizontal waves in the record groove, and right-channel information into vertical waves, two-channel, or stereo, music could be played. Basically, this is what is done in stereo records and cartridges, but with the system modified somewhat. Instead of the axes of motion being horizontal and vertical, the whole system is turned or twisted 45 degrees. If you could watch the stylus in slow motion, you would see it move in a north-

(A) Monophonic cartridges respond only to lateral movement of the stylus.

(B) Stereophonic cartridges respond to both lateral and vertical movement of the stylus.

Figure 14 — Sketch illustrating the principal difference between monophonic and stereophonic cartridges.

west-southeast direction for one channel, and in a northeast-southwest direction for the other channel. The cartridge elements are mounted with their axes forming a "V" (Fig. 14). The reason for the 45-degree twist is to make stereo and monophonic records compatible. A stereo record player can also play monophonic records. A monophonic record player can also play stereo records, but, of course, as monophonic records.

Compatibility

In the 45-degree system of stereo recording (known as the *Westrex* system) a horizontal-only movement of the stylus will result in output from both elements of a stereo cartridge. Thus, a monophonic record will produce an alternating voltage in both channels simultaneously. The same would be true from records with all the information in vertical-only movements of the stylus, but we have no such records (although the original Edison cylinders were recorded with vertical grooves, and so was an early attempt to produce high fidelity in 78-rpm records).

When stereo records are played on a monophonic cartridge, the stylus will move horizontally and the horizontal action will produce a voltage, whether the information comes from a northwest-southeast movement or a northeast-southwest movement of the stylus. Information from either channel will result in a voltage output. The compatibility of playing stereo records on monophonic cartridges stops at the point of theory. Stereo records should never be played on a monophonic cartridge, because of one of the special features built into a monophonic cartridge. That feature is the stiffness purposely designed into monophonic cartridges to reduce their sensitivity to vertical motion of the stylus. This vertical stiffness can soon ruin stereo records. Stereo records require high compliance to movement in both the lateral and vertical directions.

Today, nearly all record changers are either equipped with a stereo cartridge, or no cartridge, leaving the choice to the customer. Except in toy-type record players (which do not use changers) monophonic cartridges in new equipment are obsolete. Therefore, compatibility means the ability of the stereo cartridges to play either stereo or monophonic records, which it does with the Westrex system.

Semiconductor Cartridge

A new cartridge material is a member of the semiconductor materials in which a change in dimensions results in a change in the electrical resistance. This is similar to the strain gauge used extensively in industry to study stresses in construction materials. At this writing, there are few such cartridges on the market, and experience has been short. Therefore, not too much can be said about them (Fig. 15).

Stylus Tip Material

Two different materials are used for the stylus tips: synthetic sap-

Figure 15 — A semiconductor stereo cartridge.

phire and diamond. The sapphire tip is less expensive, while obviously, the diamond tip is more expensive, harder, and will last longer. Better cartridges today are almost exclusively diamond-tipped. Even the less expensive ceramic cartridges are frequently sapphire-tipped for 78-rpm records, and diamond-tipped for stereo microgroove records.

Figure 16 — Comparatively simple old-style changer.

Typical Mechanisms

The changer in Figure 16 must be set for the desired record size, the record support assembly is turned so that the corresponding number faces the turntable. A stack of records of the same diameter is placed on the *centerpost* (22) in Figure 17. The *record clip,* which is the plastic top of (1), is placed on top of

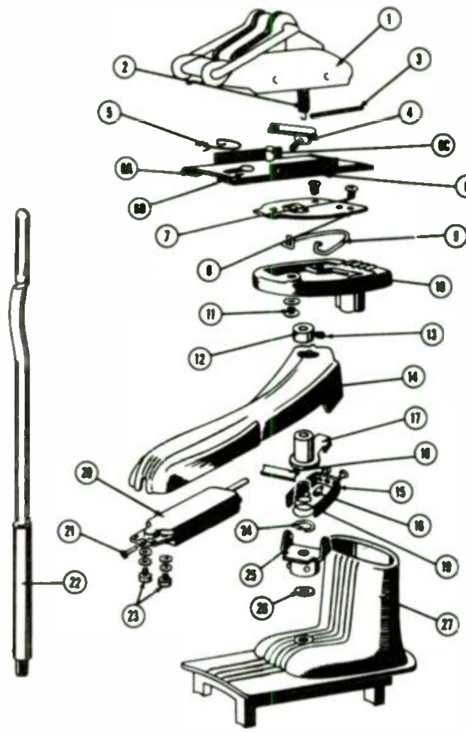


Figure 17 — Enlarged top view of changer shown in Figure 16.

the stack. The *motor switch* (36) is then turned on, and *reject button* (29) is pressed. Or, if the pickup arm is on the *rest* (29), we press down on the arm to start the changer. The bottom record drops from the stack to the turntable. Subsequently, the entire stack will be played automatically and any record will be rejected by pressing the reject button. Note that when the end of the stack is reached, the last record will be repeated until the changer is turned off.

It is helpful to review the change cycle for this type of record changer. The sequential actions are as follows:

1. As the pickup arm moves toward the center of the record, the arm control pin

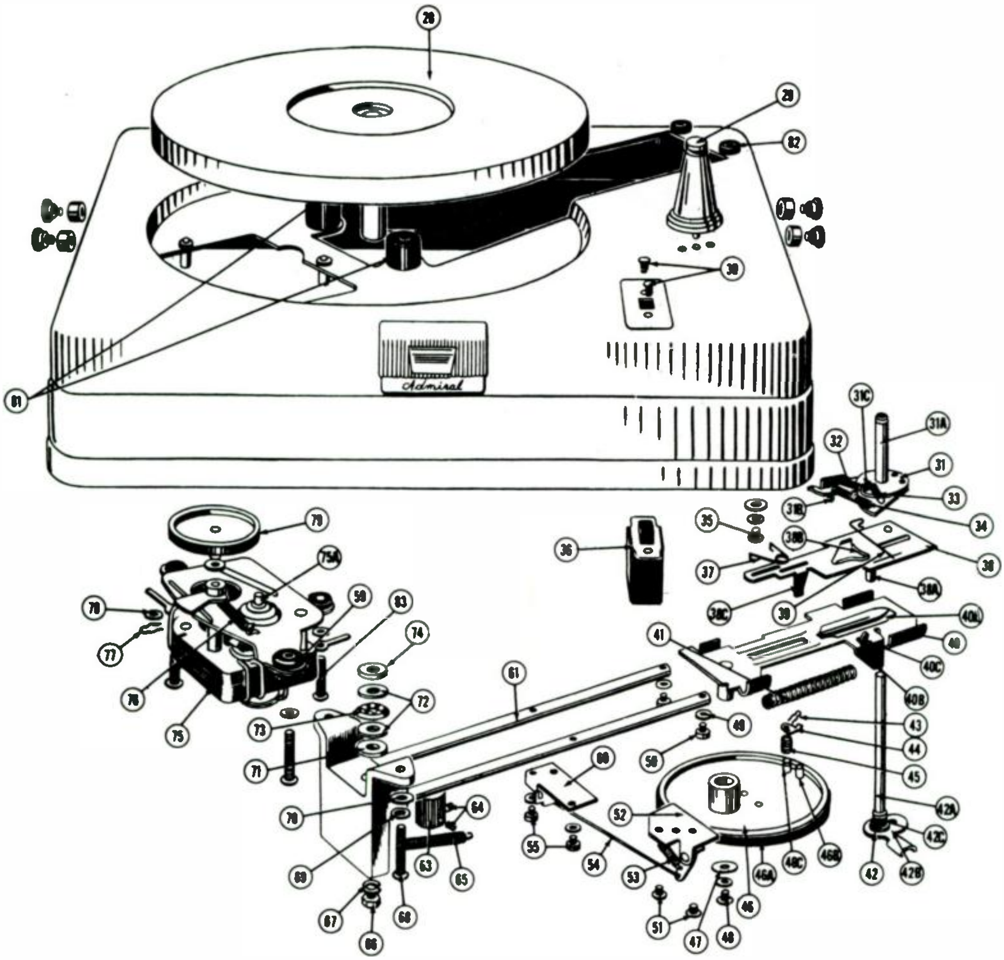


Figure 18 — Enlarged bottom view of changer shown in Figure 16.

(31B) which is shown in Figure 18 and which is on the arm control assembly (31), moves along the portion of the arm control track shown as "P" in Figure 19.

2. When the arm reaches the trip point at the end of the record, the arm control pin reaches the point on the track designated as "T" in Figure 19. As the pin moves into this recessed portion, the trip spring (37) shown in Figure 18 is then allowed to move the arm control plate (38) forward toward the centerpost.
3. Next, the stop tab (38C) is moved from behind the reject catch (44). This allows the eccentric cam (46) to be pulled over by the spring (65) until the rubber tire makes contact with the knurled roller (63) on the turntable shaft.
4. The knurled roller rotates

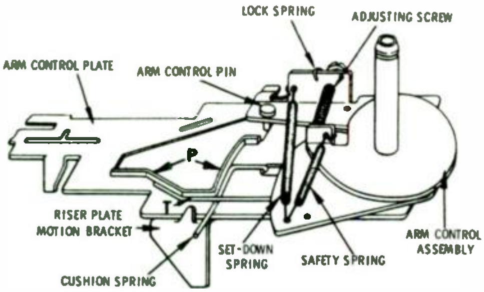


Figure 19 — Arm control track and associated parts.

with the turntable, and rotates the eccentric cam. Since the eccentric cam is attached to the riser plate (40) shown in Figure 18, the riser plate is forced back along the guide rods (61) away from the centerpost.

5. When the riser plate begins to move, the push-off cam and shaft assembly (42) rides along the inclined track (40A) of the riser plate. This causes the push-off cam and shaft assembly to be drawn downward.
6. In turn, the pickup-arm lift (17) shown in Figure 17 presses down on the arm-lift bearing pin (16), causing the pickup arm to be raised clear of the record.
7. Riser plate tab (40C) then contacts and moves the arm control assembly (31), which moves the pickup arm away from the centerpost, moving it far enough to clear the edge of the turntable.
8. As the riser plate continues to move back along the guide rods, the riser plate motion bracket (40B) contacts and rotates the push-off cam and shaft assembly. This causes push-off arm (4) to rotate, moving push plate (6B), which pushes the bottom record off the stack.
9. During the second half of the change cycle, the pressure of push plate spring (5) returns the push plate and the push-off arm to their normal positions. At the same time the motion of the eccentric cam and the pressure of the guide-rod recoil spring (41) move the riser plate (40) back toward the centerpost.
10. At this time the arm control assembly and pickup arm are moved back by the tension of the set-down spring (34). After the arm reaches a point directly over the set-down point, the riser plate has moved far enough back toward the centerpost to allow the push-off cam and shaft assembly to ride down the inclined track of the riser plate. This action lowers the pickup arm upon the record.
11. As the eccentric cam completes its revolution, aided by the eccentric cam spring (65), the rubber tire of the cam moves away from the knurled roller on the turntable shaft. Reject catch (44) then comes to rest against both the stop tab (38C) and the reject arm (60). This completes the change cycle.

Now, let us consider the reject action in this example. When the REJECT button (29) shown in Figure 18 is pressed, the reject trigger wire (54) pulls the reject arm (60) from behind reject catch (44). The eccentric cam then falls against the knurled roller and the change cycle begins.

The set-down point is controlled as follows: In the early portion of the change cycle, the arm control plate shown in Figure 18 moves in a direction away from the centerpost until the size change stop (38A) reaches the push-off cam. The distance traveled depends on the setting of the push-off cam. Thus, for the 12-inch setting, the push-off cam presents its long radius to the size change stop. For the 10-inch setting, the short radius of the push-off cam faces the size change stop.

We observe that the arm control track will move farther for the 10-inch setting than for the 12-inch setting. As a result the arm control pin (31B) shown in Figure 18 will rise along the "L" portion of the track for the 10-inch setting, and along the "S" portion for the 12-inch setting. As the pickup arm moves back toward the record during the second half of the cycle, it will be stopped when bracket (31C) reaches the adjusting screw (32). How far the arm moves before being stopped depends on whether the arm control pin has been riding on the S or the L portion of the arm control track.

Now let us consider how to adjust the set-down and trip points in this example. This changer is designed so that the 10-inch and 12-inch set-down points and the trip point are all adjusted simultaneously. This adjustment is made by means of the adjusting screw (32) shown in Figures 18 and 19. Turning this screw counterclockwise will cause the pickup arm to set down closer to the center post. Clockwise rotation will move the set-down point farther away from the centerpost. One complete turn moves the arm about $\frac{1}{4}$ inch. If the adjusting screw will not change the setting enough, the pickup arm support may be out of position.

The set-down points are slightly different for straight shank and offset shank needles. If possible, the set-down point should be adjusted for the type of needle that will be used by the customer. It is good practice to make a precise adjustment for the set-down point, because there is comparatively more latitude permissible at the trip point. If it is not known which type of needle will be used, a compromise adjustment can be made with a straight-shank needle; this means, in this example, that the set-down point will be $4\frac{5}{8}$ inches from the side of the centerpost to the needle for the 10-inch setting, and $5\frac{5}{6}$ inches for the 12-inch setting.

BASIC MAINTENANCE AND EVALUATION

Preliminary Disassembly

Instructions for removal of the changer chassis from the cabinet are seldom provided in service literature. However, the necessary procedure is easily determined by inspection. For example, we may follow the steps listed below for a Sears changer:

1. Remove the retaining ring

(clip) that snaps into a slot around the spindle. This will free the turntable on the spindle.

2. Lift the turntable off the spindle, and place it aside in a safe place where it will not fall or be struck by tools.
3. Place your fingers through the large access slot near one of the chassis mounting screws, which has been exposed by removal of the turntable. You will feel a mounting plate resting against the head of the mounting screw.
4. If the mounting screw has been loosened, so that the chassis is floating on its springs, you can slide the mounting plate off the screw (the plate is slotted for this purpose). Figure 20 shows this plate.

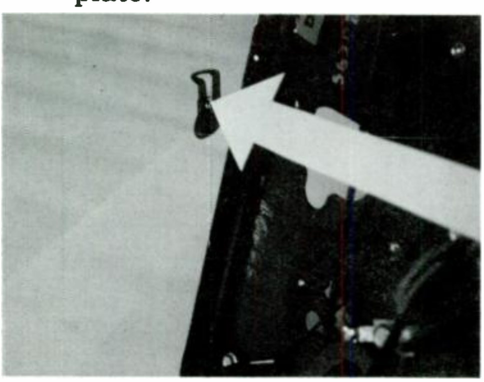


Figure 20 — Slotted mounting plate in place of mounting screw indicated by arrowhead.

5. The head of the mounting screw will now pass through the chassis. The other mounting screw can then be freed by sliding it out of the slot that is provided in the chassis.
6. Lift the chassis out of the cabinet. It can only be set on edge at this time because the motor wires are comparatively short.
7. Unsolder the motor wires. The wires that run to the amplifier are longer, and are doubled up and taped. Remove the tape. The chassis may now be moved free of the cabinet.
8. If more freedom is needed (such as for mounting in a chassis cradle), disconnect or cut the wires that run to the amplifier.

Some parts of a record changer must be lubricated; on the other hand, various other parts must not be lubricated. Lubricants such as SAE No. 10 or No. 20 oil, light grease, and adherent grease such as Lubriplate, are used where specified by the service data. Just as dirt, grime, or lack of lubrication often cause trouble symptoms, so do over lubrication, use of incorrect lubricants, or lubrication of "forbidden" parts also cause trouble symptoms. Although a record changer cannot be compared with a fine watch, it is nevertheless a precise mechanism, and must be treated with appropriate respect. Detailed discussion of lubricating procedures will be included under topical headings.

Basic Tools And Equipment

Suitable tools and equipment are required by the record-changer technician. We have previously noted the utility of a service stand or chassis cradle. Among the basic necessities are the following:

1. Large and small screw-

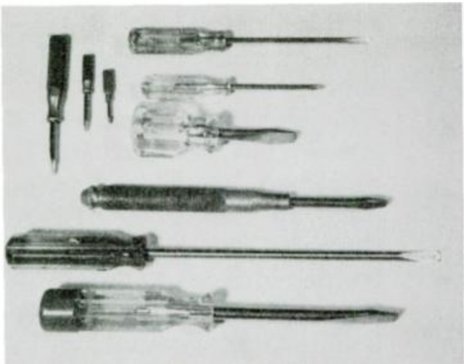


Figure 21 — A set of screwdrivers suitable for record changer servicing: $1^1/_4$ to 9 inches, blade sizes, $^1/_{16}$ to $^1/_4$ inch.

drivers, such as those illustrated in Figure 21.

2. A set of Phillips-head screwdrivers, such as shown in Figure 22. Basic hand tools are used both in maintenance and troubleshooting work.

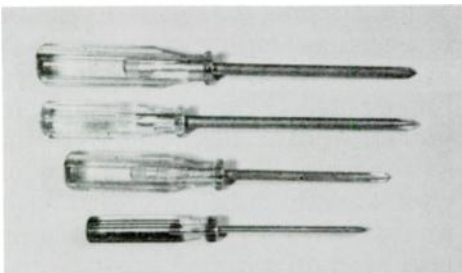


Figure 22 — Phillips-head screwdrivers: 5 to 8 inches, blade sizes, $^1/_8$ to $^1/_4$ inch.

3. Hex wrenches, shown in Figure 23 are among the basic hand tools. They not only speed up disassembly and reassembly, but also prevent "rounding" damage to hex surfaces.
4. A set of hex key wrenches, and a set of spline key wrenches, as shown in Figure 24 are essential. Key wrenches for slab-head set-

Figure 23 — Hex wrenches (nut drivers): $^1/_{16}$ to $^3/_8$ inch.

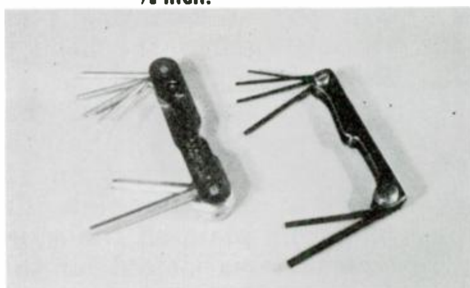


Figure 24 — Hex and spline key wrenches.

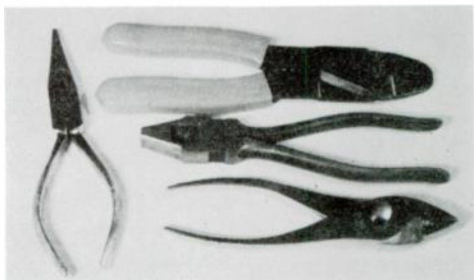


Figure 25 — Useful assortment of pliers.

screws are also needed on occasion.

5. Combination and long-nose pliers are required. In addition, a pair of electrician's pliers and a pair of all-purpose electrician's pliers are useful in repair jobs. These types are seen in Figure 25. All-purpose pliers are particularly useful for cutting machine screws to pre-

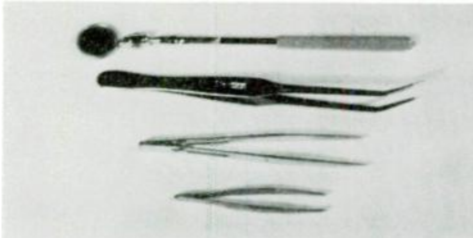


Figure 26 — Tweezers and dental-type inspection mirror.

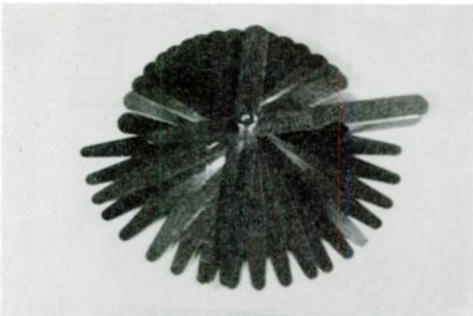


Figure 27 — Set of feeler gauges.

Figure 28 — Lubricant applicators.

cise lengths without damage to the threads.

6. Tweezers and a dental-type inspection mirror, shown in Figure 26, can save much time when one is working in cramped spaces.
7. To adjust precise clearances in changer mechanisms, a set of feeler gauges is necessary. Figure 27 illustrates a suitable set.

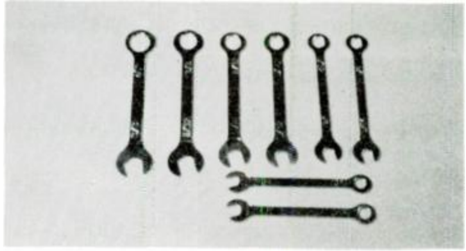


Figure 29 — Box end-wrench set: sizes $^7/_{32}$ to $^3/_8$ inch, and $^{15}/_{64}$ to $^7/_{16}$ inch.

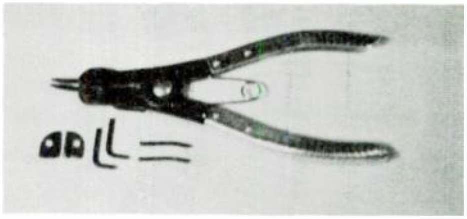


Figure 30 — Typical snap-ring pliers.

8. Lubricant applicators, such as those shown in Figure 28, are convenient in practical work, and eliminate the need for eyedroppers, toothpicks, or similar makeshifts. It is also convenient to have cleaning solvent available in suitable, leakproof applicators.
9. An ordinary magnifying glass should be kept handy at the bench.
10. Disassembly and reassembly are often facilitated by use of box end-wrenches such as are shown in Figure 29.
11. A pair of snap-ring pliers, illustrated in Figure 30 can save time and tempers when one is removing retaining rings or clips.
12. A strobe disc, shown in Figure 31, is essential for checking turntable speed.
13. Bending tools (long shafts with slots and handles) may be preferred instead of pliers for straightening strained

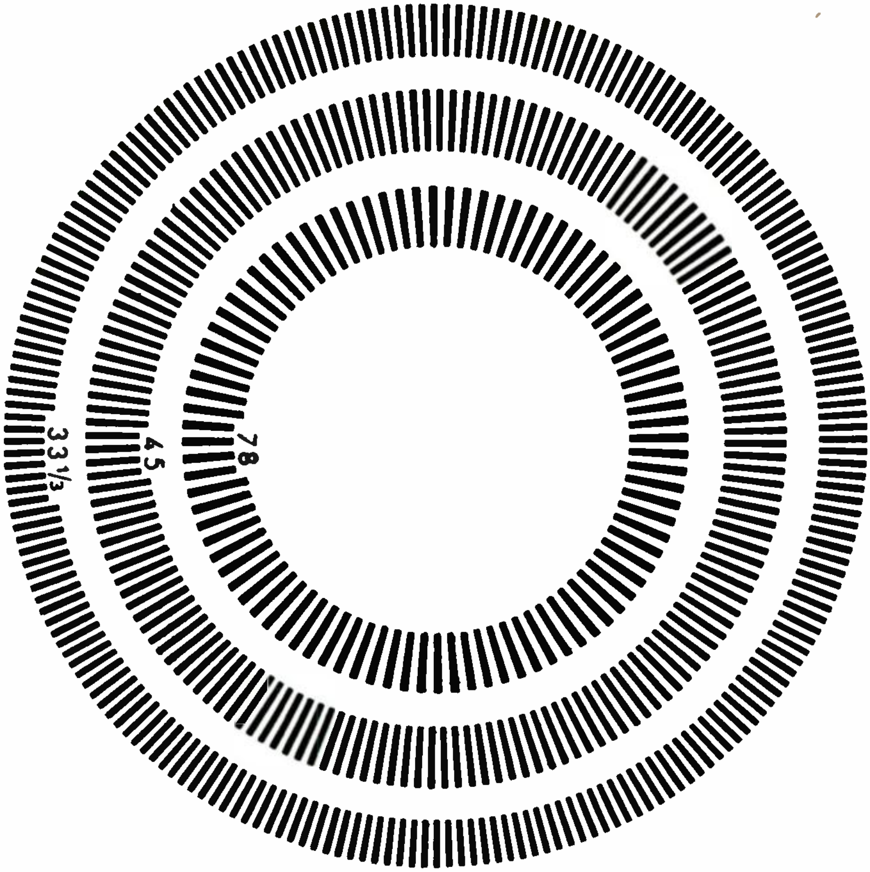


Figure 31 — Stroboscope disc used to check speed of turntable.

and distorted parts such as mechanism levers.

14. A rivet peening tool is often convenient in repair procedures.
15. Pickup-arm adjustments require the use of a needle-pressure gauge.

Functional Testing

Preliminary checks and evaluation procedures generally begin with start-up and speed tests. Let us consider the complaint of "dead motor." It might happen that the motor is actually at fault, although various other possibilities are logically investigated first. For example, the following defects are looked for at the outset:

a. Worn or erratic switch.
b. Plug not fully inserted.
c. Broken lead.
d. Cold-solder joint.

In this situation, continuity checks are basic. A VOM is used for this purpose. It is possible, though not likely, that the motor windings will be open-circuited. When a motor winding is defective, it may be repaired, or the motor may be replaced. The choice is usually based on shop facilities and personal pref-

Figure 32 — Typical volt-ohm-milliammeter.

erences from the viewpoint of experience with motor rewinding. Notes on motor repair are given in a subsequent lesson.

Next, let us consider the complaint of "wrong speed" or "changing speed." That is, the customer states that the turntable runs too fast, too slow, or changes speed from time to time. In such case, we make the following functional tests:

a. Place a strobe disc, such as that shown in Figure 31 on the turntable, turn on the power, and observe whether the turntable comes up to normal speed promptly or gradually.
b. Use the strobe disc to check operation at each speed provided by the changer.
c. If the unloaded turntable speed is correct, it is good practice to make a load check. Place the maximum permissible number of records on the turntable, and repeat the foregoing tests.
d. Remove the strobe disc, place a 1-kHz test record on top of the stack, lower the pickup arm, and listen for wow.

These are merely preliminary functional checks. When one or more of the foregoing tests gives an unsatisfactory result, we must then proceed to look further and to progressively eliminate the drive assembly, motor, and turntable from suspicion. Details of these troubleshooting procedures will be found in the following sections under pertinent topical headings.

Next, let us consider preliminary checks and evaluation procedures that are observed when the customer complaint indicates trouble with the change cycle. We proceed as follows:

a. Load the changer, and cycle the stack—press the REJECT button or lever and observe if the change cycle starts normally.
b. In normal operation,the pickup arm then rises, waits for the bottom record to drop from the stack to the turntable, and then swings in.
c. Next, the pickup arm should set down so that the needle is placed in the lead-in groove.
d. When the record has been played, the trip mechanism normally actuates the change-cycle drive; the pickup arm rises, swings out, and the next record drops from the stack.

Among abnormal operating conditions to be evaluated are jerky or rough motion of the pickup arm (or sometimes failure of the pickup arm to rise at all). Another difficulty involves failure of the bottom record to drop from the stack, or two or more records may drop. In other situations a record strikes the pickup arm as it drops. Although the pickup arm moves smoothly and is not struck by the falling record, the arm may fail to set down. A common complaint is that although the arm sets down it does not place the needle in the lead-in groove of the record. Among trip-mechanism troubles may be noted failure to operate, change-cycle drive actuated too early, or change-cycle drive actuated too late. Some of these symptoms can be corrected by simple adjustments; others require extensive troubleshooting procedures.

Pickup-Arm Adjustment

During the change cycle, the pickup arm rises to a height that provides a small clearance under the bottom record stacked on the spindle. In turn, the needle will clear the top record on a full turntable stack, provided that the specified maximum number of records has not been exceeded. If the height of the pickup arm needs adjustment, we locate the adjustment screw. For example, this screw is at (4) in Figure 33. In this example clockwise rotation of the screw increases the height of the arm, and vice versa.

In case the complaint is incorrect set-down (needle misses the lead-in groove), we locate the set-down adjustment knob or screw. For example, this knob is at (5) in Figure 33. Clockwise rotation in this example moves the pickup arm nearer the center of the record, and vice versa. Of course, if the pickup arm moves erratically, or fails to move at all, the trouble cannot be cured by a simple adjustment. Instead a systematic troubleshooting procedure must be followed, as explained subsequently.

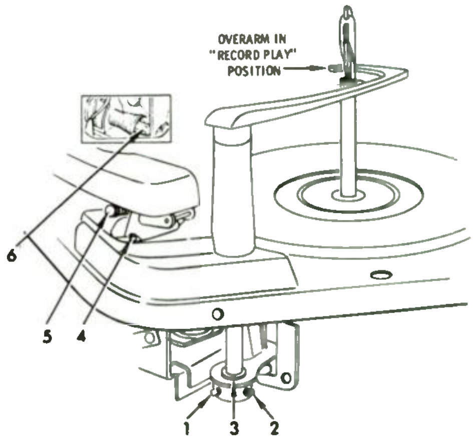


Figure 33 — Side view of overarm guide and hub assembly.

Spindle Adjustment

If the spindle is not adjusted correctly, the bottom record on the stack will not drop to the turntable during automatic operation. The spindle holds the records in position, and controls the record push-off action. In the example of Figure 34 proceed as follows to correct the spindle adjustment:

a. The changer is removed from its cabinet, and the leveling arm (also called the overarm) is placed in the record-play position shown in Figure 33.

b. Place the changer in-cycle by sliding the OFF/ON/REJECT knob momentarily to the REJECT, then rotate the turntable manually until the spindle roller (1) in Figure 34 reaches the crest of cam (2), which is mounted on main gear (3).

c. The pickup arm is placed directly over the arm rest. Also a 3/16-inch-diameter rod is inserted into the positioning hole located on the subassembly, in order to hold the cam in the desired position. This prevents the spindle roller from moving off the crest of the cam during adjustment.

d. Next, loosen lock nut (4) in Figure 34, which secures adjustment screw (5). Using a slabhead wrench, turn the adjustment screw clockwise until the record push-off pawl (9) reaches its maximum travel within the spindle.

e. Finally, tighten the lock nut. To check the adjustment, place a record on the spindle and manually cycle the changer. The record should drop to the turntable when the pickup arm moves over the pickup arm rest.

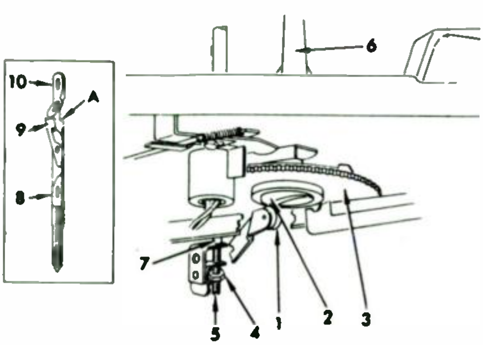


Figure 34 — Partial view of record push-off mechanism showing record push-off adjustment screw.

Note that caution must be observed in Step d; that is, if the adjustment screw is turned past the point of maximum pawl travel, spindle damage will result. In case two or more records drop, instead of one, the leveling arm is probably bent. If it is impractical to straighten the arm, it must be replaced. After replacement the arm must be adjusted, as follows:

a. In the example of Figure 33, the changer must be removed from its cabinet. Then, loosen setscrews (1) and (2) which fasten the leveling-arm hub and guide assembly (3).

b. Next, position the leveling-arm hub and guide assembly on its shaft so that the two slab-head setscrews will engage the shaft groove when tightened.

c. Finally, position the leveling arm in the record-play position (Figure 33) so that it clears the 45-rpm spindle adapter by at least 1/16 inch, but not more than 1/8 inch, and then tighten the two slab-head setscrews.

Automatic Shutoff Adjustment

If the automatic/manual adjustment screw is incorrectly positioned, automatic cycling will occur when the record changer is set for manual operation. In Figure 35, the trip-rod and weight assembly (1) actuates the automatic change cycle. Note that during manual operation, movement of the trip-rod and weight assembly is delayed by the automatic/manual adjustment screw (2), i.e., this delay prevents the record changer from going into its automatic change cycle when the pickup arm is manually placed on the record. The automatic/manual adjustment is made as follows:

a. Remove the chassis from the cabinet, and place the leveling arm in the record-play position (Fig. 33).
b. The changer is then cycled by sliding the OFF/ON/REJECT knob momentarily to the REJECT position. Manually rotate the turntable clockwise until the changer goes out of cycle and the pickup arm moves on to its rest.
c. The trip-rod weight (1) in Figure 35 is now directly over the automatic/manual adjustment screw (2). Turn the adjustment screw until it contacts the trip-rod weight.
d. Move the pickup arm toward the turntable. Movement of the trip-rod weight is normally delayed by the adjustment screw.

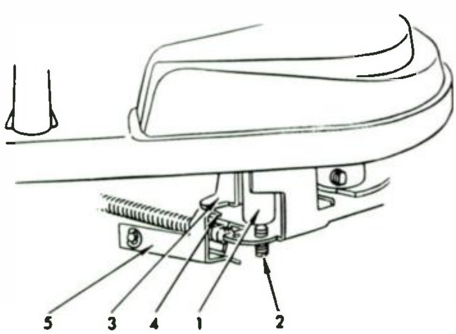


Figure 35 — Partial view of automatic/manual mechanism showing automatic/manual adjustment screw.

e. Return the pickup arm to its rest. The trip-rod weight normally repositions itself over the adjustment screw.

Lubrication Procedures

An experienced technician knows how to lubricate a record changer; he also knows where (and where not) to apply lubricants. The beginner should rely on service data for the changer. There is a trend toward the use of motors that have self-oiling bearings. This type of motor normally requires no lubrication. In the example of Figure 36, self-oiling bearings are not used. Observe the following steps in lubrication of this changer:

a. Apply Andok *"B"* or Texaco *Sta-Put* to the cam grooves on top side of cam gear (47) in Figure 36B.
b. One drop of light mineral oil is applied to the mounting shaft of cam gear (47).
c. A drop of light mineral oil is also applied to the turntable bearing, seen in the center of Figure 36A.
d. Also, a drop of light mineral oil is applied to the top and the bottom motor bearings; the motor appears in the lower left-hand corner of Figure 36B.

The service data for some changers specify lubrication of the pickup-arm bearing and the leveling-arm bearing, as well as the pivot points for these components. Unless the technician is thoroughly familiar with the particular type of changer that he is servicing, it is

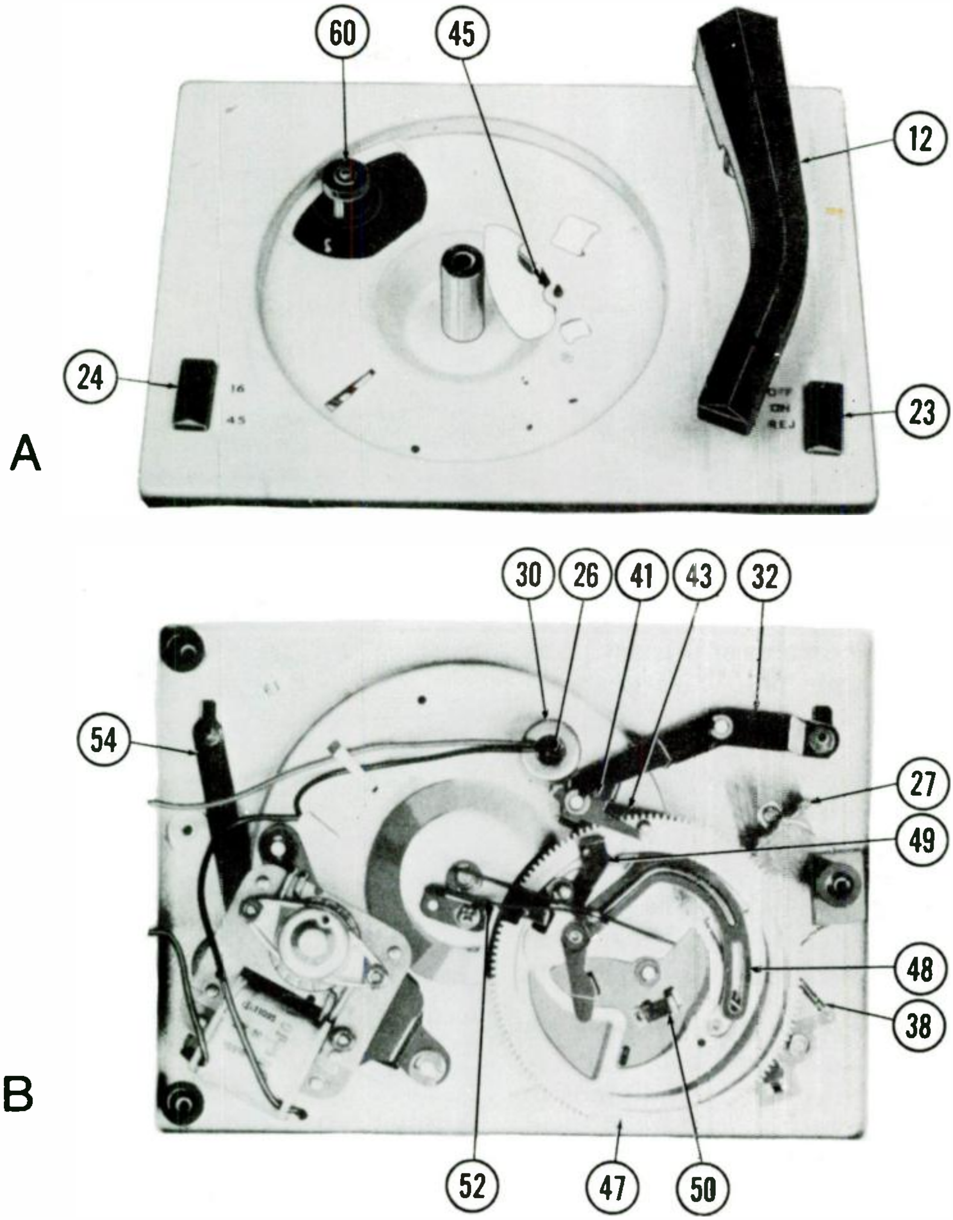


Figure 36 — Lubrication points on a typical record changer.

advisable to consult the service data for lubrication instructions.

Cam and Lever Actions

Cam and lever action is utilized extensively in the change-cycle drive mechanism. For example, cam (83B) in Figure 37 determines how far the pickup arm swings in after a new record has been dropped from the bottom of the stack. Set-down adjustment (83C) can be bent in or out slightly to

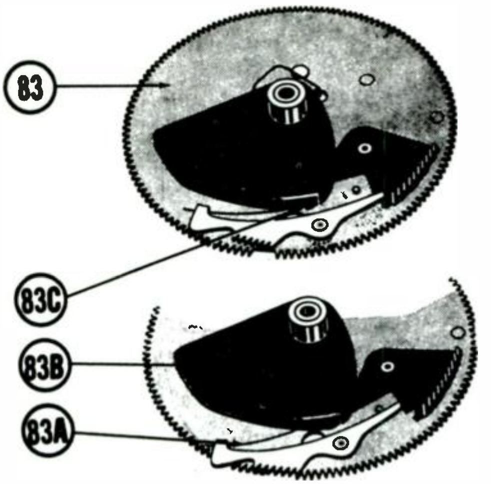
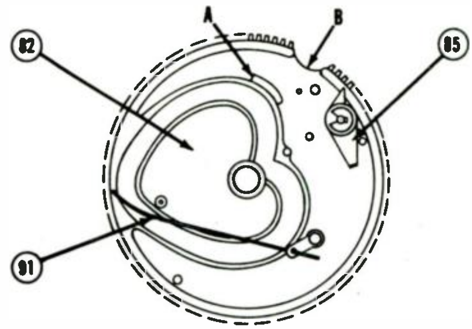


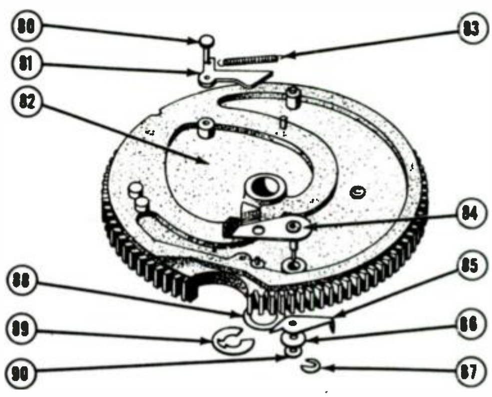
Figure 37 — Drive-gear mechanism in a Perpetuum-Ebner record changer.

adjust the set-down point of the pickup arm precisely. (Spring 83A does not concern us at present.) Another example of a cam gear assembly is shown in Figure 38. We recognize that B is the "dead spot." Cam pawl or trip pawl (84) is used to engage the teeth on cam gear assembly (82) with the teeth on the turntable hub gear. The heart-shaped groove-type cams actuate the record-dropping and arm control levers as the cam gear rotates.

Cam locator (81) in Figure 38 operates as a change-cycle brake. A gear drive has inertia and tends to continue rotating past the "dead spot" at the end of a change cycle. Therefore a detent brake is commonly used to stop the cam gear assembly precisely. In this example, a projecting stud on the cam gear assembly strikes the leading edge of the cam locator, thereby braking the rotation of the cam gear. However, when trip pawl (84) eventually engages the turntable hub assembly to start a new change



(A) Bottom view.



(B) Top view.

Figure 38 — Cam gear assembly.

cycle, the force that is thereby applied is sufficient to overcome the tension of cam assembly spring (83), so that the stud lifts the cam locator and permits the cam gear assembly to rotate.

Analysis of Common Symptoms

1. Changer Continues to Cycle, Instead of Dropping Out of Cycle

a. The trip pawl may be binding. See trip pawl assembly (84) in Figure 38. Foreign matter may be present which needs to be cleaned away. After cleaning, relubricate between

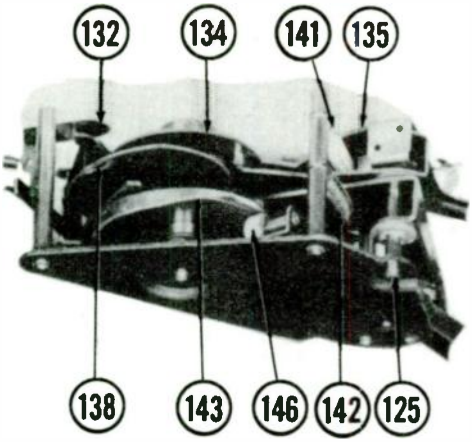


Figure 39 — Cam assembly in a Lesa changer.

cam pawl and cam with No. DC4 grease, avoiding excess.

b. Damaged striker or striker friction plate; these are parts of the intermediate drive gear and striker assembly (77) shown in Figure 42. Inspect for possible damage and replace any parts that prove defective.

c. Cam assembly spring (locator spring) loose or fallen off. Replace spring (83), Figure 38, and check for proper tension.

d. Cam locator (81), Figure 38, binding. Check for foreign matter or mechanical interference. Clean the surfaces and bearing if necessary, and replace the locator if it is damaged.

e. The reject slider may be frozen, so that the drive mechanism does not go out of cycle. Inspect the slider for foreign matter; clean it if necessary and lubricate it lightly. If slider is mechanically distorted, replace it with a new slider.

f. In some changers, the roller on the bottom of the cam may break off, so that the retractable segment on the gear is not reset. (see Figure 37). Replace the roller assembly.

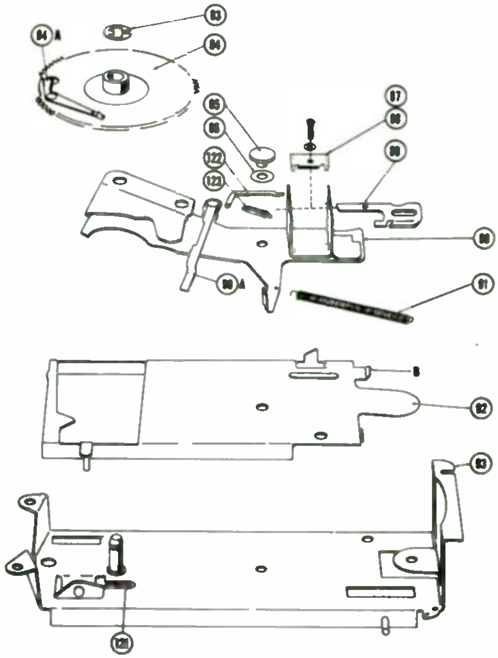


Figure 40 — Exploded view of a slide mechanism.

g. The segment spring (51) shown in Figure 43 may be bent or loose, which prevents the segment gear from locking.

h. In the arrangement (Fig. 43) the tab on the end of the segment gear may not be bent properly. Bend the tab as required to reset the segment gear when it passes the gear mounting bracket.

In many cases trouble is caused merely by hardened or contaminated grease, foreign material such as threads, or accumulation of dust and grime. Cleaning and careful lubrication will restore normal operation in this situation. Figure

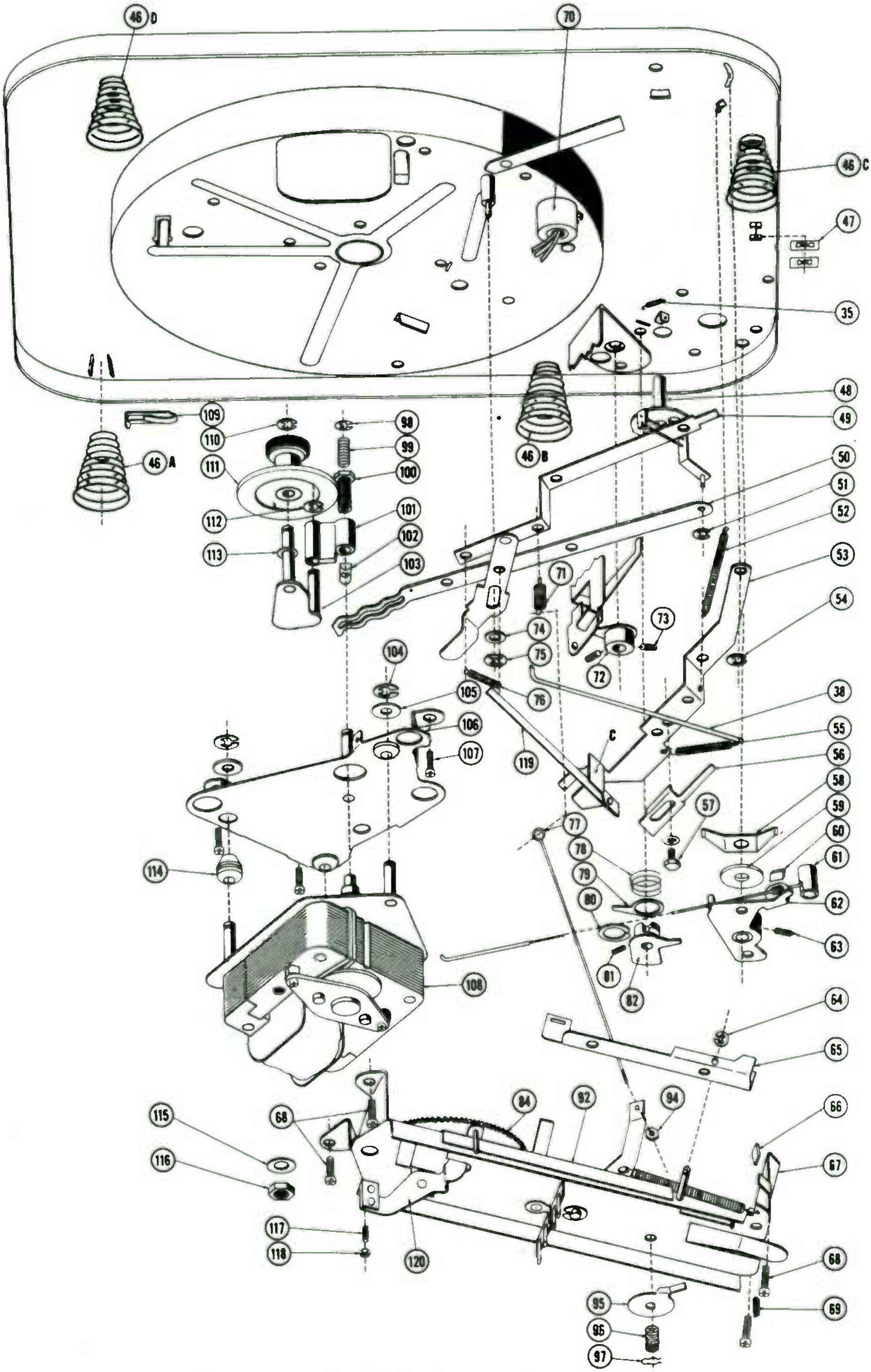


Figure 41 — Exploded view of parts below baseplate.

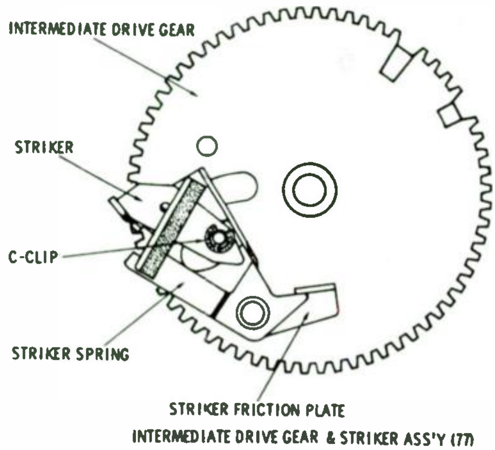


Figure 42 — Intermediate drive gear and striker assembly.

44 depicts typical greasing instructions.

2. Control Knob Cannot Be Turned to ON Position

Possible causes of mechanical interference that prevents the control knob from being turned to the ON position are as follows:

a. Changer may have been turned off while in cycle. Rotate the turntable by hand clockwise, until the control knob is free and can be turned to its ON position.

b. If turntable does not rotate easily, do not apply force; the change-cycle drive mechanism may be jammed. Determine whether the turntable can be rotated slightly backward. Inspect mechanism for loose screws or nuts, or a spring that may have fallen into the mechanism. Replace damaged part or parts.

c. Control knob assembly may be defective (infrequent, but possible).

3. Turntable Does Not Revolve When Control Knob Is Turned ON

a. Changer may have stalled while in cycle. The general procedure is the same as explained under Topic 2.

b. In some changers the control-knob assembly not only applies power, but also moves a control lever to pivot the trip pawl on the gear assembly. Inspect the control lever to see if the switch tab may have become bent out of position.

c. Spindle slide plate (120), exemplified in Figure 45, may have become bent and jammed. Replace it, if required, along with associated parts that may also be damaged.

d. Frozen drive-gear bearing (less likely, but possible). Replace drive-gear and bearing assembly.

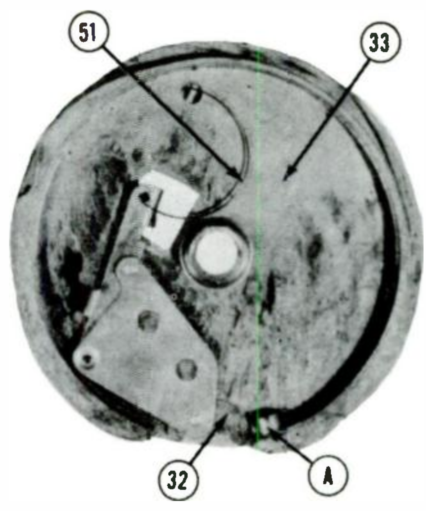


Figure 43 — Cam gear assembly showing segment gear and segment spring.

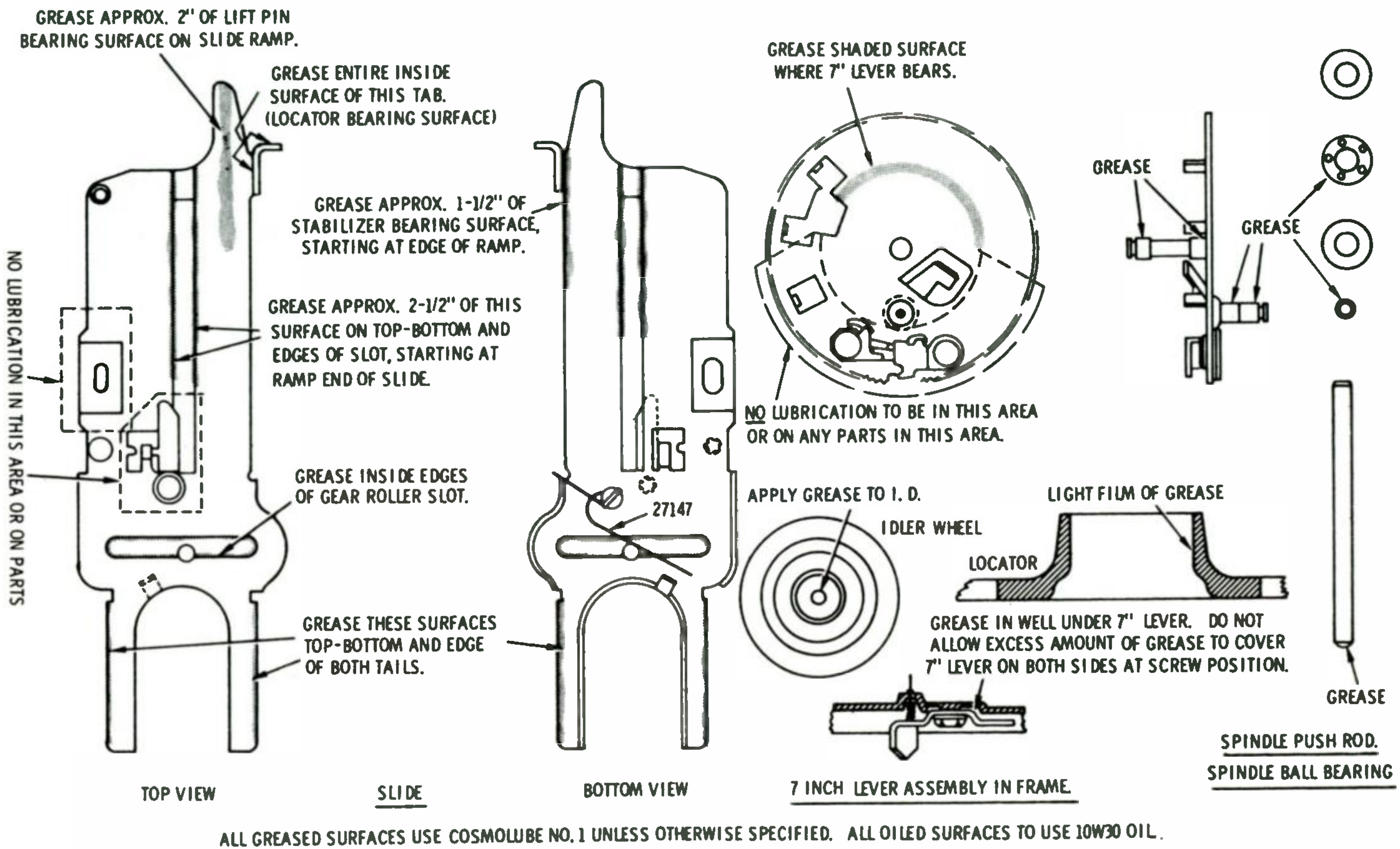


Figure 44 — Lubrication chart showing appropriate lubrication points.

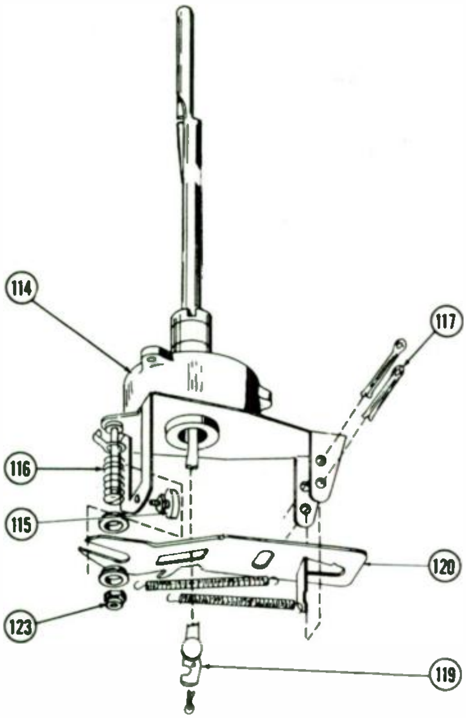


Figure 45 — Record-dropping mechanism.

4. Changer Does Not Cycle When Control Knob Is Turned to REJECT

a. Observe trip pawl, to see if it is binding and failing to rise. This condition is usually corrected by cleaning any grime, dirt, or hardened grease from the contacting surfaces and bearing. Service data may specify light lubrication.
b. In some changers, the trouble may be due to an incompleted cycle. Refer to Topic 2 of this section .
c. If failure to cycle is accompanied by control knob flipping to its OFF position, check the intermediate-gear lever assembly for burrs or mechanical distortion. An intermediate gear is depicted in Figure 42.
d. If the trouble is accompanied by failure to cycle after a record has been played, it is likely that the turntable hub gear or drive gear has broken teeth. Replace damaged gears.

5. Changer Does Not Cycle After Record Has Been Played

If the changer does not cycle after a record has been played, the most likely cause is a defect in the trip mechanism. However, it is also possible that the discussion under Topic 4 may be applicable.

a. The function switch may have been set to its MANUAL position by mistake.
b. A nonstandard record or a defective record may be the culprit.
c. The control knob may be loose on its shaft, so that the AUTO position is indicated when the changer is actually in its MANUAL mode of operation.

6. Turntable Stalls During Cycle

a. The mechanism may be jammed (see Topic 2b). Note also that a lever will sometimes jump out of its track in the cam and interfere with rotation.
b. The spindle plate sometimes bends or jams (see Topic 3c).
c. The main cam might be binding, due to worn and out-of-tolerance rollers and slides. Rotate the turntable slowly by hand (without forcing), while inspecting the action of rollers and slides.

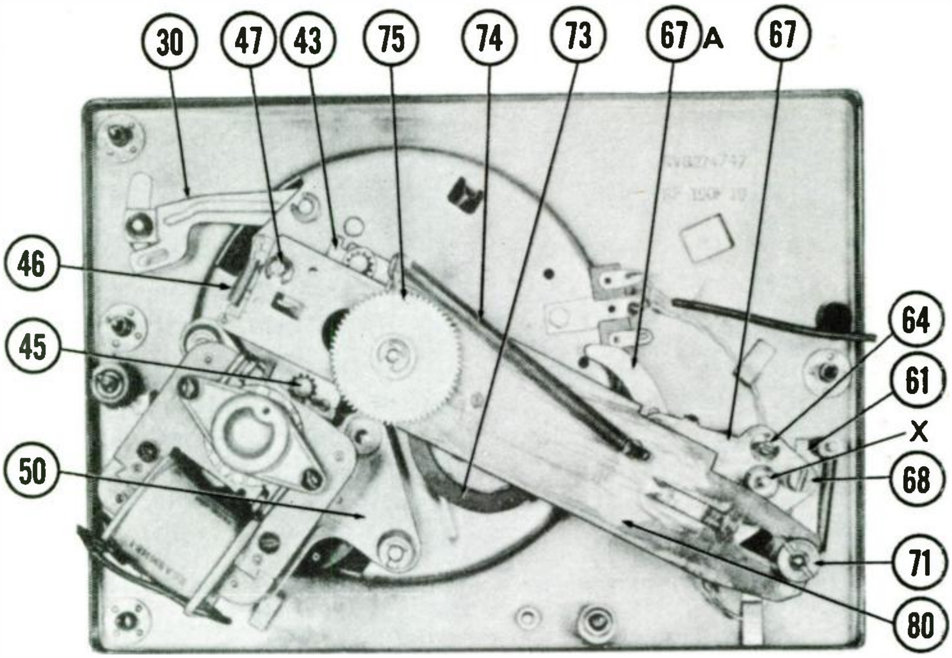


Figure 46 — Bottom view of a Westinghouse record changer chassis.

d. In unusual situations, the drive-gear bearing might be seizing at a certain point in the cycle. Disassemble, clean, and lubricate it as specified in the service data.

7. Only a Portion of the Change Cycle Is Completed

a. Broken teeth on turntable hub gear and/or drive gear. Replace defective gears.

b. Belt drive is occasionally used to drive the change-cycle mechanism; since maximum torque is demanded during the change cycle a worn or loose belt or grease on the belt can be responsible. Rim drive is also used occasionally; look for oil or grease on turntable rim.

c. Slide assembly return spring (74) shown in Figure 46 may be loose or missing. This spring holds cycling wheel (73) against a knurled roller.

d. Knurled roller that operates the cycling wheel may be slipping on its shaft. Tighten the setscrew in the knurled roller.

Note that the basic distinction between Topics 6 and 7 is that the turntable does not stall when the defects listed under Topic 7 occur; that is, the turntable continues to rotate, but the subsequent record is not played due to incompletion of the change cycle.

8. Erratic Operation

a. Main gear binds, due to foreign matter in the gear teeth, or a bent bearing.

b. Defective ball bearing, damaged thrust-bearing washer, or ball wedged in thrust-bearing race.

c. Binding between lift-pin cam surface on slide-and-cam assembly, and the surface of the pickup-arm lift pin.

d. Excessive friction due to grime or dirt in slide mechanism. Clean the latter with carbon tet (or equivalent), and lubricate it as specified in the service data.

TRIP-MECHANISM TROUBLES

The trip mechanism starts a change cycle after a record has been played; that is, the trip mechanism has a "trigger action." We will find that many bench servicing jobs are concerned with defective trip action. The technician is most often called on to service the *position-trip* or the *velocity-trip* system. Certain arrangements are merely variations of position or velocity designs. Occasionally, you may encounter an *eccentric-* or *oscillating-trip* arrangement. The modern trend is to some form of velocity trip, as it is the most versatile design to contend with variations and tolerances in record run-off grooves. Common trouble symptoms caused by defects in trip mechanisms are as follows:

1. Position trip starts the change cycle too early.
2. Position trip fails to initiate the change cycle.
3. Velocity trip starts the change cycle too early.
4. Velocity trip fails to initiate the change cycle.
5. Change cycle repeats continuously (position or velocity trip).
6. Eccentric trip fails to initiate the change cycle.
7. Needle does not set down properly.
8. Needle does not track grooves properly.

Velocity Trip

Let us consider an example of a velocity trip. A typical arrangement is depicted in Figure 47. When the pickup arm swings in an arc, it rotates the trip finger cam and shaft assembly (73). As the pickup arm approaches the end of a record, trip finger cam (73) pushes trip link (82), which in turn engages trip lever (81), thereby rotat-

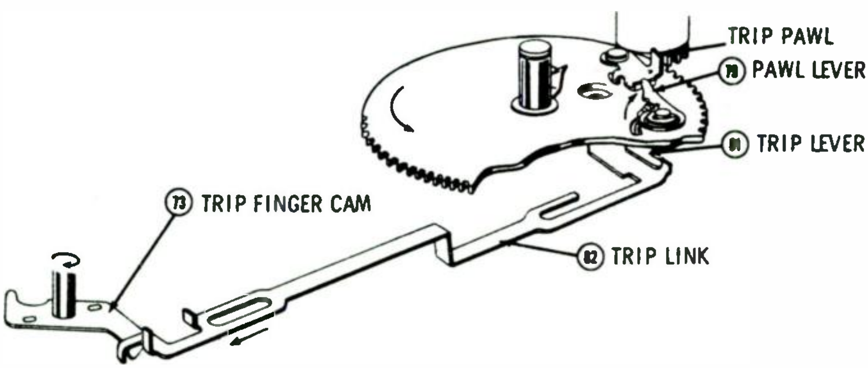


Figure 47 — Typical velocity-trip linkage.

ing pawl lever (79) toward the turntable hub. In turn, the trip pawl is moved toward the turntable hub. There is a projection provided on the turntable hub, which strikes the trip pawl as the pawl approaches the hub.

We recognize from Figure 47 that the change cycle cannot be started as long as the pickup arm is moving *slowly* toward the center of the turntable. On the other hand, the change cycle starts when the pickup arm moves rapidly toward the spindle. After the record has been played, the needle enters the widely spaced finishing or run-off grooves of the record. Because of

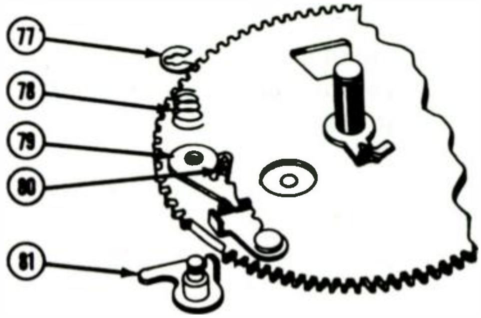


Figure 48 — Main gear in a VM changer.

this wide spacing, the trip pawl in Figure 47 is moved a substantial distance toward the turntable hub during one revolution. Therefore, when the hub projection completes a revolution it does *not* strike the trip pawl lightly or move it back slightly. Instead the hub projection

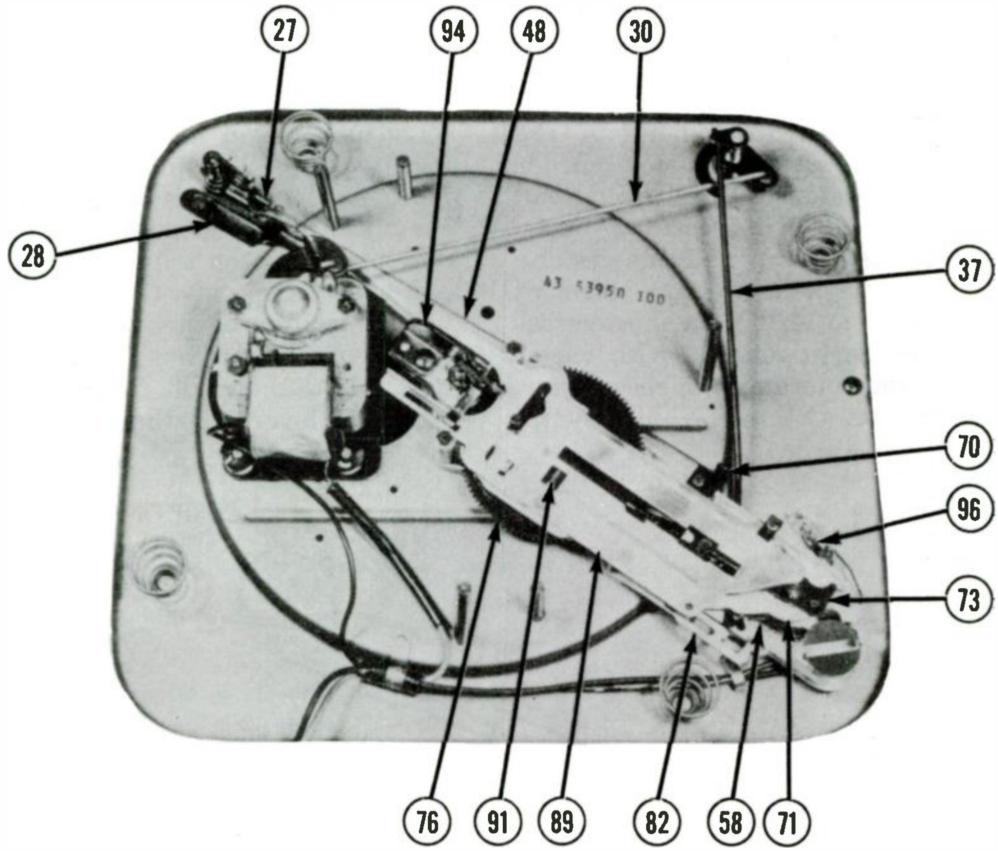


Figure 49 — Bottom view of VM changer chassis.

catches or "latches on" to the trip pawl, thereby carrying the main gear forward through a small arc.

This forward rotation of the main gear moves it out of the "dead spot" with respect to the hub gear, and the main-gear teeth engage with the hub-gear teeth, thereby starting a change cycle. When the control knob is turned to its REJECT position, the control shaft assembly (58) shown in Figure 49 moves trip link (82) to the rear (see Fig. 47 also). Thereby, the trip pawl on the main gear is manually actuated, and a change cycle is started.

Eccentric Trip

You will occasionally encounter an eccentric-trip mechanism. This is a very reliable arrangement, but sometimes has the disadvantage of an appreciable time lag between the time that a recording ends and the time that a change cycle starts.

When the placement of the eccentric grooves on a record is compared with that of the circular label outline, it is seen that the eccentric grooves are cut "off center" (Fig. 50). The practical result is that the pickup arm oscillates back and forth, toward and away from the spindle hole. It is this oscillating motion of the pickup arm that is utilized in the operation of the eccentric trip mechanism. Briefly, a ratchet-and-pawl (Fig. 51) arrangement is used to change the oscillatory motion of the pickup arm into a rotational movement of the trip lever in order to start a change cycle. The basic reliability of the eccentric trip stems from the fact

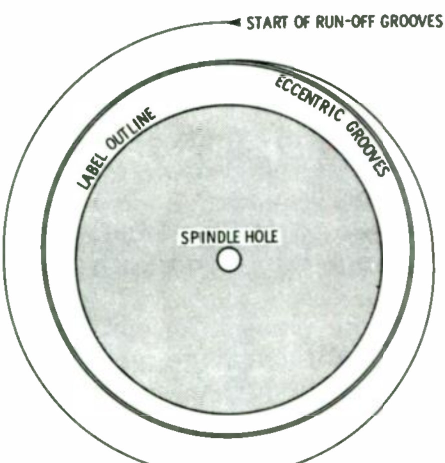


Figure 50 — Spiral run-off grooves terminating in eccentric grooves.

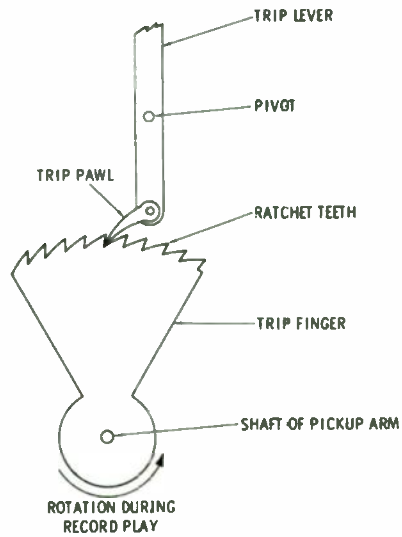


Figure 51 — Plan of eccentric-trip mechanism.

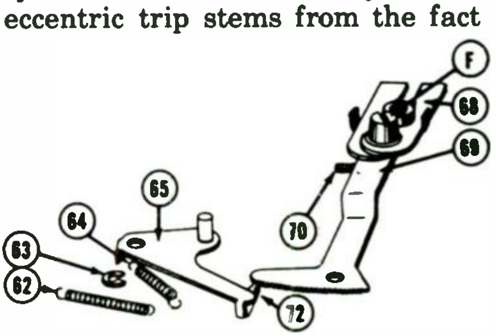


Figure 52 — Eccentric-trip components used in a typical changer.

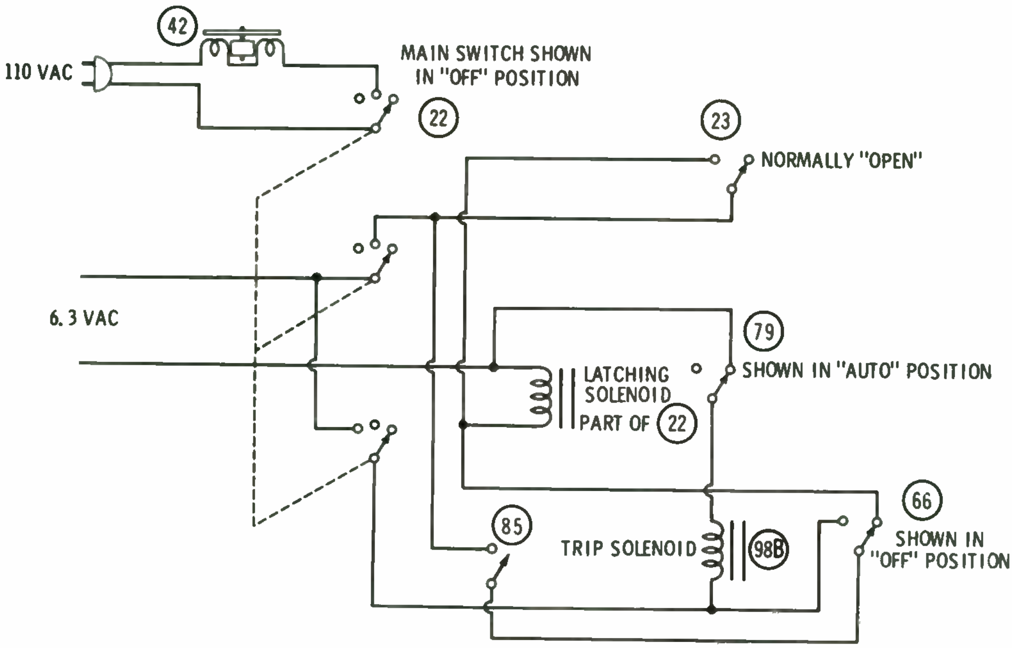


Figure 53 — Wiring diagram of a solenoid trip assembly.

that the oscillatory motion of the pickup arm must necessarily continue until the change cycle is started and the needle and pickup arm are raised from the record.

Solenoid Operation

Instead of using mechanical action exclusively, some record changers include solenoids (electromagnets) in the trip assembly. Let us consider a typical example. With reference to Figure 53, trip solenoid (98B) pulls the starting pawl in the main cam, thereby starting a change cycle. The trip solenoid is energized when trip switch (85) is closed at the end of record play. Note that the trip switch may be positionally, velocity, or eccentrically controlled in various changers.

Trip action is associated with automatic shutoff action, from the general viewpoint of changer operation. When the last record drops from the stack to the turntable, the mechanism operates bale switch (66) in Figure 53. Then, after the record has been played, trip switch (85) is operated. In turn, the circuit is closed that energizes latching solenoid which is part of main switch (22), the latching solenoid trips main switch (22), and the changer is shut off automatically.

Analysis of Common Symptoms

1. Position Trip Starts the Change Cycle Too Early

Possible causes of premature starting of the change cycle, due to defects in the trip mechanism, are as follows:

a. Trip mechanism may be incorrectly adjusted. Turn trip-adjusting screw as required to start a change cycle after the record has been completely played.

b. Record may be an obsolete type. Check trip action with a modern record.

c. Bent lever in trip mechanism, throwing trip-adjusting screw out of range. Replace the lever.

2. Position Trip Fails to Initiate the Change Cycle

a. Trip mechanism may be incorrectly adjusted. Turn trip-adjusting screw as required to start a change cycle when the pickup arm is suitably positioned.

b. Trip-adjusting screw may be loose, so that it does not hold its position. Replace the trip assembly.

c. If solenoid control is used, look for a defect in the trip switch (see trip switch (85) in Figure 53). If switch is okay, check solenoid for continuity.

d. Trip finger spring may be defective or missing; replace if necessary.

e. Record may be an obsolete type. Check the trip action with a modern record.

f. Bent lever in the trip mechanism, throwing trip-adjusting screw out of range. Replace the lever.

3. Velocity Trip Starts the Change Cycle Too Early

a. Spindle hole in record too large; if the hole is too large, the pickup arm will have more or less of an eccentric motion, which can cause premature tripping.

b. Binding of trip link; replace if cleaning and lubrication do not correct the difficulty. Trip link (82) in Figure 47 shows the typical construction.

c. Friction clutch on trip pawl defective; remove any burrs with a fine-toothed file. Clean, and replace worn or damaged parts.

d. If the friction clutch uses a felt washer, clean hardened deposits and dirt from washer; replace the washer if worn excessively or damaged.

e. If the changer employs a dragging lever, such as dragging lever (60) depicted in Figure 54, this lever may be binding. Inspect to determine the reason, and loosen or replace the lever.

4. Velocity Trip Fails to Initiate the Change Cycle

a. The spring projection on the turntable hub may be loose or

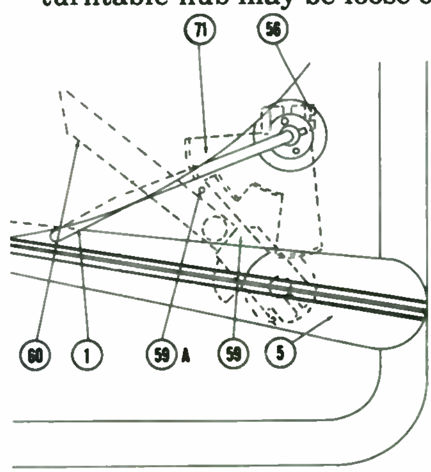


Figure 54 — Use of dragging arm (60) to actuate trip mechanism.

missing. Tighten, or replace it.

b. The record may be obsolete or nonstandard. Check trip action with a known good record.

c. The needle may be jumping out of the grooves, due to excessive trip pressure. Check for binding in the pickup-arm bearing. NOTE: Needle might be badly worn; if so, replace it.

d. If solenoid action is employed in the trip mechanism, check the coil winding for continuity; check circuit for opens and shorts. Figure 55 shows a typical wiring diagram, exclusive of the switch.

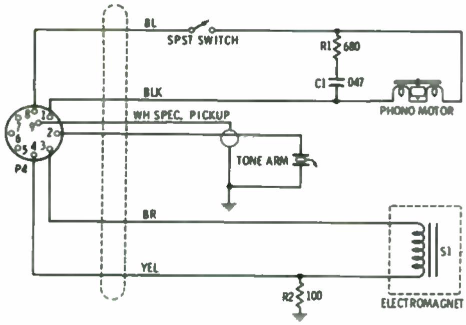


Figure 55 — Wiring diagram showing solenoid circuit.

5. Change Cycle Repeats Continuously (Position or Velocity Trip)

a. Make certain that the trip link is not frozen in the reject position; Figure 47 depicts trip link (82). Clean, and lubricate it lightly. If linkage is bent, replace it.

b. The changer control lever may be binding due to burrs, dirt, or mechanical distortion. Replace it if necessary. Changer control lever (58) illustrated in Figure 49 is typical.

c. Trip pawl, trip lever, and pawl lever must be free to turn easily. These components are exemplified in Figure 47.

d. The changer control linkage must also be free to actuate the trip assembly. Shut-off rod (37) and changer control lever (58) in Figure 49 are the parts that should be inspected.

6. Eccentric Trip Fails to Initiate the Change Cycle

a. The pawl spring may be loose or missing; pawl spring (64) in Figure 52 is an example.

b. If spring (62) in Figure 52 is loose or missing, the change cycle will not start.

c. The trip screw may be incorrectly adjusted. Trip screw (70) in Figure 52 is typical.

d. The record may be obsolete or nonstandard, with inadequate or no eccentric grooves. Check the trip action with a known good record.

7. Needle Does Not Set Down Properly

a. A bent trip finger cam. Replace it with a new part.

b. The record may be nonstandard (an occasional 12-inch record is found which is undersized).

c. In position-trip assemblies, the trip actuator may be a part of the set-down actuator. If correct trip point does not occur when adjustment is made for correct set-down point, mechanical distortion has probably occurred. Replace the position-trip assembly.

d. The adjusting screw may be loose, and does not hold the set-down position. Replace it.

8. Needle Does Not Track Grooves Properly

a. Binding in trip mechanism, causing excessive force of reaction against tone arm. Clean and lubricate the trip mechanism per service data. If difficulty persists, replace it.

b. A trip mechanism in normal condition may cause difficulty if the record is worn, and its grooves are defective. Check with a known good record.

c. The dragging arm may be binding; clean, or replace if required. Dragging Arm (60) in Figure 54 is an example.

d. The trip pawl may not be free; its movement can be obstructed by dirt on the face of the cam gear. Clean and lubricate it per service data. Remove any burrs that might be present. Replace it if necessary.

PICKUP-ARM AND ASSEMBLY TROUBLES

Although the pickup arm (also called the tone arm) is one of the most prominent components in a record changer, the working parts of the pickup-arm assembly are hidden from view. The sections of this assembly can be categorized into the pickup-arm–raising subassembly, the pickup-arm–swingout subassembly, the arm swing-in subassembly, and the arm set-down subassembly. At this point it is helpful to note the common trouble symptoms caused by defects in the pickup-arm assembly mechanism:

1. Height of arm cannot be adjusted.
2. Arm-height adjustment changes.
3. Erratic arm-raising action.
4. Failure of arm to rise.
5. Failure of arm to lower.
6. Lowering action retarded or intermittent.
7. Arm does not swing out.
8. Swing-out action is erratic.
9. Arm does not swing in.
10. Swing-in action is erratic.

Analysis of Common Symptoms

1. Height of Arm Cannot Be Adjusted

a. Height adjustment screw has stripped threads. Figure 58 shows the usual locations for this screw. Another example is shown in Figure 59. If the threads are stripped, the screw and/or its mating part must be replaced.

b. Slide cam bent. If the adjustment screw is out of range, cycle the changer manually and observe the slide-cam action (Fig. 56). If the slide cam is bent so that the push rod is not actuated, the cam must be straightened or replaced.

c. Push rod seized in channel. If the push rod becomes frozen in position, look for foreign

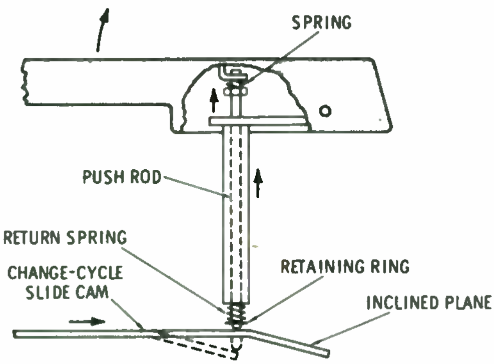


Figure 56 — Plan of a slide-cam mechanism for raising tone arm.

matter or burrs; push-rod seizure will also cause damage to the slide cam.

2. Arm-Height Adjustment Changes

a. Spring (11) in Figure 60 may be damaged or missing. This spring normally exerts ample friction to prevent the adjustment screw (12) from drifting.

b. Threads on adjustment screw and/or mating part may be worn so that screw is insecure.

c. The slide cam assembly may be worn and have excessive mechanical tolerance. Figure 56 depicts a typical slide cam arrangement.

d. Check all parts in the assembly to determine if a washer or similar part might have been left out during a previous troubleshooting procedure.

3. Erratic Arm-Raising Action

a. Push rod or equivalent part

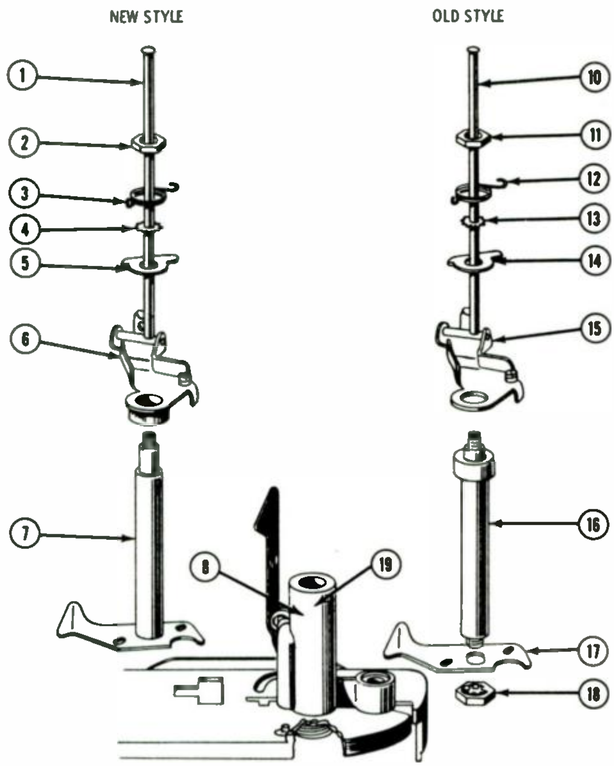


Figure 57 — Examples of hinge assemblies.

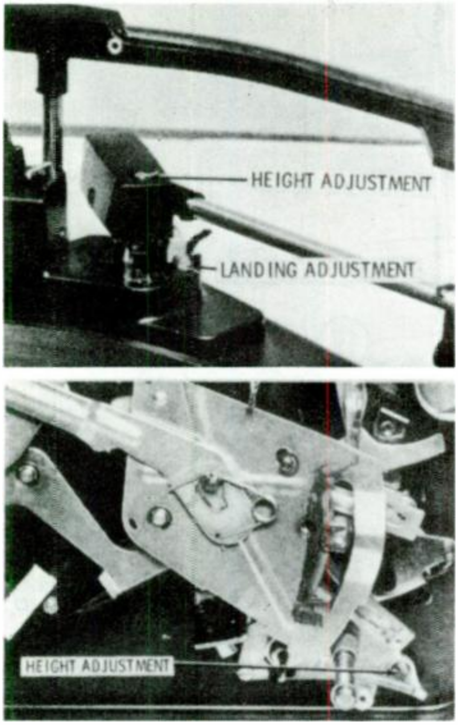


Figure 58 — Two common locations for the height adjustment screw.

binds. Clean and lubricate per service data.

b. Encrusted dirt or foreign matter on incline cam surface. Clean and lubricate as required.

c. Follower arm spring broken or loose. For example, see follower arm spring (38) in Figure 61.

d. Loose nut or screw in arm-raising mechanism. Make a systematic check while cycling the changer manually.

4. Failure of Arm to Rise

a. Height adjustment screw missing. Replace it.

b. Push rod seized in its channel. Clean and lubricate it, or replace if necessary. Check associated parts for mechanical distortion; repair or replace.

c. If changer employs a pickup-arm-lifting spring, this spring may be weak or broken.

d. Broken linkage, due to user trying to move the arm manually during the change cycle. Replace linkage.

5. Failure of Arm to Lower

a. Hinge pivots may be rusted; cone bearings may have been turned up too tight; bearing may be encrusted with foreign matter.

b. If a return spring is used to move the arm down, this spring may be weak or broken.

c. Push rod may be corroded, have burrs, or may bind in its channel. Repair or replace as required.

d. Ejector lever on ejector bracket bent.

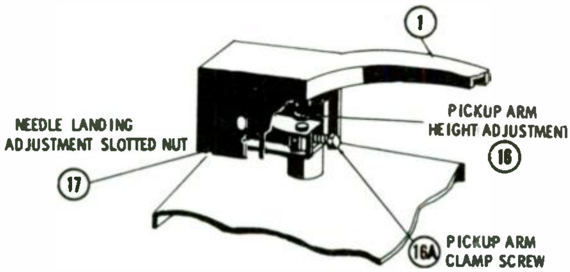


Figure 59 — Example of pickup-arm height adjustment.

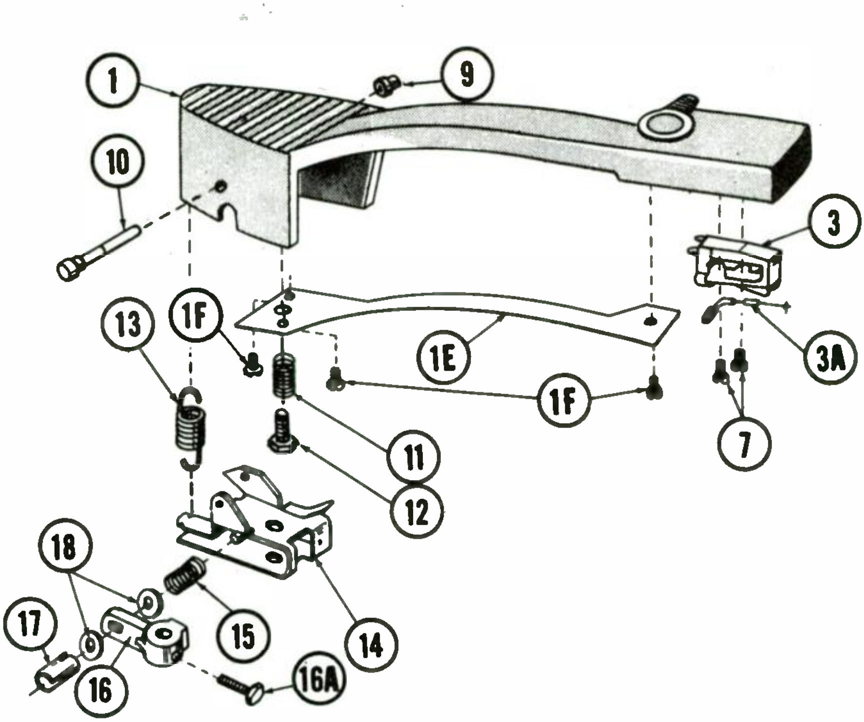


Figure 60 — Enlarged view of an arm assembly.

6. Lowering Action Retarded or Intermittent

a. Defective hinge bearings may impose marginal friction as arm lowers.
b. Return spring may have weakened, without causing complete failure.
c. Foreign matter between the push rod and its sleeve may retard rod movement.
d. In cold weather unsuitable lubricants can impede the normal action of the pickup assembly.

7. Arm Does Not Swing Out

a. Connecting lead trapped. Free the lead and replace it, routing it properly. Inspect swing-out mechanism for resulting bent or broken parts.
b. Many changers employ a safety spring as part of the swing-out linkage, to minimize the possibility of damage in case the user grasps the arm during the change cycle. (See safety spring (3) or (12) in Fig. 57.) Inspect the safety spring for breakage.
c. If a safety spring is not utilized, check the arm-actuating lever for damage. Whenever the pickup arm is blocked or restrained from moving freely and no safety spring is provided, damage to the mechanism is inevitable.
d. An actuating spring is used to the arm-actuating lever in some changers. Check the actuating spring for breakage.
e. Less often, a loose nut, bolt, or setscrew in the swing-output mechanism is the culprit.

8. Swing-Out Action Erratic

In most cases, erratic swing-out action involves the same defects as noted under Topic 7.

9. Arm Does Not Swing In

a. Connecting lead trapped.
b. Arm-return spring broken or missing.
c. Clutch between arm-return lever and arm control lever worn. Replace the cork disc.
d. Arm-return lever fouled with foreign matter. Clean and lubricate as specified in the service data.

10. Swing-In Action Erratic

Erratic swing-in action usually involves the same defects as noted under Topic 9, except that the defect is marginal.

RECORD-DROPPING-MECHANISM TROUBLES

Faulty record-dropping action is a comparatively common complaint. In some cases the difficulty is due to attempted operation with badly worn or nonstandard records. However, if the trouble persists when known good records are placed on the spindle, the trouble will be found in the record-dropping mechanism. Note that standard records may not be dropped normally if the mechanism is out of adjustment. Since the record-dropping mechanism is associated with other actions in the change-cycle system, interaction symptoms may also occur due to defects in the record-dropping mechanism. Common trouble symptoms caused by defects in the record-dropping assembly are:

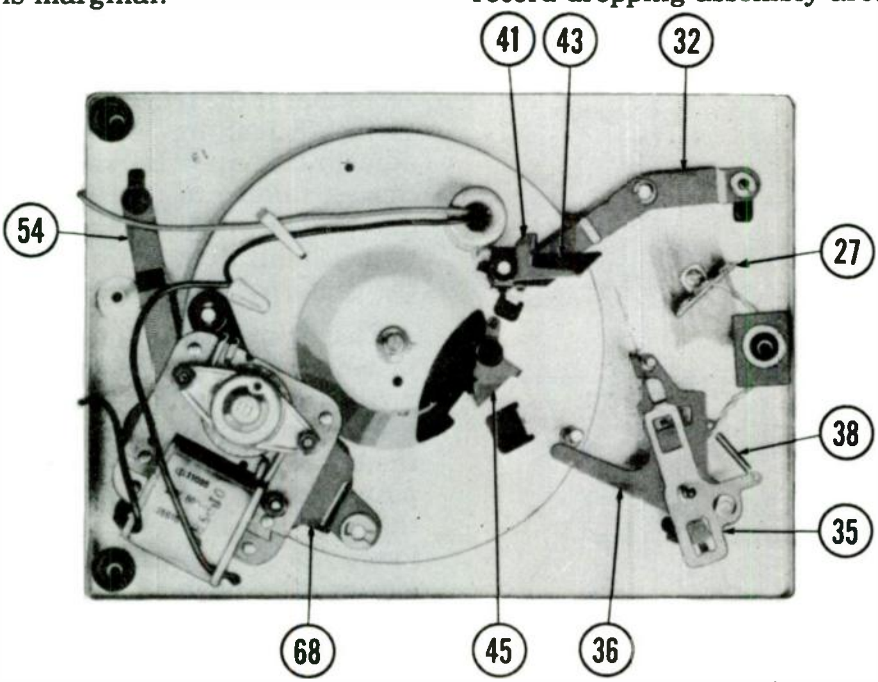


Figure 61 — Bottom view of VM changer with cam gear removed.

1. Several records drop at the same time.
2. Turntable loses speed as record drops.
3. Records fail to drop, or drop improperly.
4. Record strikes tone arm.
5. Records fall to turntable unevenly.
6. Records fail to separate properly.
7. Records jam between shelf and spindle.
8. Spindle damages records.

A typical spindle-tripping arrangement is depicted in Figure 62.

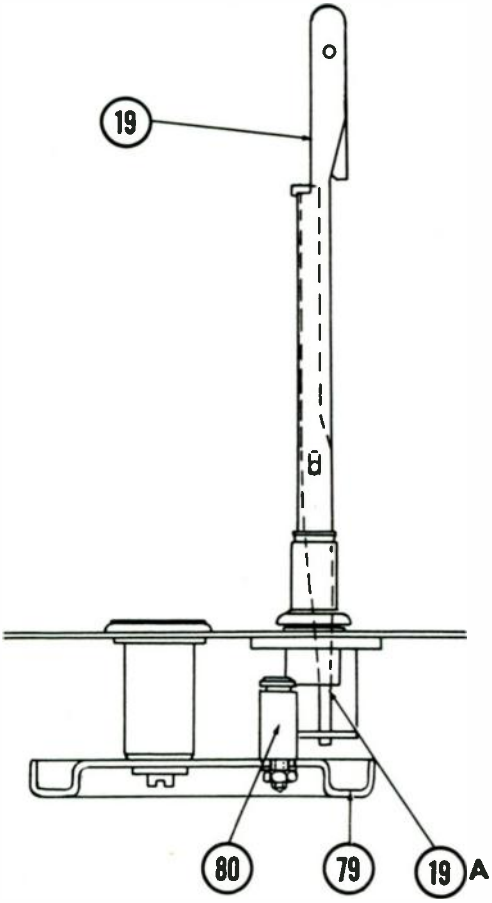


Figure 62 — Diagram of spindle-tripping mechanism.

Spindle (19) holds a stack of up to 10 records. The bottom record is separated from the stack by movement of a finger in the spindle; the dotted lines show the shape of the finger. Reject lever (19A) moves the finger when contacted by roller (80). This roller is carried by cam disc (79). A spindle arrangement of this type is called a *shelf ejector.* The shelf is the offset portion of the spindle; it is also called the *spindle ledge.* To separate the bottom record, the finger engages the spindle hole in the record, and slides it over the edge of the shelf, so that the record drops to the turntable.

Another example is shown in Figure 63. Record push-off is accomplished by means of an ejector (finger) and push-off shaft built into the centerpost. During the change cycle, the ejector and push-off shaft are moved by a safety spring. This spring is shown in Figure 63 between push-off lever (95) and push-off adjustment nut (98). Note that if the travel of the ejector is insufficient for record push-off, adjustment may be required. Of course, failure to push off may be due to a defective safety spring or to mechanical interference inside the centerpost.

Ejector travel in Figure 63 is adjusted by turning the push-off adjustment nut. In this example, the ejector extends just slightly beyond the edge of the shelf on the center post when properly adjusted. Note that additional travel must be allowed for the push-off shaft and ejector after push-off lever (95) has moved its full distance. The push-off adjustment procedure in this example is as follows:

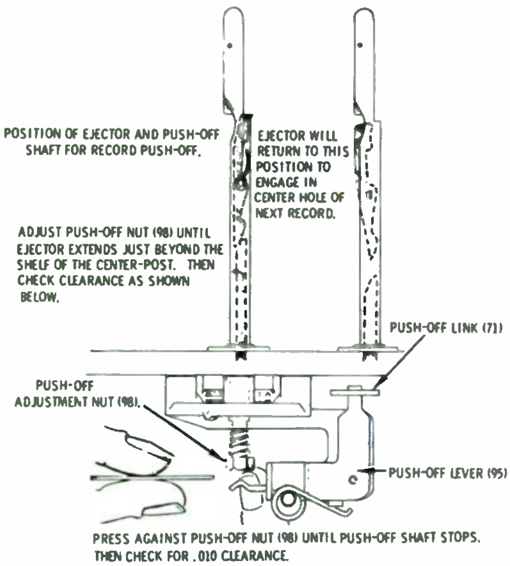


Figure 63 — Adjustment for record push-off.

1. Rotate the turntable by hand. Slide the reject pointer to the REJECT position and let it return to the ON position.
2. Continue rotating the turntable slowly until the roller on the drive eccentric engages push-off link (71) in Figure 63. Rotate the turntable until the roller has moved the link its full distance. Push-off lever (95) is now extended to its maximum travel.
3. Check the position of the ejector at the shelf of the center-post. The ejector should extend just beyond the edge of the shelf. If the ejector does not extend beyond the edge of the shelf, turn push-off adjustment nut (98) counterclockwise to increase the amount of push-off. A $^1/_4$-inch open-ended wrench should be used in this adjustment.
4. Note that the push-off adjustment nut in this example is specially slotted in order to make it stay tight on the push-off shaft after adjustment is made. The nut should not be turned all the way on the push-off shaft, because this will spread the slots and permit the nut to drift from its proper position.
5. Press on the adjustment nut to check for additional travel before the push-off shaft stops. The ejector should move out past the shelf slightly more than necessary for push-off before it stops.
6. Slide a ten-thousandths of an inch (0.010-inch) feeler gauge between the flat surface of the adjustment nut and the safety spring; make the final adjustment so that the gauge passes freely.
7. The additional travel that is provided for the push-off shaft will vary in some cases for optimum push-off action. In this example, the clearance of 0.010 inch must not vary by more than ±0.005 inch.

Record Support Arm

The record support arm, also called the *stabilizer arm,* is illustrated in Figure 64; it is sometimes termed a record-leveling arm, because it serves to hold the stack of records level. This arm engages the automatic shutoff mechanism also, but at this point we are chiefly concerned with its relation to the record-dropping function. The spindles depicted in Figures 62 and 63 cannot operate normally if the stack of records is tilted. Abnormal tilt will cause more than one record to drop

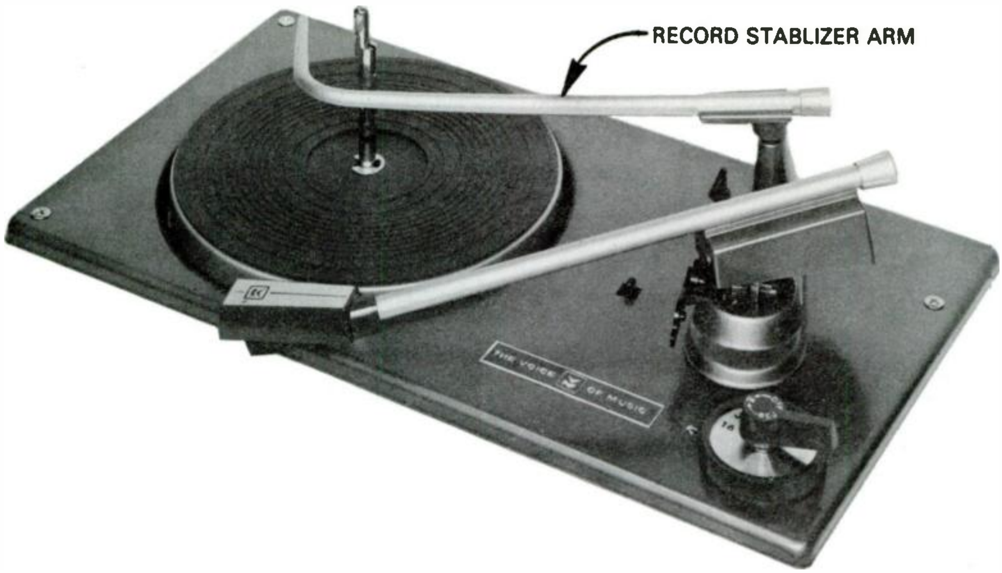


Figure 64 — View of changer showing record stabilizer arm.

at a time or may prevent the bottom record from dropping. Therefore, if the record-support arm has been bent out of shape, it must be straightened or replaced. Damage is usually the result of pulling at the arm from a point near the spindle.

45-RPM Spindles

Seven-inch 45-rpm records can be played on a conventional changer if a special 45-rpm spindle is used, such as the one depicted in Figure 65. To mount the 45-rpm spindle, it should be grasped between the thumb and the forefinger, pressing actuator (128) slightly. The 45-rpm spindle is then slid over the center spindle, and turned as required to make the bottom slot line up with the centerpost gate. Finally, the 45-rpm spindle is pressed down until it comes to rest on the turntable. It is then ready for operation.

The center spindle serves the same basic purpose and functions the same as before the 45-rpm spindle was placed on the changer. As the centerpost is actuated, its ejector lever contacts actuator (128) in Figure 65. The actuator is pushed, which causes separators (130) to move out; in turn, bolts (131) are pulled in. As the bolts recede the separators above the bolts move out, thereby permitting the bottom record to drop to the turntable, while the remainder of the stack is supported. The ejector lever on the center post then moves to its rest position, allowing the actuators on the 45-rpm spindle to return with it by pressure of spring (133), causing the separators to move in and the bolts to move out. This permits the bottom record to drop from the separators to the bolts.

SET-DOWN INDEXING TROUBLES

It has been previously noted that

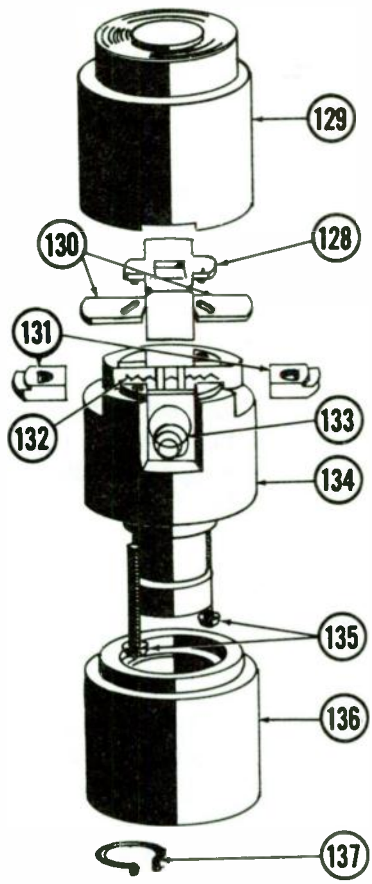


Figure 65 — 45-rpm spindle.

the more elaborate types of record changers will play a stack of intermixed (differently sized) records. However, all of the records in the stack must be of the 78-rpm type, or an LP type of a given speed. In other words, "intermixing" refers to a difference in record diameter only. The standard diameters are 7, 10, and 12 inches. The function of the set-down indexing mechanism is to control the set-down position of the pickup arm in accordance with the diameter of the record. As explained previously the set-down position is always the same for a changer that does not accommodate an intermixed stack of records. We also noted how the set-down position is adjusted in this type of record changer.

When the set-down position is corrected in a changer that plays an intermixed stack of records, the set-down adjustment is usually made with reference to a 10-inch record. Figure 66 depicts a typical set-down adjusting assembly. In normal operation, the pickup arm will automatically set down correctly on 7-inch and 12-inch records, if set-down adjusting screw (16) has been set properly on a 10-inch record. It is important to operate the turntable in a level plane; otherwise the adjustment may be in error or the needle may drift off the edge of the record. Common trouble symptoms produced by defects in the set-down and indexing mechanism are as follows:

1. Failure of automatic shutoff.
2. Feeler does not move against the next record.
3. Pickup needle does not land on record.
4. Pickup needle lands in playing grooves.
5. Set-down action is not uniform from one record to another.
6. Set-down action defective on one size of record only.

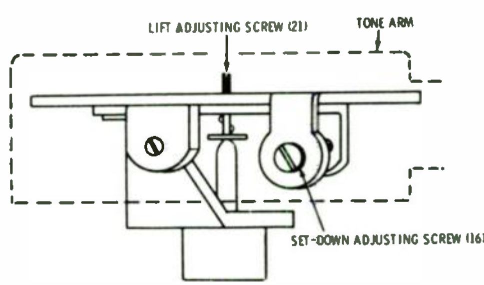


Figure 66 — Tone-arm set-down and lift adjustment.

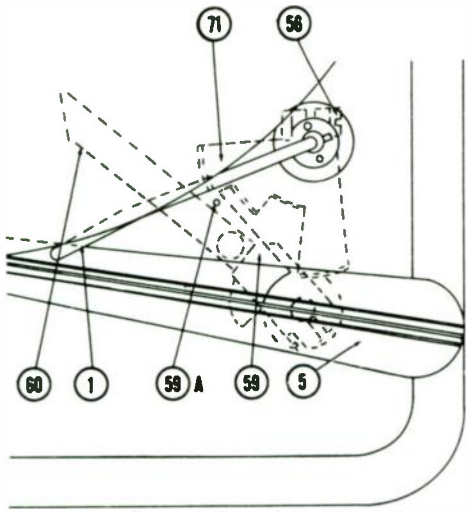


Figure 67 — Record size selector arm diagram.

7. Intermittent operation of indexing mechanism.

General Discussion

With reference to Figure 67, at one point in the change cycle, pickup arm (5) is moved out and over its rest via stop lever (59). At about the same time record selector arm (1) approaches the record and touches its edge. Stop piece (71) is connected to the bottom of the record selector arm, and is also stopped by the record edge. As the pickup arm then starts its inward movement stop pin (59A) is caught in its proper notch by stop piece (71); the notch that is employed depends on the size of record that is being played. The selector arm in this example is adjusted as follows.

With reference to Figure 68, rotate cam disc (79). This positions control lever (52) so that the record selector arm (1)—shown in Figure 67—is free. Next, put a 12-inch record on spindle (19)—depicted in Figure 69—and move the record selector arm over to the edge of the record manually. Then loosen screw (72) shown in Figure 70, and twist stop piece (71) on its shaft; the stop piece is depicted in Figure 67 and in Figure 70. Stop pin (59A) in Figure 67, mounted on stop lever (59), will move before the 12-inch stop at a distance of 1/64 to 3/64 inch, and will strike against the 10-inch stop. Then tighten screw (72), shown in Figure 70.

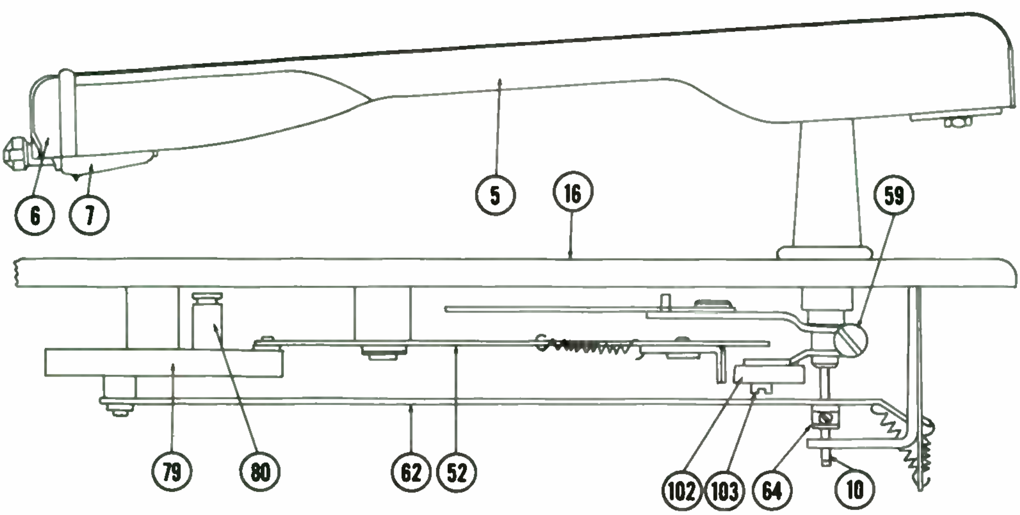


Figure 68 — Side view diagram of mechanism.

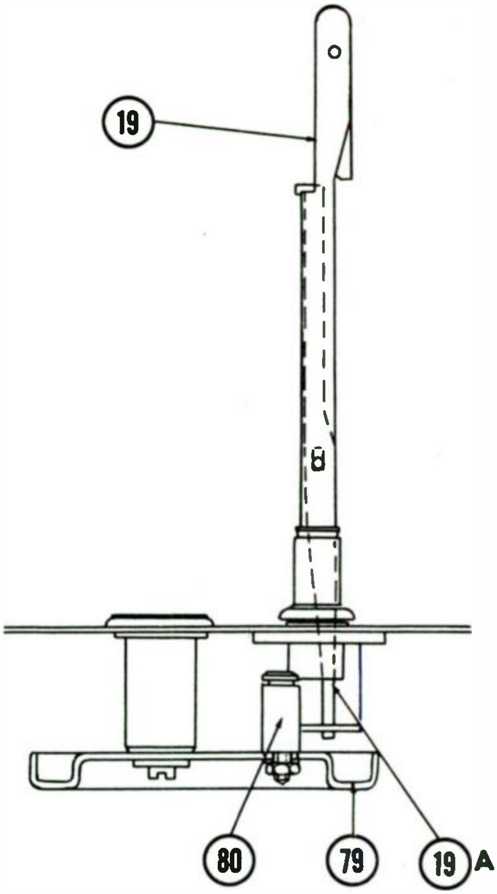


Figure 69 — Spindle-tripping diagram.

Conical spring (75), shown in Figure 70, must be so mounted that it twists record selector arm (1) counterclockwise. It is also important that the record selector arm is properly adjusted for the rest position. Turn cam disc (79) to its rest-position notch. Stop piece (71) must be so placed that the distance between the nearest part of the stop piece to the edge of the chassis plate is between 19/32 and 23/32 inch. If this distance is incorrect, regulate adjusting angle (54) on angular lever (53) as required. Although a particular example has been cited, the general principles that are involved are the same. For details of various brands and models of changers, it is necessary to consult the changer service data.

With reference to the example of Figure 71, index finger cap (76) is provided as a "feeler." That is, a 10-inch record will extend past the edge of the turntable far enough for the index finger cap to momentarily "feel" the edge of the record. Note that the index finger cannot rise as high as it could before a record obstructed its travel. In this manner the set-down index is positioned to provide proper set-down for the 10-inch record. Figure 72 shows the set-down index assembly. It has three slots, each of which determines how far the pickup arm can swing in. When the index finger cap is pressed down, the assembly moves on its pivot by lever action.

A 7-inch record cannot obstruct the index finger in Figures 71 and 72. Therefore, the set-down index is left in a position which permits the index pin (not shown) to enter the first slot. As the pickup arm swings in, its travel is limited to the depth of the slot. Thus the set-down point is established. However, suppose that the index finger cap is pressed down by a 10-inch record, as noted previously. In such a case the index pin must enter the second slot. The swing-in travel of the pickup arm is less, in order to establish the correct set-down point for the 10-inch record. Finally, note set-down trigger (30) in figure 71. It is set sufficiently far back that it is triggered only by a 12-inch record.

This set-down trigger is also a

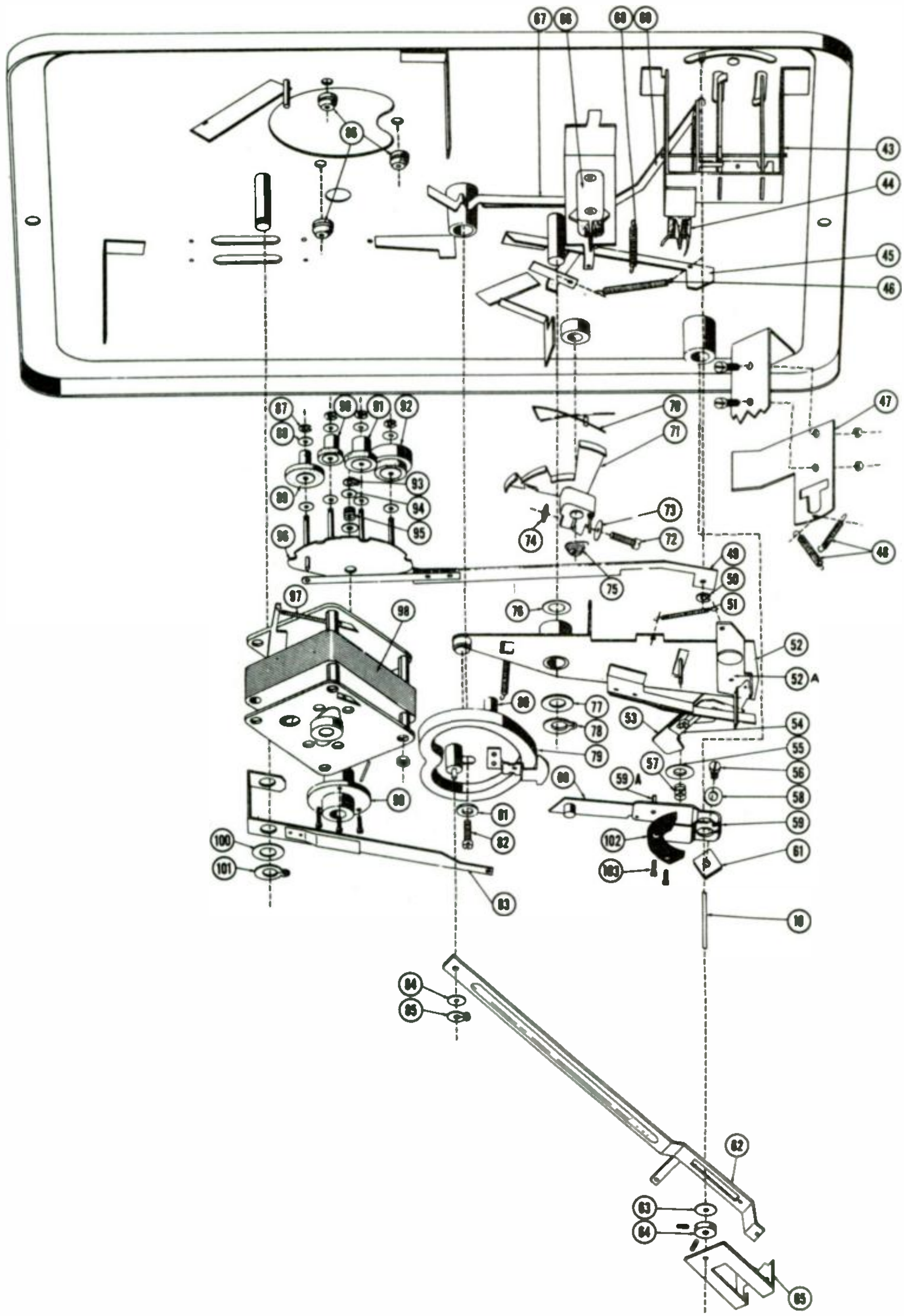


Figure 70 — Enlarged view of mechanism below baseplate.

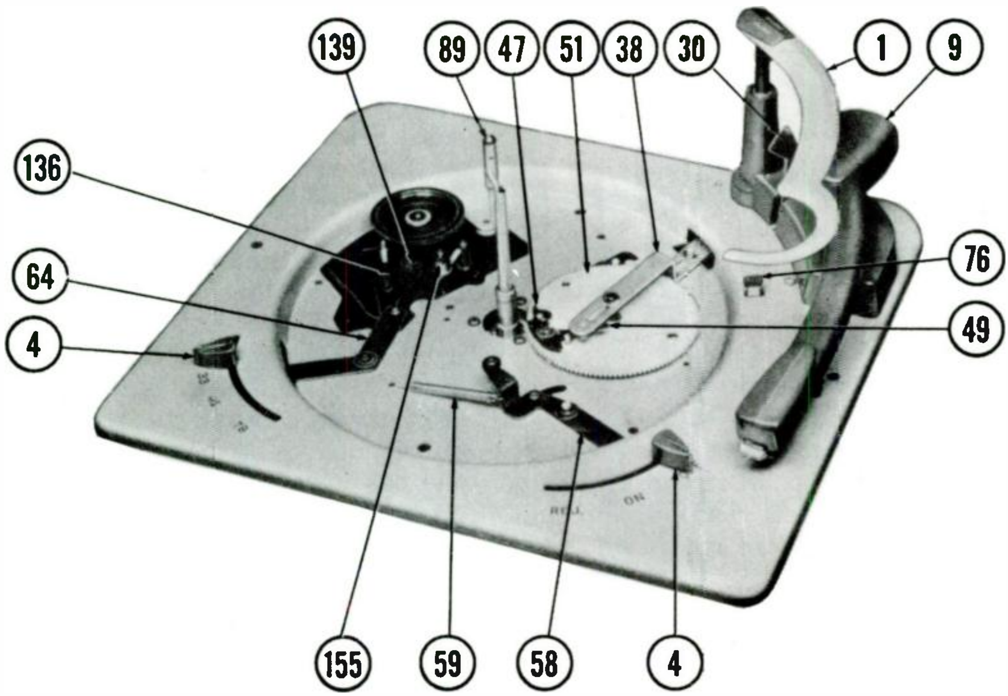


Figure 71 — Top view of chassis with turntable removed, changer out of cycle.

"feeler" to provide information to the mechanism concerning the presence of a 12-inch record. As the record drops down the spindle, it momentarily forces the set-down trigger back, thereby releasing the 12-inch set-down slide. This slide holds the set-down index so that the index pin enters the third slot. In turn, the swing-in travel of the pickup is still less than before, to establish the correct set-down point for the 12-inch record. Intermix of any combination of 10-inch and 12-inch records is accomplished by this arrangement, because only the index finger cap will be pressed down by a 10-inch record, and both the index finger cap and the set-down trigger will be actuated by a 12-inch record.

In theory, it makes no difference in which order we place 7-, 10-, or 12-inch records in an intermixed stack. In practice, also, random intermixing often causes no difficulty. However, if 7-inch records are placed at the bottom of a stack and 12-inch records placed on top, the result is that the small records drop to the turntable first and the large records must rest on top of the small ones. This sometimes causes the large records to tilt as they are

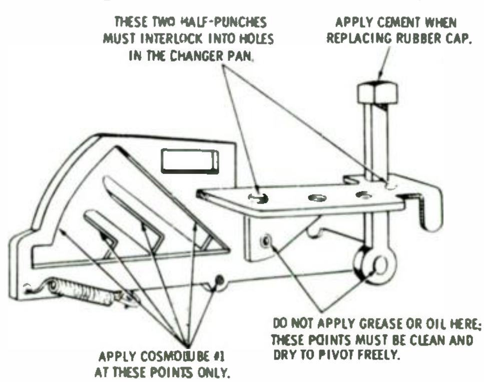


Figure 72 — Set-down index assembly.

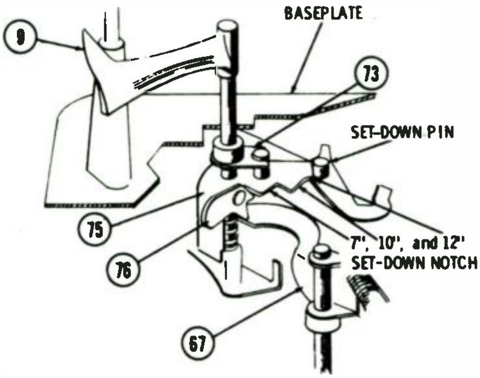


Figure 73 — Semaphore set-down index assembly.

being played, with the result that tracking is poor. Poor tracking causes distorted reproduction and rapid wear of both record and needle.

Semaphore Random Intermix Index

Another example of an index assembly is shown in Figure 73. This is called a *semaphore* arrangement, because the mechanism is actuated by a radial-lever device that has some resemblance to a semaphore. As the record size bracket (75) rotates at the beginning of a change cycle, the pin on top of the bracket rides within the fork of semaphore link (73) and causes semaphore (9) to swing toward the spindle. When pawl (76) disengages from raising lever (67) the record size bracket (75) moves so that its 7-inch set-down notch is in position to block the set-down pin which is located on top of the shutoff plate (61), illustrated in Figure 74.

As the pickup arm swings to its outer limit, the bottom record is pushed off the spindle shelf. If the record has a 7-inch diameter, it will

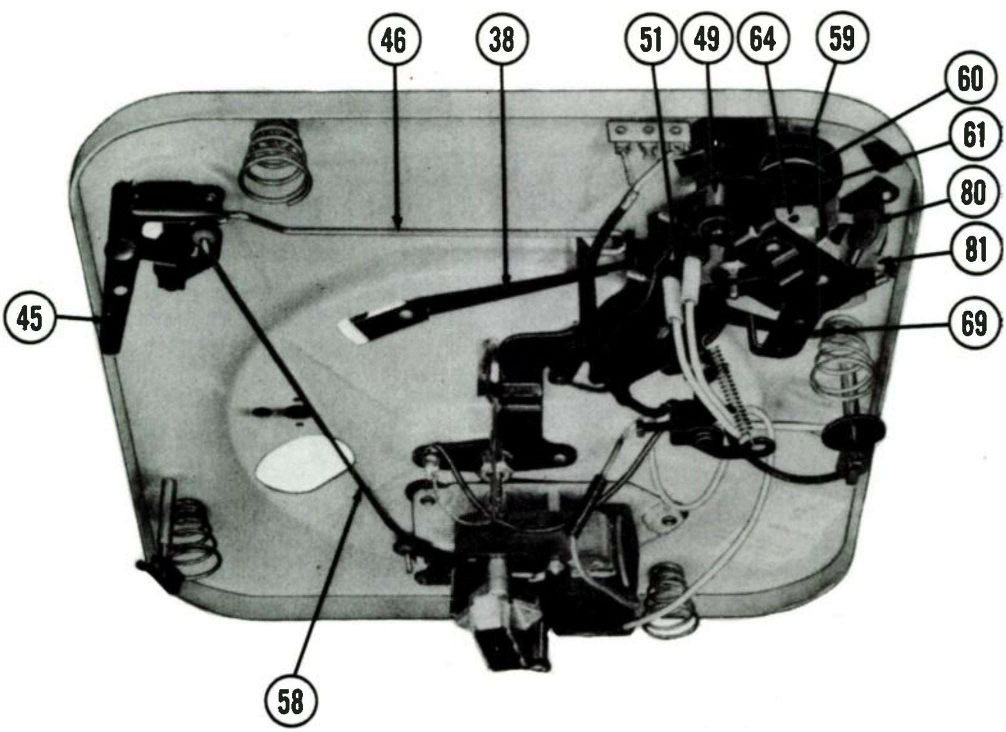


Figure 74 — Under-chassis view of Webcor changer.

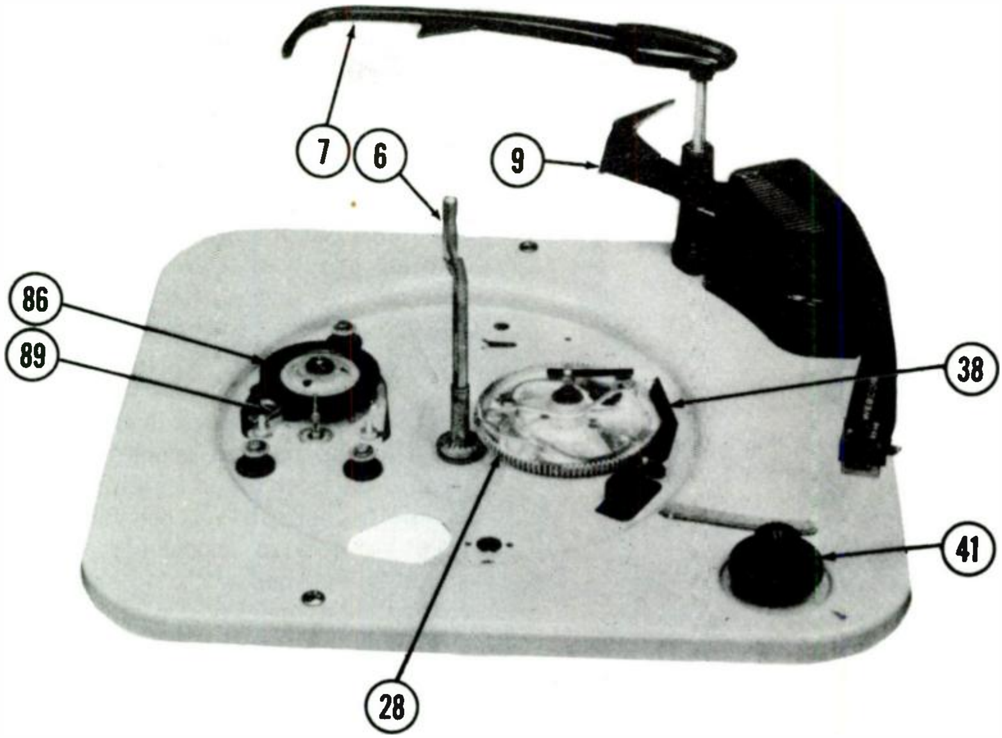


Figure 75 — Above-chassis view of Webcor changer.

clear semaphore (9); the semaphore diagrammed in Figure 73 is also illustrated in Figure 75. Because the small record does not contact the semaphore, the position of record size bracket (75) will not be changed. On the other hand, if the record that drops has a 10-inch or 12-inch diameter, it will hit against one of the sloping sides of the semaphore, and push it back more or less toward its original position. A 10-inch record will push the semaphore approximately half-way back, whereas a 12-inch record will push the semaphore all the way back. This motion is transmitted to record size bracket (75) and thereby positions the bracket to block the pickup-arm on its inward swing at the correct position.

Adjustment of the semaphore is required if link (73) shown in Figure 73 becomes loose during operation, or if erratic or improper indexing occurs. Adjustment is also required after the semaphore has been replaced in course of a repair job. This adjustment involves positioning of semaphore link (73) on its shaft so that the mechanism operates properly. The link is secured to its shaft by means of a setscrew which is accessible from the rear of the changer in this example. The adjustment procedure is as follows:

1. Loosen the setscrew and permit link (73) to drop until it rides on the top of record size bracket (75), shown in Figure 73.
2. With the semaphore held firmly against the housing of

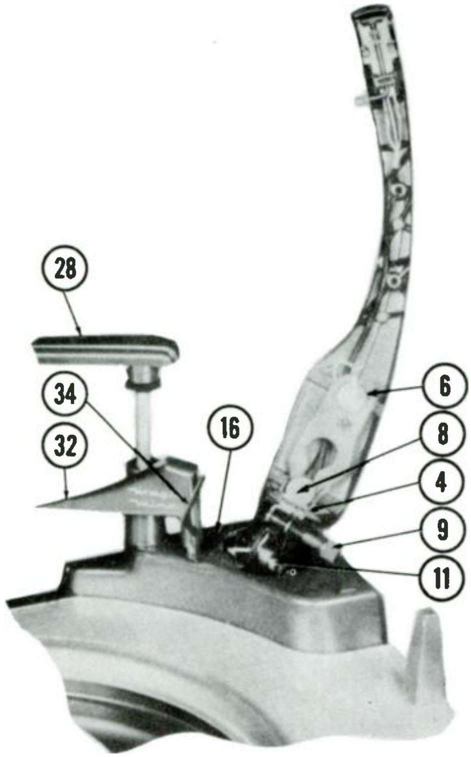


Figure 76 — View of semaphore, feeler, and tone-arm.

the record-leveling arm (see Fig. 7-10), rotate record size bracket (75) clockwise as far as possible (see Fig. 73).

3. Then semaphore link (73) in Figure 73 is lifted until it is within 1/64 inch of the underside of the main plate. Finally, the setscrew is tightened so that the link is firmly secured to the semaphore shaft.

Pickup-Arm and Automatic Indexing Action

A variation in the semaphore indexing arrangement is seen in Figure 76. Semaphore (32) determines the correct pickup-arm set-down and speed change for 7- and 10-inch records. The semaphore and 12-inch feeler (34) determine the pickup-arm set-down for 12-inch records. Set-down of the pickup arm for various sizes of records is basically the same as that just explained. When the pickup arm in the example of Figure 76 enters the run-off grooves, thereby initiating the change cycle, lift tab (D) in Figure 77 is slid from underneath record size bracket assembly (1).

If the speed selector is set to 78 or 33, the record size bracket in Figure 77 is positioned to engage the 10-inch position (B) on the cam lever and arm assembly. If the speed selector is set to 45 or 16, the record size bracket finger is positioned to engage the 7-inch position (A) on the cam lever and arm assembly. When spindle roller (1) in Figure 78 reaches the crest of cam (2) on the main gear, a record drops to the turntable. A 12-inch record will deflect the 12-inch feeler. This causes the feeler to disengage from the record size bracket shaft (1) in Figure 77, and the record size bracket assembly lowers. The record size bracket finger (1) shown in Figure 77 is now in position to engage the 12-inch position (C) on the cam lever and arm assembly.

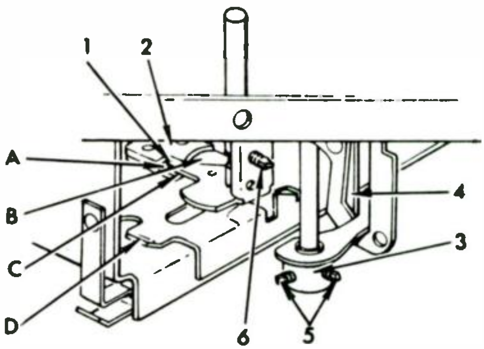


Figure 77 — Partial view of tone-arm set-down assembly.

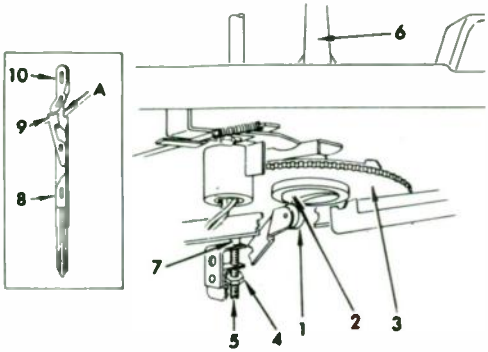


Figure 78 — Partial view of record push-off mechanism showing push-off adjustment screw.

As the change cycle progresses, the pickup arm swings in and stops when the record size bracket finger engages the 7-, 10-, or 12-inch position on the cam lever and arm assembly. This determines the swing-in distance for the pickup arm. Record size bracket (1) shown in Figure 79 determines set-down for the pickup arm. The record size bracket is actuated by speed selector bracket (24) via the record size link (22) shown in Figure 80. When the record size bracket is adjusted

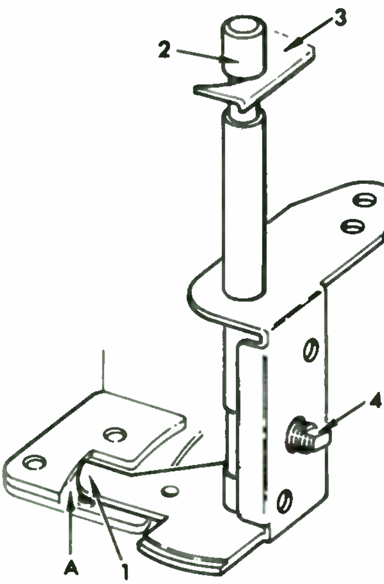


Figure 79 — Tone-arm set-down mechanism.

correctly, the pickup arm in this example sets down as follows:

Speed Selector Set At	*Tone Arm Will Set Down For*
16	7- or 12-inch records
33	10- or 12-inch records
45	7- or 12-inch records
78	10- or 12-inch records

To adjust the record size bracket in this example, swing the record-leveling arm out, and set the speed selector to 45. Then cycle the changer manually. When the pickup arm swings out to its limit of travel, position record size bracket finger in Figure 79 in its 7-inch stop (A) on the cam lever assembly. Next, position the record size shaft (2) so that it is firmly seated on the step of the 12-inch feeler (3). Finally, tighten record size bracket setscrew (4). It is important to note that the record size shaft is easily bent under excessive pressure. The setscrew should be tightened only to 3 inch-pounds, using a torque wrench. If a slab-head screwdriver must be used, tighten the setscrew by grasping the shank of the screwdriver, in order to limit the amount of pressure that is applied.

Analysis of Common Symptoms

1. Failure of Automatic Shutoff

1. The record size bracket (1) in Figure 79 may be loose on its shaft. Tighten as explained

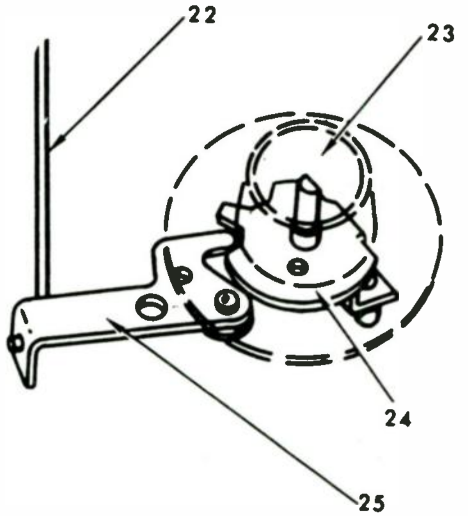


Figure 80 — Speed selector bracket and record size link.

previously. Replace the parts, if defective.

b. Incorrect automatic shutoff adjustment. See instructions in the service data for the particular changer.

c. The symptom may be associated with tripping faults (see Fig. 81 for common causes). Details are explained in a later lesson.

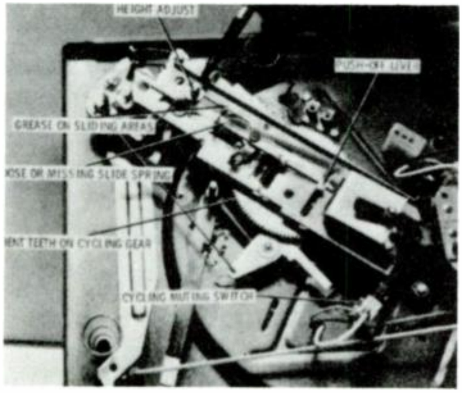


Figure 81 — Points to check for possible cause of tripping problems.

2. Feeler Does Not Move Agains t Next Record

a. Stop piece (71) in Figure 67 may be adjusted incorrectly. In this example adjust the stop piece as explained at the beginning of the General Discussion in this lesson.

b. Feeler mechanism in pickup head (Fig. 82) defective; change the shell only—not the cartridge. In this arrangement the pickup arm first sets down about 3 inches from the spindle. The arm then moves out until the feeler drops over the edge of the record and actuates the index assembly.

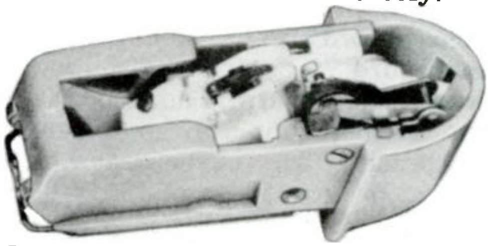


Figure 82 — Cartridge assembly showing feeler.

c. Feeler mechanism in pickup head may be insufficiently retracted. Push the pickup head into the pickup arm until it clicks (catch spring on side must engage).

d. In some changers the feeler may bind due to foreign matter. If the mechanism does not operate freely after cleaning, replace the defective part.

e. Mechanical interference is sometimes the culprit. Look for a connecting wire obstructing the feeler linkage, for example.

f. If the feeler is operated against spring tension, look for a weak or broken spring.

3. Pickup Needle Does Not Land on Record

a. Set-down adjustment incorrect, or stripped threads may be found on the adjustment screw. Check adjustment; replace any defective parts.
b. The 12-inch feeler may be binding. Clean, eliminate mechanical interference, or replace defective parts, as required.
c. Record size bracket assembly may be loose on semaphore shaft or may be incorrectly adjusted.
d. Record may be nonstandard, in that it is less than $11\frac{7}{8}$ inches in diameter. Check landing with a known good 12-inch record.
e. In some changers the trouble may be due simply to the fact that the pickup arm had been returned to rest manually at the previous playing. Stop the changer, and press the starting button.

4. Pickup Needle Lands in Playing Grooves

a. Check set-down adjustment. Replace defective parts, if necessary.
b. In some changers set-down in the 7-inch position instead of the 10-inch position may not be due to a fault in the index assembly but to the fact that the knobs of the turntable rubber cover do not seat properly into corresponding holes in the turntable. Correct the placement of the rubber cover.
c. If the 12-inch record selector does not set normally against spring tension, check for a broken spring.
d. Sometimes the index finger becomes bent. Inspect it; straighten or replace it as required.
e. The changer may employ a return locator cam with a tab (check the service data). If this design is used, bend the tab slightly outward.

5. Set-Down Action Is Not Uniform From One Record to Another

a. Feeler spring is weak, or there is marginal binding in mechanism.
9 b. Record size bracket shifts slightly on semaphore shaft. Tighten setscrew.
c. Check records to determine whether the grooving is standard.
d. Pickup-arm shaft-and-sleeve assembly defective. Replace defective parts.
e. Pickup hinge pivots loose. Tighten pivots.

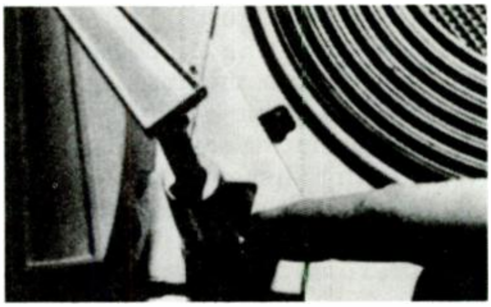


Figure 83 — Index lever that must be tripped by record to correctly position tone arm.

6. Set-Down Action Defective on One Size of Record Only

a. Check for a broken spring or foreign matter in the 12-inch record selector mechanism.
b. Marginal adjustment of record size bracket on semaphore shaft. Adjust bracket as specified in changer service data.
c. The records that are not played normally may have enlarged center holes, subnormal diameters, or be otherwise nonstandard.
d. If a 45-rpm spindle is being used, the spindle may be defective, or the set-down adjustment may be incorrect.
e. Apparent set-down trouble is sometimes actually due to a defective speed control. Look for obvious defects first, such as a loose knob.

7. Intermittent Operation of Indexing Mechanism

a. Ambient temperature may be lower than usual, with the result that lubricated joints are stiffer. Clean and lubricate joints per service data.
b. Index lever may be chipped or otherwise defective. As pointed out in Figure 83 the index lever must be tripped by the record to obtain proper positioning of the pickup arm.
c. Loose nut or screw in the indexing assembly. A systematic "tightening job" will either correct the intermittent or remove this possibility from suspicion.
d. Apparent intermittent operation of the indexing mechanism is sometimes actually due to worn or loose parts in the pickup-arm shaft and sleeve assembly, or to loose pickup hinge pivots.

DRIVE AND TURNTABLE TROUBLES

Defective turntable and drive assemblies cause a considerable proportion of the complaints made by customers concerning changer operation. Most of these troubles are comparatively easy to pinpoint and correct. As we briefly noted, the drive assembly applies torque from the motor to the turntable in such a manner that the turntable normally revolves at a predetermined constant speed. The speed may be $33^{1}/_{3}$, 45, $16^{2}/_{3}$, or 78 rpm, depending on the type of record to be played. Since the nominal speed of the motor is usually 1800 to 3600 rpm, it is evident that the drive assembly must include a speed-reduction arrangement. Common symptoms of trouble in the drive and turntable assembly are:

1. Noisy operation.
2. Incorrect speed.
3. Varying speed.
4. Intermittent operation.
5. Flutter or wow.
6. Record slippage.
7. Record wobble.

There are several turntable drive arrangements, some of which are merely variations of the same basic design. Most drive assemblies employ a friction system between wheels that are typically provided with rubber rims. Although reduction-gear trains are occasionally used, these are comparatively expensive. It is practical to utilize friction turntable drives, because the overall reduction in speed is considerable: for example, 40 to 1. Problems of slippage or other forms of abnormal torque transfer can be controlled in practice. On the other hand, gear drive is generally used between the turntable and the change-cycle mechanism. This positive method of torque transfer is employed, not only because the speed reduction is moderate, but because a comparatively large amount of torque is required to drive the change-cycle mechanism.

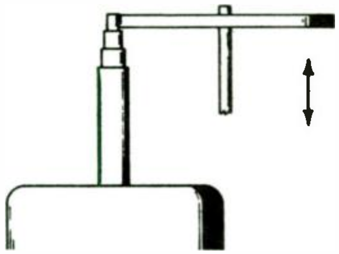


Figure 84 — Speed change is accomplished by moving idler wheel to proper step on motor shaft.

In a simple example of turntable drive the end of the motor shaft provides four steps in diameter, as depicted in Figure 84. Depending on the setting of the speed selector in the changer, one of these steps on the shaft will press against the rubber tire of the *idler wheel.* In turn, the idler wheel presses against the inner surface of the turntable rim. It is obvious that sufficient friction must be provided to supply the required torque. This entails not only a minimum amount of pressure between the surfaces, but also appropriate surface textures. With reference to Figure 85, if grime, dust, or grease contaminates the operating sur-

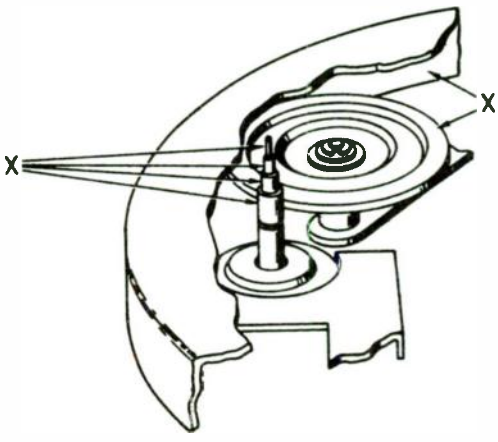


Figure 85 — Motor drive surfaces.

faces, torque transfer will be impaired.

Some of the symptoms of contaminated friction-drive surfaces are uneven speed (wow), stalling during the change cycle, and intermittent operation. This type of defect can be corrected by cleaning the drive surfaces marked "X" in Figure 85. In this example the turntable must be removed to gain access to the drive assembly. You will usually find that the turntable is secured to the spindle by means of a C ring, as depicted in Figure 86. It is a simple job to expand the ring slightly, and slide it out of its slot in the spindle. Drive surfaces should be cleaned with a cloth

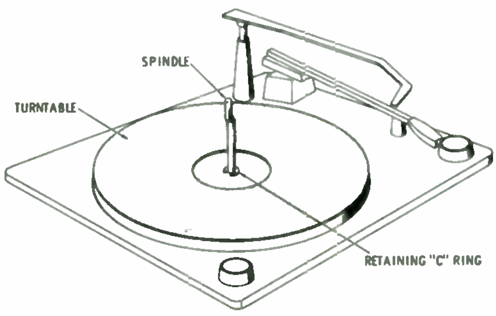
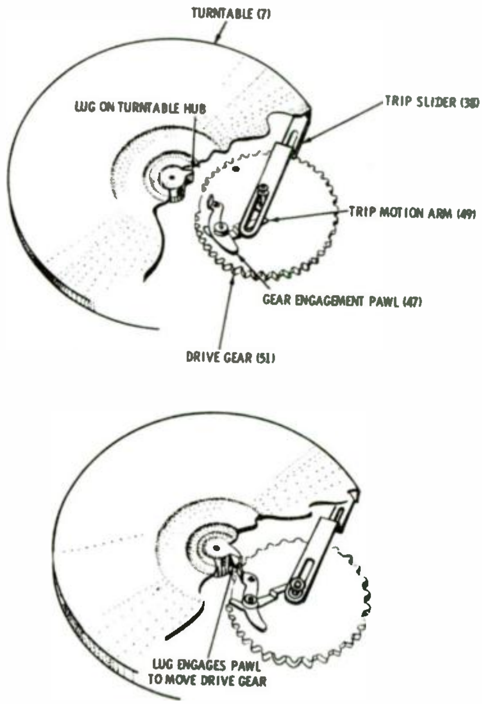


Figure 86 — Turntable is usually secured to the spindle by a C ring.

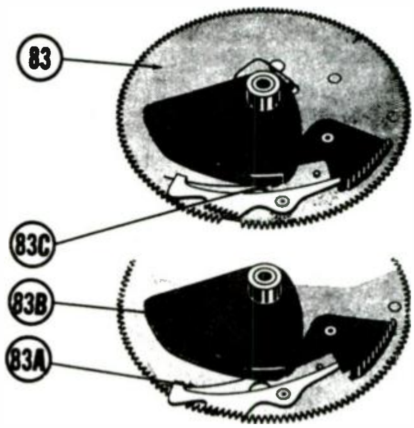
Figure 87 — Record guide (4) slides in top part of spindle.

dampened in a recommended cleaner.

Note that when the turntable is replaced, it will be interfered with by record guide (4) in Figure 87, unless the record guide is lifted in the spindle while the turntable slides down. It is important to recognize the difference between stalling caused by a defective turntable drive and stalling caused by a defective change-cycle drive. Recall that the turntable hub gear engages the drive gear by one means or another at the start of the change cycle, as shown in Figure 88. If the gear-engagement pawl, or equivalent, is damaged, the turntable may stall as the change cycle begins. Or, if the teeth are damaged on either the drive gear or the hub gear, stalling may occur during the change cycle.



(A) Method used in an Admiral changer.



(B) Method used in a Perpetuum-Ebner changer.

Figure 88 — Two principal methods of change-cycle drive engagement.

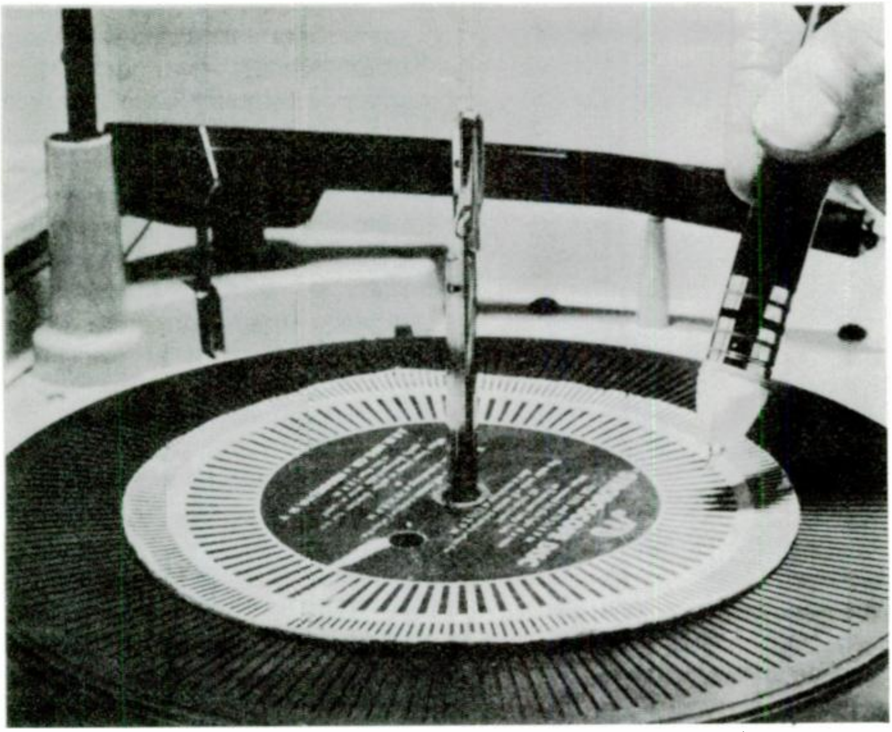


Figure 89 — Strobe disc used for checking turntable speed.

It was noted in a previous lesson that a strobe disc is the most convenient device for checking the speed of the turntable (see Fig. 89). At normal speed the pertinent bars seem to stand still. If the turntable runs too slowly, the bars appear to revolve in a direction opposite to that of the turntable motion, and

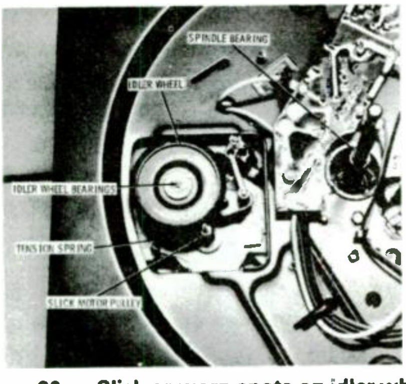


Figure 90 — Slick or worn spots on idler wheel can reduce turntable speed.

vice versa. A subnormal speed of rotation can be caused by a worn idler wheel or a slick turntable. The idler wheel should be checked for slick or worn spots (see Fig. 90). Even a trace of oil on the idler wheel will cause it to slip and thereby reduce the speed of the turntable. Check for grease or oil on the turntable drive surface or motor drive pulley. Dry the turntable inner surface, and then dress with liquid resin or equivalent, as illustrated in Figure 91.

Periodic slippage may be accompanied by a thumping sound from the turntable. In this situation, check for a dent or flat spot on the rubber idler wheel. Shiny idler wheels can be cleaned with a cloth moistened in alcohol. The necessity for adequate contact friction has

Figure 91 — Applying a nonslip dressing to inner surface of turntable.

been noted previously. Check the idler wheel spring for proper tension (see Fig. 92). If the spring is loose, it is often practical to snip off a couple of turns with a pair of side cutters. This will increase the spring tension when it is hooked in place. In summary, most slow-speed symptoms are caused by mechanical defects in idler wheels, aside from oil slicks. A defective wheel must be replaced.

Of course, slow speed problems can also be caused by motor defects; this topic is discussed in detail in the next lesson. We will find that some changers employ separate idler wheels for each turntable speed. In such a case, replace only the defective wheel. An idler wheel bearing can become dry and the resultant binding can reduce the turntable speed. Pry up the idler wheel to remove it, clean the bearing, and then place a drop of oil inside the bearing. The bearing shaft is also cleaned before reassembly. Excess lubrication, of course, must be avoided to prevent oil slicks from developing on the rim of the idler wheel.

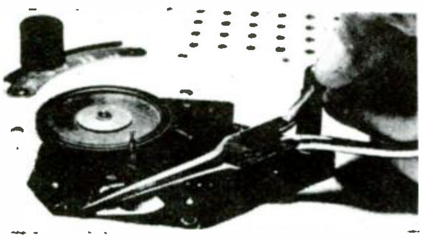


Figure 92 — Incorrect tension of idler-wheel spring can reduce turntable speed.

Wow and Flutter

An irregular rotation of the turntable produces frequency modulation of the recorded audio information, which distorts its reproduction. Rapid frequency modulation is called *flutter,* while slower frequency modulation is called *wow.* The presence of flutter or wow is also visible in a strobe-disc test. This type of distortion can be caused by oil spots on the turntable inner rim, idler rim, or drive pulley. It can also be caused by an idler wheel that is riding improperly on the drive pulley (see Fig. 93). If the idler wheel is improperly positioned, so that it rides up on the

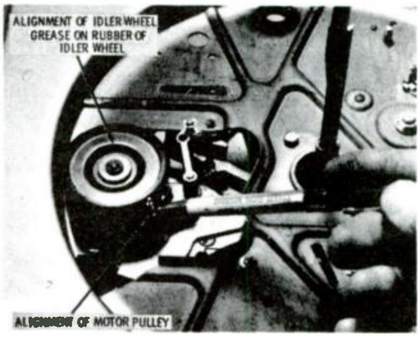


Figure 93 — Points to check for possible causes of "wow" or "flutter."

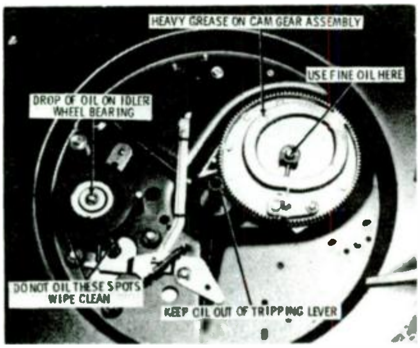


Figure 94 — Lubrication points on record changer assembly.

next section periodically, the turntable speed will vary accordingly. Look for deteriorated rubber mounting grommets in the motor assembly.

A bent idler wheel may also cause wow or flutter symptoms. It may be possible to straighten a defective wheel; otherwise, it must be replaced. Check to see that the replaced wheel is properly positioned for each speed. Finally, when lubricating the turntable assembly, do not let oil enter the tripping lever area (see Fig. 94). In some cases, wow is caused by mechanical interference with turntable rotation. For example, the edge of the turntable may be scraping the chassis. This is usually the result of rough handling; if a turntable is dropped on the floor, it can be mechanically distorted so that normal clearance from the chassis is not maintained.

Speed Adjustment

Correct turntable speed depends both on lack of defects in the turntable drive assembly and on the exact amount of speed reduction that is provided by the assembly. When you are checking the turntable speed, as illustrated in Figure 89, the "drag" imposed by the needle is absent. Therefore, it is desirable that the speed of rotation be a trifle faster than normal, rather than a trifle slower; that is, the load of the needle in the groove of a record has the effect of slowing down the turntable speed by a slight amount. As explained in the next lesson, an electrical speed control may be provided. However, this is the exception and not the rule.

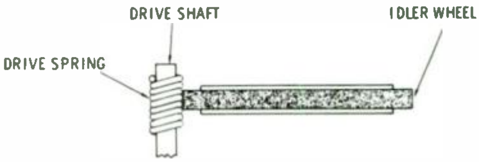


Figure 95 — Drive spring used to obtain proper turntable speed.

If turntable speed is a trifle slower than normal, it is advisable to check the drive pulley spring, to determine if it may be out of tolerance. Figure 95 shows how a drive spring is mounted. If the spring is worn down appreciably, it should be replaced. If a replacement does not increase the turntable speed as much as desired, just slip a slightly larger spring on the shaft, as illustrated in Figure 96. It is good practice to make a final inspection of the ends on the spring to see if they are rough or protruding; file down any sharp or rough ends, and ob-

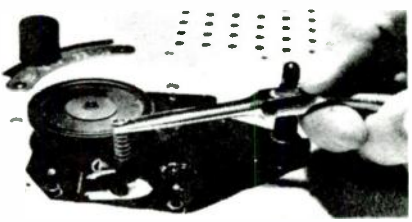


Figure 96 — Larger-diameter spring will increase turntable speed.

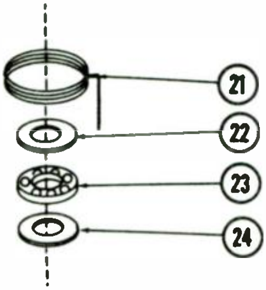


Figure 97 — Ball bearing (23) and washer (22) must be placed as shown to avoid turntable binding.

serve the mechanical action as the speed control is set to its various positions.

Analysis of Common Symptoms

1. Noisy Operation

a. Ball bearing and washer (Fig. 97) incorrectly assembled. The turntable normally has a small amount of end play when the circlip (C washer) is inserted in the spindle slot.

b. Damaged ball bearing or defective washer (Fig. 97). Replace defective parts.

c. Ball wedged in thrust-bearing race. Replace washer and other damaged parts.

d. Protruding screw or foreign object under turntable. Inspect for mechanical interference.

e. Turntable may be damaged and wobbling. Replace it.

f. Idler wheel may be bent. Straighten or replace it.

g. Dry bearings may cause noisy operation. Clean and lubricate them per service data.

2. Incorrect Speed

a. Motor pulley may be incorrect

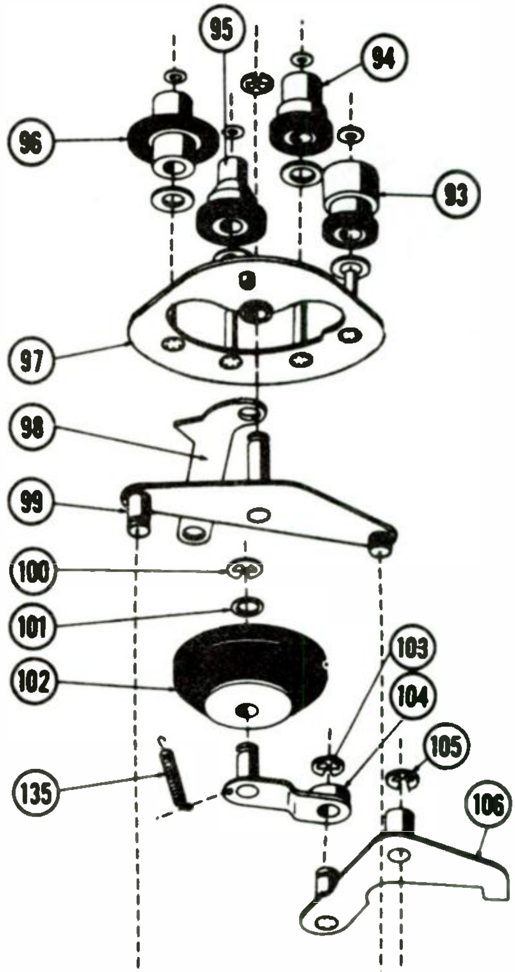


Figure 98 — Drive wheels must be clean and oil-free to operate normally.

for frequency of local supply (occurs in foreign-made changers). Replace with correct-size pulley.

b. Slipping drive. Clean oil and grease from friction surfaces of wheels, as in the example of (93), (94), (95), (96), and (102) in Figure 98.

c. Bearings in turntable drive assembly may be dry. Clean and lubricate them as specified in the changer service data.

d. Stepped pulley on drive shaft may be loose. Tighten pulley.
e. Weak spring in drive assembly causing insufficient friction. Replace spring.

3. Varying Speed

a. If the turntable slows down when a refrigerator starts up, for example, the trouble is due to line-voltage fluctuation.
b. Economy-type changers may have lightweight turntables. In the latter, the speed tends to vary somewhat with the amplitude of the recorded information. Excessive needle pressure aggravates the condition.
c. Check the turntable drive train for slippage. Clean as explained previously.
d. Dry bearings can cause speed variation. Clean and lubricate the bearings.
e. Look for a loose drive pulley, weak spring, or bent idler wheel.

4. Intermittent Operation

a. Retaining ring for idler wheel may be missing, so that the wheel is not secured in normal position.
b. "Flat" or "valley" on rim of idler wheel (this defect is often accompanied by a thumping sound). Replace the rubber rim or the entire wheel.
c. Edge of turntable damaged (this defect is also accompanied by a thumping sound in many cases). Replace defective turntable.
d. Turntable bearing defective, with occasional seizing. Replace bearing.
e. Idler wheel bearing defective, with intermittent seizing. Replace bearing.

5. Flutter or Wow

a. The defects noted in Topics 3 and 4 are associated with flutter and/or wow.
b. Records may be warped, so that they slide on each other. Check with known good records.
c. Center hole in record may be abnormally large or eccentric. Discard record.
d. Turntable mechanically distorted. Replace turntable.
e. Rubber mat not seated properly on turntable.
f. Enlarged bore in drive pulley. Replace pulley.

6. Record Slippage

a. Missing or defective mat or pad. Replace turntable covering.
b. Warped records. The trouble is aggravated by excessive needle pressure. Discard defective records. Adjust needle pressure correctly.
c. Broken needle point, which cuts and holds back the record. This trouble is accompanied by severely distorted sound output. Replace needle.
d. Foreign object that rubs against edge of record. Inspect top chassis.

7. Record Wobble

a. Foreign matter on turntable

pad or mat. Pad may be partially unglued.
b. Turntable bearing worn and distorted. Replace bearing.
c. Shim under turntable hub missing. Put in new shim.
d. Record may be warped. Check for wobble with new record.
e. Spindle may be bent. Inspect and replace it if necessary.

MOTOR TROUBLES

Although motor troubles occur less frequently than malfunctions in the change-cycle mechanism or in the turntable drive assembly, various symptoms such as "dead" changer, slow-speed turntable rotation, rumble, and wow or flutter can be caused by motor defects. Motor faults may be either electrical or mechanical, and the same symptom may have more than one possible cause. For example, a motor that does not rotate could have an open circuit, or it might have a seized bearing. If the motor does not develop normal torque, it could have shorted turns, or the shaft could be binding. Common trouble symptoms caused by motor defects are as follows:

1. Overheating.
2. Noisy operation.
3. Subnormal speed.
4. Fluctuating speed.
5. Excessive vibration.
6. Intermittent operation.

Analysis of Common Symptoms

1. Overheating

Common defects that cause motor overheating are as follows:

a. Bearings are dry and impose excessive friction; in serious cases, a bearing will "seize." Clean, lubricate, and replace defective parts.
b. Worn bearings that permit the armature to rub against the field poles. Replace defective bearings.
c. Shorted turns in a motor coil. In most cases it is advisable to replace the motor, instead of rewinding the defective coil.
d. Starting capacitor may be open (see Fig. 99). The motor will not start, and overheats. Replace defective capacitor.
e. In a shaded-pole induction motor the shading coil may be open (not likely, but possible). If open, solder ends of coil securely together.

2. Noisy Operation

a. Dry and/or worn bearings. Lubricate them per service data. Replace defective bearings.
b. Motor assembly screw(s) loose. Inspect, and tighten as required.
c. Shock mounts deteriorated. Replace defective shock mounts.
d. Improperly soldered connection to motor, causing vibratory contact.
e. Coil loose on core; insert necessary shims, and shellac in place.

3. Subnormal Speed

a. Foreign matter between armature and field. Clean the parts as required.

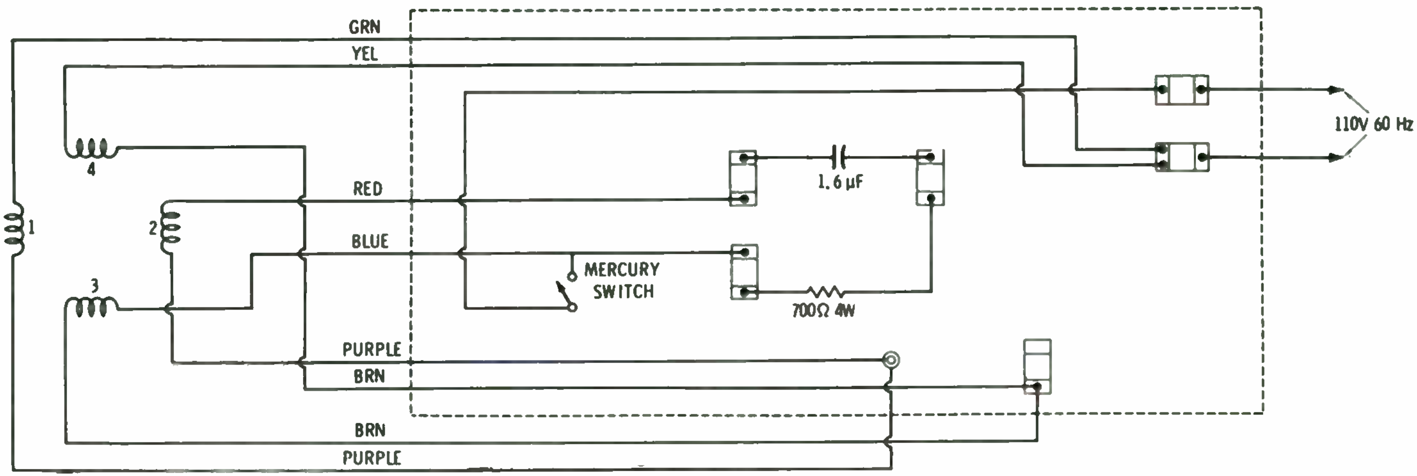


Figure 99 — Control circuit of a capacitor-start/run motor.

b. Armature off-center. Assemble with shims temporarily inserted to provide accurate spacing.
c. Dry bearings. Lubricate them per service data.
d. Subnormal terminal voltage at motor. Check line voltage. If it is normal, look for a circuit connection with appreciable resistance (the defective connection will run very hot).
e. Defective coil in motor. Replace motor.

4. Fluctuating Speed

a. Armature rubbing slightly against field poles or contacting grit between surfaces. Check for worn or improperly adjusted bearings, and clean the parts as required.
b. Fluctuating terminal voltage at motor. Check for cold-soldered or otherwise defective connection.
c. Defective switch, with badly pitted contacts. The switch will run very hot. Replace switch.
d. Intermittent short-circuit between turns or layers in motor coil. Coil runs hot. It is usually advisable to replace the motor in this situation.

5. Excessive Vibration

a. Shock mounts deteriorated. Replace mounts.
b. Motor bearings badly worn. Replace bearings.
c. Leads to motor may be drawn tightly. Provide a small amount of slack.
d. Assembly screw(s) loose. Check and tighten as required.
e. Field coil loose, and moving on core. Insert shims, and shellac in place.

6. Intermittent Operation

a. Connecting wire broken inside of insulation. Replace defective lead.
b. Worn and erratic switch-contact action. Replace switch.
c. Cold-solder joint in motor circuit. Reheat joint and solder securely.
d. Defective coil insulation, often caused by serious overheating. Motor should usually be replaced in this situation.
e. Loose assembly screw that causes mechanical interference when vibration moves it out of normal position.

SUMMARY

The purpose of this lesson is to acquaint you with the actions and associated parts and assemblies in typical record changers. It is nearly impossible to cover all the types and variations of automatic changers in existence. Before attempting to service any particular changers always refer to specific literature for that record player. Service literature is available from the manufacturer's service agency or from the Howard Sams Company in a PHOTOFACT package.

Automatic changer repair is not difficult, but you must be observant. Always question the customer before accepting the repair job. Try to discover if the problem developed over a period of time or occurred suddenly. The answer can be the clue you need to lead you quickly to the source of the problem. A situation that develops over a period of time is probably due to a marginal adjustment and/or wear; whereas, a problem that occurs suddenly is most likely caused by a broken, bent, or jammed part.

The tools recommended in the early part of this lesson are fairly standard and definitely necessary if you do a lot of record changer work. In addition, certain manufacturers recommend and/or will sell specific gauges and adjustment tools for their particular changer. These special tools are generally listed in the manufacturer's literature along with their part numbers.

Care should always be used when repairing any record changer. Considerable confusion can be created if you alter adjustments and create new problems before the original problem has been solved.

TEST

Lesson Number 73

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-073-1.

1. **The function of an automatic record changer is to accept a stack of records and play**
   A. all of them, one at a time.
   B. one record and then shut off.
   C. one record and wait.
   D. only one size record.

2. **An automatic record changer may also be called a/an**
   A. record spinner.
   B. manual turntable.
   C. automatic turntable.
   D. disc recorder.

3. **The trend in modern record players is toward**
   A. heavy tone arms.
   B. large motors.
   C. crystal cartridges.
   D. low needle pressure.

4. **The grooves toward the center of a record which initiate the change cycle are called______grooves.**
   A. reject
   B. run-out
   C. set-down
   D. land

5. **The two most commonly used forms of trip encountered in automatic changers are**
41 A. velocity and position.
B. eccentric and oscillating.
C. magnetic and electromagnetic.
D. clutched and geared.

6. **The mechanism that supplies power for an automatic record**
66 **changer is the______assembly.**
A. loop
B. drive
C. trip
D. slide

7. **If only a portion of the change cycle is completed it may be due to**
A. broken teeth on the hub or drive gear.
B. oil or grease on the drive pulley, belt or driven surface.
40 C. slide return spring weak, loose or missing.
D. one or more of the above.

8. **When the change cycle is not initiated by the velocity trip it may be due to a/an**
A. defective motor.
46 B. defective cartridge.
C. obsolete non-standard record.
D. defective function switch.

9. **The failure of the tone arm to set down uniformly from one record to another may be due to loose or worn parts in the**
A. motor.
65 B. tone arm hinge-pivot or shaft-sleeve assembly.
C. intermediate drive gear.
D. spindle-tripping mechanism.

10. **Noisy operation of an automatic record changer may be due to**
72 A. dry or worn motor bearings.
B. defective cartridge wiring.
C. a defective power switch.
D. low voltage.

Notes

Notes

Notes

Portions of this lesson
RECORD CHANGERS-HOW THEY WORK
by Louis M. Dezettel
RECORD CHANGER SERVICING GUIDE
by Robert G. Middleton
Courtesy of Howard W. Sams, Inc.

"*School Without Walls*"
"*Serving America's Needs for Modern Vocational Training*"

PRACTICE WHAT YOU LEARN

As you study these lessons on the servicing and repair of the different types of electronic units, you are acquiring the knowledge necessary to understand these systems. The next step is to put what you learn into practice.

A good way to do this is to obtain an inoperative radio or any other piece of electronic equipment which you can use for practice. A neighbor's attic or basement is usually the best place to find one. You may get it free or you may have to pay a small amount for it, but it would be well worth it for the amount of experience you will gain.

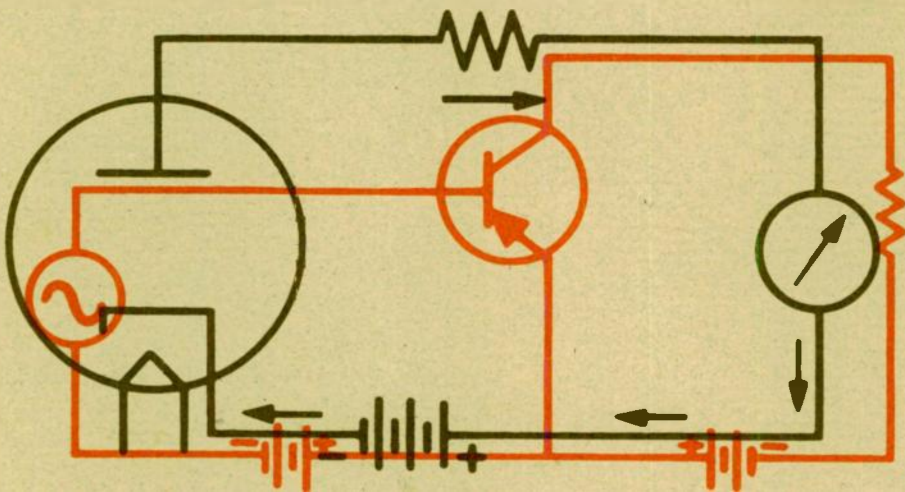
Take the unit apart. See for yourself how it is made. Go over your lessons again with the unit in front of you. Try to find the defective stage by using your test equipment. Then repair or replace the component causing the trouble.

Learn with your mind and then learn with your hands. This is an unbeatable combination. ASI Training stresses this throughout your entire Radio and TV course. This is how you will find success the ASI way.

S. T. Christensen

LESSON NO. 74

TAPE RECORDERS PART 1



RADIO and TELEVISION SERVICE and REPAIR

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LESSON CODE
NO. 52-074
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Contents

TAPE RECORDERS PART 1

INTRODUCTION

Although comparatively few shops specialize in tape-recorder servicing, this area of electronics is a substantial source of supplementary income. Efficiency in recorder servicing involves both theory and experience. Most of the basic principles in the electronic section are the same as in audio or high-fidelity amplifiers. That is, a tape recorder must provide high gain at audio frequencies. In the high-quality types of recorders, this amplification is accomplished at very low distortion (less than 1 percent). However, there are some aspects to tape-recorder servicing that are unusual from the viewpoint of radio and TV servicing.

The "heart" of a tape recorder is a magnetic circuit in which audio-frequency fields are impressed on a ferromagnetic film or coating with the aid of an ultrasonic bias field. Efficient recorder servicing requires that the technician understand this magnetic circuit from a practical standpoint, know how to interpret trouble symptoms, how to measure bias and erase currents, etc. The oscilloscope is a very useful troubleshooting instrument, and is sometimes the "best bet" as in trouble symptoms involving tape hiss which is often caused by a nonsinusoidal AC bias waveform. A scope is also a most useful signal tracer when servicing tape recorders.

Another problem that the radio or TV technician must contend with is the mechanical portion of the tape recorder. However, the mechanical assembly is much simpler in comparison to its counterpart in an automatic record player. Although the end result is the same in every case, various manufacturers use somewhat different configurations to obtain the result. For example, each head may be separate, or a pair of heads may be combined in the same housing. Most recorders employ AC bias and AC erase; however, we find quite a few inexpensive recorders that employ permanent magnet bias and permanent magnet erase. An occasional recorder uses AC bias and permanent magnet erase.

Competence in recorder servicing can be acquired rapidly. There is a minimum of involved theory to contend with, compared to the circuit theory that must be learned before tackling a color-TV chassis.

After some introductory experience has been gained, it will be found that trouble symptoms are less difficult to interpret than in TV servicing.

HISTORY OF MAGNETIC RECORDING

The history of magnetic recording covers a period spanning more than half a century. Yet magnetic recording remained practically undeveloped until shortly before the beginning of World War II. From its inception in 1898 until its real commercial application in Germany, starting in 1935, magnetic recording remained little more than a scientific curiosity. Historians of invention during that era regarded it as scarcely worth mentioning.

Valdemar Poulsen of Copenhagen, Denmark, pictured in Figure 1, built the first magnetic recorder in 1898. His *Telegraphone* magnetically recorded crosswise on a steel piano wire, but the wire would twist and throw the crosswise recording out of alignment, thus ruining its quality. To overcome this difficulty, Poulsen replaced the wire with a more bulky and cumbersome steel tape which could not twist. A *Telegraphone* manufactured in the United States by the American Telegraphone Company around 1920 is shown in Figure 2. The spools of wire are mounted horizontally and turned by the 100-volt motor pictured at the lower right. No provision for automatic rewind of the wire was made; the spools of wire had to be interchanged for rewind and playback.

A series of financial misfortunes beset Poulsen's United States firm, the American Telegraphone Company. Lacking present-day persuasive promotion and selling techni-

Figure 1 — Valdemar Poulsen, inventor of magnetic recording in 1898.

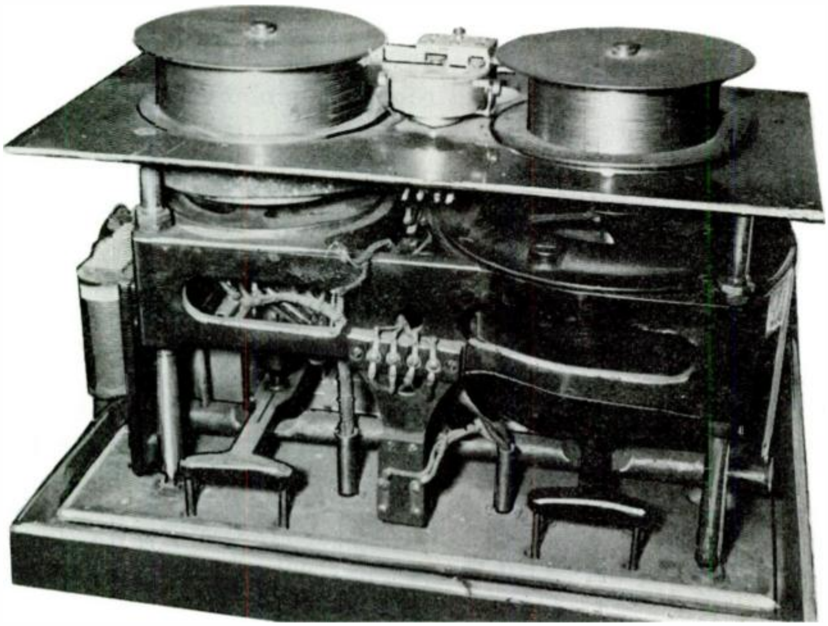


Figure 2 — The Telegraphone designed by Poulsen and manufactured by the American Telegraphone Company around 1920.

ques, coupled with inherent defects in the recorder itself, the firm soon collapsed and the stock became valueless. A Danish firm was also organized in 1909 to manufacture the *Telegraphone.* The firm failed in 1916 without having commercially marketed a single recorder.

Electronic engineers who examine Poulsen's patent today are amazed at how closely his machine, crude as it was, resembles the modern magnetic recorder. His recorder worked, and Poulsen proceeded to commercially market the *Telegraphone.* Oscar Dupue, in an account of his experiences with Burton Holmes, then the world's leading travelogue exponent, recalled having used the *Telegraphone*:*

"I have mentioned previously the second trip to Norway in 1907 to make another film of the fjord trips. It was on this trip that I purchased a Poulsen wire recorder in Copenhagen . . . I was able to operate it in my steamer cabin while en route home. I had a lot of fun talking into it and playing back, and soon I had a procession of passengers eager to record and hear their own voices. Several theatrical notables were present, including the famous Jimmie Powers . . . he was full of hit songs and stories, so we recorded a few. When he finished, I spoke into the recorder saying that Powers' record was made on the twenty-eighth day of August,

* Oscar Dupue, "My First Fifty Years in Motion Pictures," *Journal of the Society of Motion Picture Engineers,* December, 1947.

1907, in mid-ocean aboard the S.S. *Augusta Victoria.* Thirty years later, I rerecorded Powers' voice on film. The wire had retained the record as clearly as when it was first made."

Since Poulsen had a working magnetic recorder fifty years ago, why did magnetic recording have to wait until World War II to be fully developed? One obvious answer to this question lies in Poulsen's recorder. Since the recorder originally employed wire and later a steel tape, it was undoubtedly very awkward and difficult to operate. Because the speed at which the tape traveled in recording was as fast as was practical for the mechanism to handle, it was impossible to speed up the rewind time. Also, since it recorded crosswise, or in a perpendicular direction, the quality could not have been too good, although undoubtedly it represented an achievement when contrasted to the sound standard prevailing at the time. Frequency response was limited. The dynamic recording range did not exceed approximately 20 decibels. The noise level was excessively high. However, the main reason for the lack of development can be attributed to the low acoustical output of magnetic recording in comparison with the then competitive mechanical systems such as disc recordings.

4

Not until the late Dr. Lee de Forest, pictured in Figure 3, invented the vacuum-tube grid was it possible to obtain sufficient amplification to satisfactorily reproduce the weak signal on magnetic tape. In fact, the relative positions of the now fast-rising magnetic recording medium and phonograph industry might today have been reversed through a little-known experiment conducted in 1912. But as is so frequent in the history of invention, the full significance of the experiment was not realized at the time.

Dr. Lee de Forest himself wrote:

"Speaking of the necessity for the three-electrode tube amplifier in connection with magnetic-tape recording and reproducing, you may be interested to know that in the spring of 1912 I used the tube as an amplifier in connection with the old steel-wire Poulsen *Telegraphone.* I am sure this is the first combination of those two great inventions. No one could foresee at that early date the immense development and priceless applications of the magnetic-tape *Telegraphone.* In fact, one of the very first applications of the three-electrode tube as an amplifier was in connection with the *Telegraphone.*"

Other roadblocks besides amplification existed. The two principal ones were removed with the abandonment of perpendicular magnetization in favor of longitudinal magnetization and the discovery of the AC or high-frequency bias technique. Originally the magnetic field was recorded perpendicular to the recording medium (wire, steel band, or tape). While this system worked, it required very-high tape speeds since the magnetic field in the region of the tape could not be concentrated but covered a rather wide area (Fig. 4).

However, with the invention of

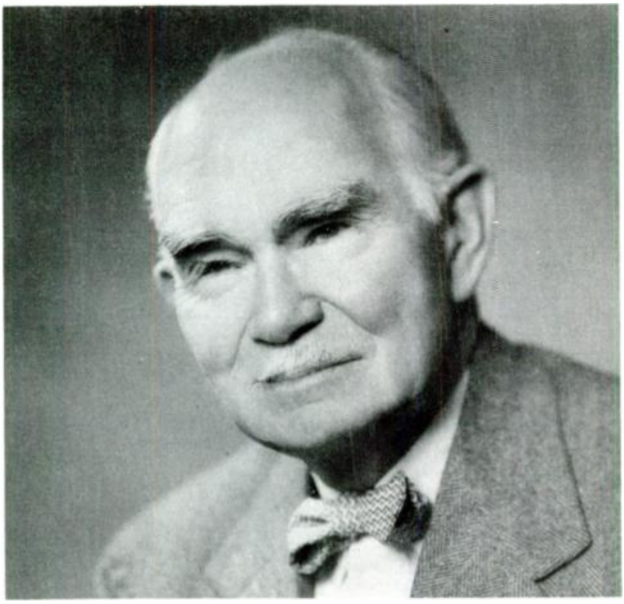


Figure 3 — Dr. Lee de Forest inventor of the vacuum tube.

the ring-type head the magnetic field could be confined as far as the tape is concerned to the area between the pole pieces or to the magnetic gap. This permitted recording wavelengths as short as .00025 inch (video-recording wavelengths are now being recorded to a fraction of this amount).

Thus, with the ring-type head and longitudinal recording (recording in the direction of tape travel rather than perpendicular to it as illustrated in Figure 5, engineers were able to make practical low tape speeds, and the storing of a large amount of information on a small reel.

The AC or high-frequency bias technique was discovered by W. L. Carlson and G. W. Carpenter of the U.S. Navy. The AC bias technique eliminated the high background noise generally associated with recordings made using the older DC bias method. However, even with the removal of these obstacles, the progress of magnetic recordings was slowed for many years through lack of imagination and any serious desire to perfect existing techniques.

Working independently, a German inventor named Pfleumer, was busily engaged conducting experiments with various types of recording mediums including paper and plastic tapes coated with iron-oxide particles. Sensing a large and growing market, the Allgemeine Electrizitats Gesellschaft (AEG), the German equivalent to General Electric Company, joined with the I. G. Farben Company, and took over Pfleumer's early pioneering work in coating paper and plastic materials. The grain size of the magnetic materials was relatively large. The early paper tape, coated

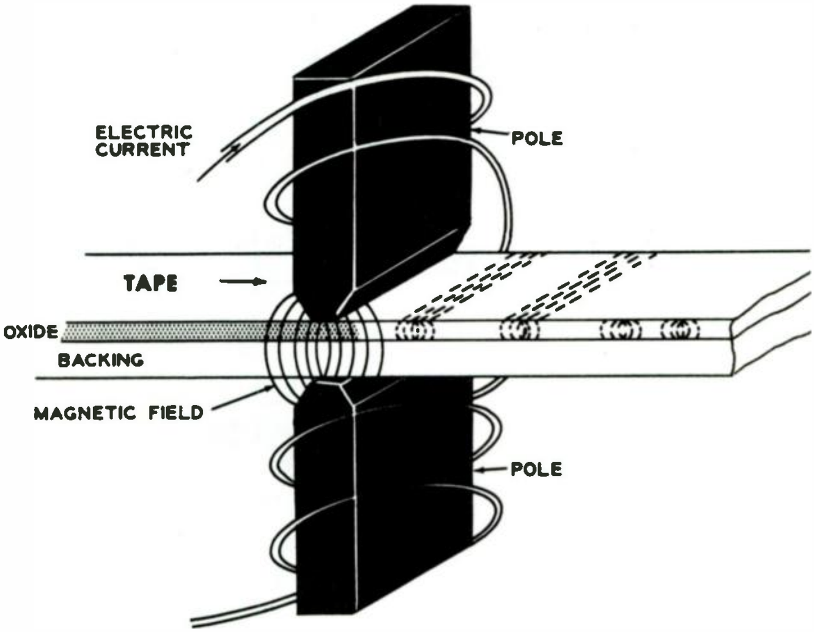


Figure 4 — Perpendicular magnetic recording.

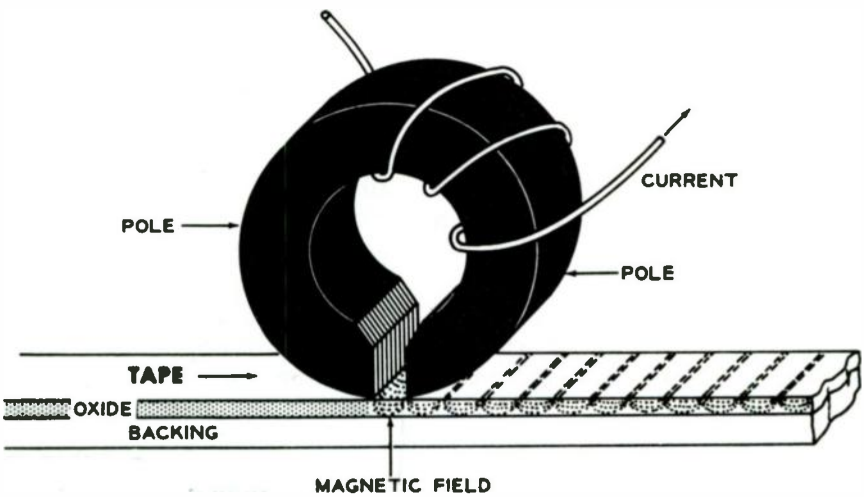


Figure 5 — Longitudinal magnetic recording magnetization.

with the powdery magnetic substance, closely resembled sandpaper. When the tape was run through recorders, a spray of powder clouded the air.

The first *Magnetophone,* produced by AEG, was exhibited in 1935 at the German Annual Radio Exposition in Berlin. Although the *Magnetophone* was inferior to many earlier German magnetic recorders, it was an instantaneous success, the hit of the exhibition. Employing coated paper tape as opposed to wire or steel bands, the magnetic-recording tape cost only fifteen cents per minute of recording time; the price of steel bands was a dollar or more per minute. Naturally, paper tape was less unwieldy, threaded easily, and was infinitely more convenient to store.

Meanwhile, in the United States, Bell Telephone Laboratories was the only large corporate name in the electronics field to be associated with magnetic recording. Bell Telephone Laboratories designed a steel-tape recorder, the *Mirrophone,* that was put to work announcing the weather and time signals on the telephone. At the New York World's Fair in 1939, the *Mirrophone* amazed thousands of visitors who recorded their voice into the machine and gasped in surprise to hear a chance remark of a moment instantly played back with full fidelity. The *Mirrophone* was also a featured electronic performer in the Bell Telephone exhibits which toured the schools of the nation as part of a continuing public-relations program.

Magnetic-recording equipment had not been manufactured commercially in the United States until 1937 when the *Soundmirror,* a steel-tape recorder, was placed on the market. Brush Development Company purchased rights to the *Soundmirror,* which was originally built by Acoustic Consultants. Figure 6 shows one of the early Brush *Soundmirror* recorders. The cover is removed so that the mechanical

Figure 6 — An early Brush Development Company Sound mirror with cover removed.

layout may be seen. Although the machine could record only one minute on a steel tape, countless applications were immediately found for it. Brush inaugurated an intensive research program which made many fundamental contributions to the body of knowledge comprising magnetic-recording techniques. During World War II, Brush built large quantities of magnetic-recording equipment for the Armed Services. In cooperation with the Office of Scientific Research and Development, Brush helped develop coated paper-tape and plated-wire recording mediums.

Immediately following the end of World War II, Webster-Chicago and Sears, Roebuck and Company began large-scale wire-recorder production. War workers with pockets still filled with money provided a wide market base of home consumers, topped off with specialized office dictation uses and other applications. Encouragingly, large quantities of wire recorders were sold during the first few months of large-scale production. However, commercial television began to show promise of sweeping the country, and with automatic home appliances, automobiles, and other types of consumer products increasingly available, sales of wire recorders began to slow. The anticipated wire-recording boom failed to materialize.

Early attempts at manufacturing magnetic tape were made by the Brush Development Company and Indiana Steel, who used a unique magnetic-iron material with high coercive force but which was difficult to record and erase. Minnesota Mining and Manufacturing Company, in mastering the production of high-quality magnetic tape, made substantial improvements over early German attempts. The task was not an easy one. The technical specifications for the production of quality magnetic tape were substantially more exacting than those of any other type of coating process previously known.

The problem of high tape speed was solved by the introduction of a new type of magnetic oxide. The new oxide gave the American tape about 12 db more output than was available with the German tape. The higher coercion of the oxide gave the tape excellent high-frequency response characteristics, making possible the adoption of slower tape speeds.

With the improvements made in magnetic tape, recorder speeds were progressively halved, first from 30 to 15 inches per second (IPS), then from 15 IPS to 7.5, 3.75, $1^7/_8$, and $^{15}/_{16}$ IPS. Figure 7 gives the recording time obtainable at each speed for various size reels. Since in copying or duplicating tapes, it is easier to build machines that work in multiple speeds of each other, each progressive speed change was obtained by dividing by two.

At the present time there are numerous brands of magnetic tape on the American market alone, the great majority being private labels. The magnetic-tape field is a very competitive one, accounting for rapid technological advances and improvements.

Tape speed is one important factor in determining the upper frequency limit of a recorder. Until recently it was possible to obtain, using an arbitrary rule-of-thumb measurement, one thousand Hz of response for every inch of tape speed. For example, if a recorder operated at a tape speed of 15 IPS, it was possible to get 15,000 Hz response. However, recent improvements in magnetic heads, recorder design, and still further advances in magnetic-tape construction permit the doubling of frequency response. Tape response at 7.5 IPS now goes out to 18,000 Hz and beyond.

The Revere Camera Company helped expand the growing home market for recorders by pioneering the 3.75-IPS speed, made possible by subsequent developments in the manufacture of magnetic tape.

Professional tape speeds have narrowed down to 15 IPS for high-quality audio work, while 7.5 IPS is

Reel	Tape	Speed				
Size	Length	15/16 ips	1 7/8 ips	3 3/4 ips	7 1/2 ips	15 ips
3"	150'	30 min	15 min	7 1/2 min	3 3/4 min	1 7/8 min
3"	*225'	45 min	22 1/2 min	11 1/4 min	5 5/8 min	2 13/16 min
4"	300'	1 hour	30 min	15 min	7 1/2 min	3 3/4 min
5"	600'	2 hours	1 hour	30 min	15 min	7 1/2 min
5"	*900'	3 hours	90 min	45 min	22 1/2 min	11 1/4 min
5"	†1,200'	4 hours	20 hours	1 hour	30 min	15 min
5"	‡1,800'	6 hours	3 hours	90 min	45 min	22 1/2 min
7"	1,200'	4 hours	2 hours	1 hour	30 min	15 min
7"	1,500'	5 1/3 hours	2 2/3 hours	80 min	40 min	20 min
7"	*1,800'	6 hours	3 hours	90 min	45 min	22 1/2 min
7"	2,000'	7 hours	3 1/2 hours	106 min	53 min	27 min
7"	†2,400'	8 hours	4 hours	2 hours	60 min	30 min
7"	3,000'	10 2/3 hours	5 1/3 hours	2 2/3 hours	80 min	40 min
7"	‡3,600'	12 hours	6 hours	3 hours	90 min	45 min
10 1/2"	2,400'	8 hours	4 hours	2 hours	1 hour	30 min
10 1/2"	*3,600'	12 hours	6 hours	3 hours	1 1/2 hours	45 min
10 1/2"	†4,800'	16 hours	8 hours	4 hours	2 hours	60 min
14"	5,000'	16 1/2 hours	8 1/3 hours	4 1/6 hours	125 min	62 1/2 min
14"	*7,200'	24 hours	12 hours	6 hours	3 hours	90 min

* 1-mil extra-recording tape.

† 1/2-mil double-recording tape.

‡ Tempered-mylar triple-recording tape.

All times are for 1-direction 1-track only.

For total monotime on multiple-track recorders, multiply by number of tracks.

For total stereotime on 2-track recorders, use given figures.

For total stereo time on 4-track recorders, multiply time by 2.

Figure 7 — Recording time for various Magnetic-tape speeds and tape lengths.

quite popular in the broadcasting field. In the recording industry 15 IPS is the most popular speed for its convenience in editing. The home tape-recorder speeds are now generally standardized at 3.75 and 7.5 IPS. Voice and ordinary music recordings taped from the radio use 3.75 IPS, while 7.5 IPS is preferred for serious high-fidelity home recording. At both extremes are the 30-IPS speed, which still finds some advocates in the recording industry, and the 15/16-IPS speed used for long-time, voice-quality recordings, primarily in dictation applications.

Fortunately, however, the length of playing time need not be sacrificed for faster tape speeds since the recent introduction of a much thinner magnetic tape. With a reduction in the coating thickness of 50% and backing thickness of 30%, 1,800 feet of magnetic tape can now be wound on a single 7-inch plastic reel which formerly held only 1,200 feet. This 50% increase in playing time is further extended by the use of .5-mil double-recording tapes which increase the capacity of a 7-inch reel to 2,400 feet—a 100% increase in playing time. An even further extension in playing time is obtained by using tempered-mylar triple-recording tapes. Using these tapes a 3,600-ft., 7-inch reel which gives a 200% increase in playing time is available.

The tape recorder has now become the fundamental recording tool for all professional applications. A typical professional installation is shown in Figure 8. Even though disc recordings are marketed in large numbers, they are but copies from master magnetic tapes. The sound for movies is originally recorded, rerecorded, and edited on magnetic film. In many systems the sound is recorded on a magnetic stripe (or stripes) alongside the picture on the release print. Packaged regional and network radio and TV shows, as well as much local programming, are broadcast from magnetic tape. In all professional recording applications tape has virtually replaced every other recording medium as the prime source of high-quality sound.

The development of the *Videotape* recorder for television by Ampex was perhaps the most significant recent development in magnetic-tape recording. Black and white or color pictures and the accompanying sound are recorded on tape similar to that used with audio recorders. The top frequency response of such recorders is 4,000,000 Hz compared to 15,000 to 18,000 for most audio recorders. This wide-range response is made possible by the development of a rotary recording head which moves rapidly perpendicular to a tape passing the head.

Today, television tape recorders are in use throughout the world.

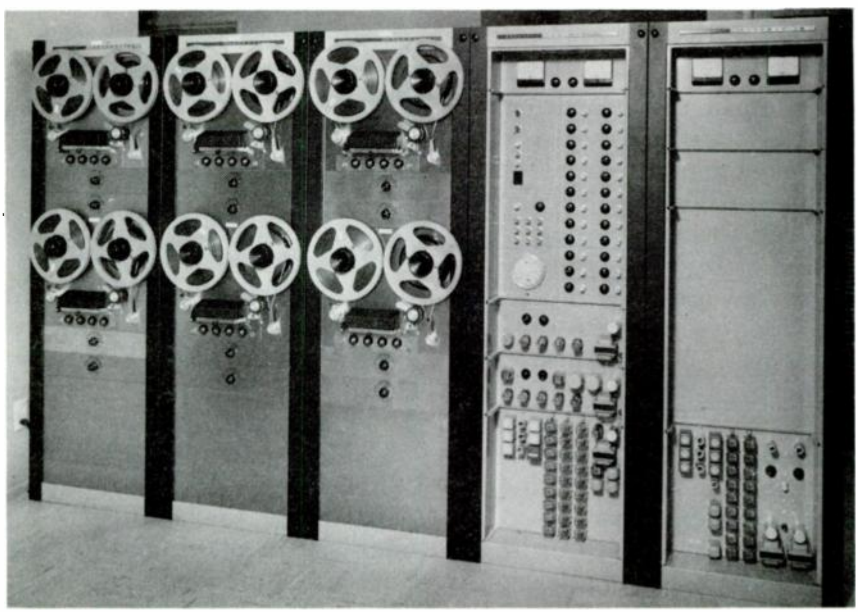


Figure 8 — Typical professional recording installation.

Recent developments in transistors have made compact and portable television tape recorders available to education, industry, military training, and sports.

At the present time instrumentation recording is the major field for many tape-recorder and tape manufacturers. Tape recorders are standard equipment at missile tracking stations and are used more and more in processing medical data and in industry. The use of computers has broadened the field tremendously. The information fed into computers is coded and stored on magnetic tape, thus forming the memory banks of the various digital and analog computers.

The more recent home tape recorders have been ingeniously designed to make recording as simple as possible. A number of machines are push-button operated (Fig. 9), still others have greatly simplified control mechanisms. Well on its way toward becoming America's new pastime hobby, home tape recording is as simple as clicking a camera shutter for ever-increasing thousands of American sound enthusiasts. No matter how inexperienced or inept the tape-recorder owner may be, the chances are overwhelming that he will come up with acceptable sound on his tapes.

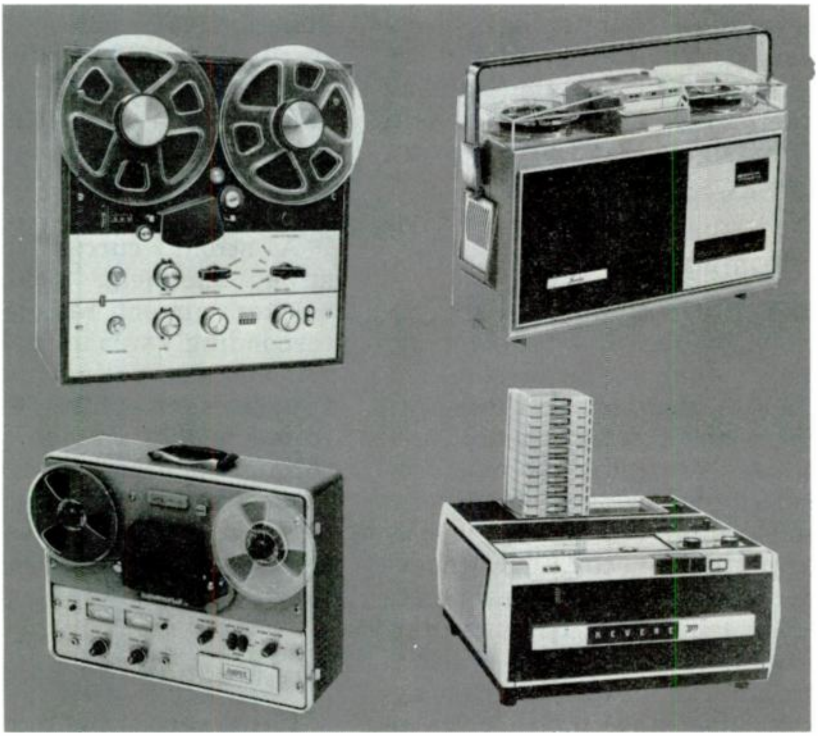


Figure 9 — Present-day tape recorders.

THEORY OF MAGNETIC RECORDING

In the same way that the camera fan realizes that he can improve his pictures by learning what happens when he clicks the shutter, the tape enthusiast learns how to get the most out of his recorder when he understands how it works.

There has been an abundance of papers presented before technical society symposiums on the theory and principles of magnetic recording. The technical journals repeatedly carry highly detailed scientific material, and books have been written on the subject of magnetic recording. Nevertheless, physicists and engineers are still not in complete agreement on some of the finer points. Symposiums have broken up in disagreement. Controversy is still prevalent among magnetic-recording theoreticians, a healthy sign of industry growth and progress.

Electromagnets

Magnetic recording is an extremely complex process, involving a study of advanced physics. The mechanics of magnetic theory are complex, and even experienced academicians sometimes become confused. The following explanation is intended to give a general idea of the magnetic-recording process rather than a specific, highly technical explanation of how it works. No mention is made of either a direct-current or an alternating-current bias, since the theories involved are lengthy and require considerable use of higher mathematics and special treatment of the characteristics of magnetic materials.

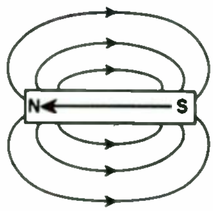
An electromagnet is made by wrapping an iron core with wire to form a coil. When current flows through the wire, the core becomes a magnet. One end, or pole, of the iron core is a north pole. The other end is a south pole. If the direction of the current flow changes, the polarity of the electromagnet is reversed.

Around any magnet is an area of magnetic attraction commonly known as a *field,* which is illustrated in Figure 10 in terms of lines of magnetic force. The more closely spaced are the lines, the stronger is the magnetic attraction. These lines of magnetic force also have direction. Physicists have arbitrarily defined force lines as going from north to south outside the magnet, then completing their circuit by going from south to north inside the magnet.

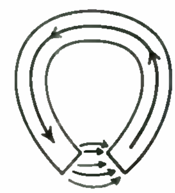
A strong current produces a strong magnetic field, while a weaker current results in a correspondingly weaker field. Similarly, an alternating-current cycle causes each pole of the electromagnet to change in polarity through one complete cycle from north to south and back again to north. Both half cycles of the alternating current are shown in Figure 10C.

The Magnetic Recording Head

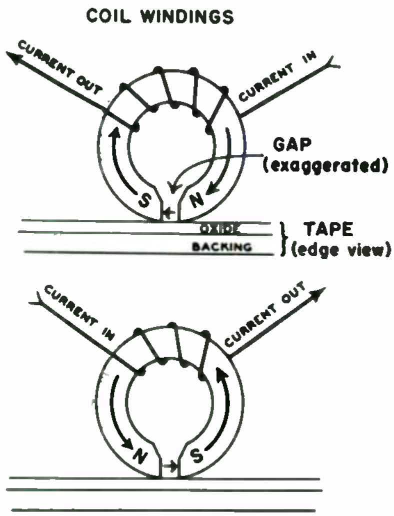
In the case of the recording head shown in Figure 10C, the core is cut in a rectilinear shape with the poles almost touching, as little as



A Permanent bar magnet.



B Permanent horseshoe magnet.



C Electromagnetic (nonpermanent) recording head.

Figure 10 — Similarity between permanent magnets and magnetic recording heads.

.00004", or .04 mil. apart. This distance is referred to as the *gap* of the head.

The cores of the recording head are magnetically "soft." That is, the head becomes magnetized easily and instantly when current flows into the coil, but loses its magnetism just as rapidly when the current stops. The recording head is unlike a permanent magnet, or even the oxide on the tape itself, which is made from a magnetically "hard" material. The iron-oxide coating on the tape, being magnetically "hard," will hold any magnetism induced in it for an indefinite period of time.

Whenever a surge of positive current from the microphone goes through the coil, it magnetizes the recording head in one direction. When the current alternates and sends a surge of negative current into the coil, the head is magnetized in the opposite direction. Thus, the polarity at each pole will alternate between north and south according to the direction of the current.

Tape Magnetization

When the iron-oxide-coated tape is in contact with the recording head, it offers an easier path for the magnetic lines of force to follow than does the air gap. Therefore, following the course of least resistance, most of the magnetism gets across the gap by flowing through the iron-oxide-coated tape.

While the magnetically "soft" iron ring of the electromagnet loses its magnetism when the current stops, the magnetically "hard" coating on the tape retains its magnetism and the magnetized area becomes a small bar magnet itself (Fig. 11). Because the lines of force left inside the tape point in one direction, that direction necessarily must be north. The other end, therefore, becomes south. This is shown at point A in Figure 12.

At point B, the current entering the coil is zero at its point of alternation and, consequently, does not create a magnetic field at that time. As a result, the tape moves a fraction of an inch without being magnetized any further. At point C, when a surge of negative current comes into the coil, a magnetic field in the opposite direction is set up, causing the polarity of the electromagnet to reverse. Again, the lines of magnetic force at the poles find it easier to flow through the iron-oxide-coated tape than across the air gap. Thus the tape is permanently magnetized, but this time, in the opposite direction.

At point D, the tape has again moved, but since the current is not flowing, no new lines of force are set up at that point. As a result, the surges of alternating current leave the tape permanently magnetized by setting up a series of force lines of opposite polarity, creating a series of bar magnets on the tape.

Because the tape is moving, these poles occur at recurring intervals along the tape, in a definite pattern. The frequency of the signal and the speed at which the tape moves determine the distance between poles, while the strength of the current, or voltage, determines the magnetic strength of each pole.

As shown in Figure 12, the magnetic pattern on the tape, for a 30-Hz tone, consists of 30 magnetic fields pointing toward south, alternating with 30 magnetic fields

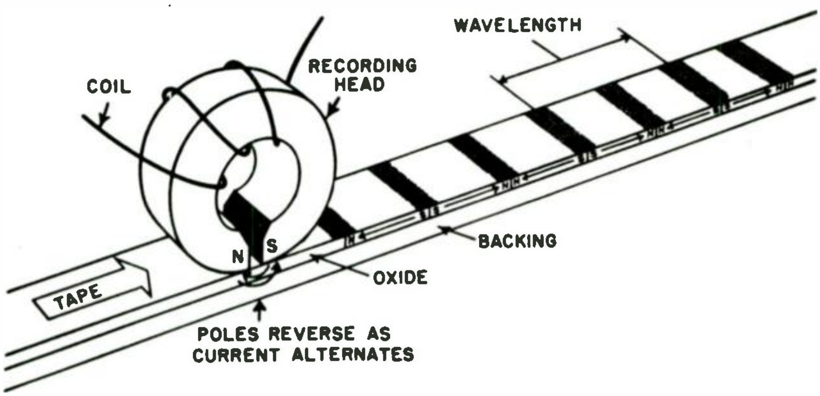


Figure 11 — Magnetized tape becomes a series of small bar magnets.

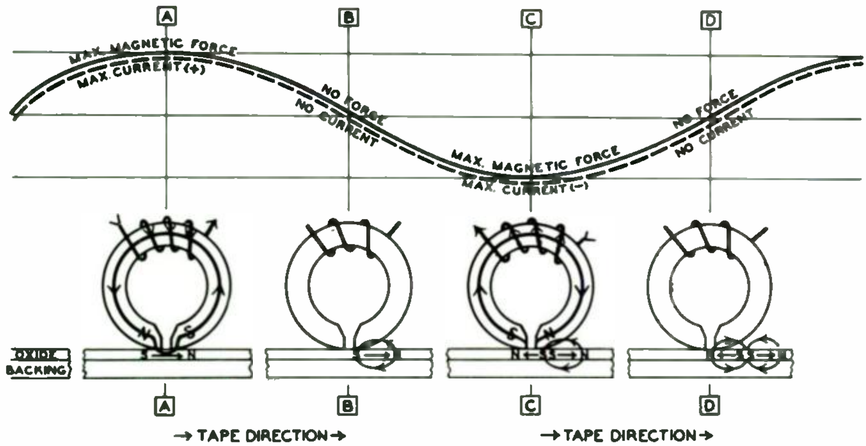


Figure 12 — Magnetization or recording process.

pointing toward north. In effect, the oxide coating of the tape is broken up into 60 individual bar magnets, laid end to end, every second the tape moves across the gap. On a tape recorder operating at 7.5 IPS, the 60 bar-magnet patterns would cover a space of 7.5 inches on the tape. A 10,000-Hz note would be represented on the tape as 20,000 such magnetic patterns in the same space.

Some of the actual magnetic patterns on tape can be made visible by a simple process. A short piece of recorded tape is dipped into a solution of lighter fluid and carbonyl-iron, then is allowed to dry. As the lighter fluid evaporates, the very fine particles of carbonyl-iron will remain magnetically attracted to the tape in definite patterns visible to the naked eye (Fig. 13). A much more definite pattern can be observed by viewing the tape through a microscope as shown in the photograph of Figure 14.

The heavily magnetized intervals on the tape (the poles) attract the carbonyl-iron particles, appearing as narrow lines across the tape. The stronger the pole, the heavier the line. The lower the frequency of the current, the greater the distance between lines. The actual wavelength of the original tone is equal to twice the distance between the lines.

The 3-M Company has recently placed on the market a magnetic-tape viewer (Fig. 15) that allows viewing of the sound track on magnetic tape without any chemicals or other extras. The viewer is placed over the tape and then tapped gently for the image to appear.

The Recording Process

In summary, then, sound waves pulsate through the air, and cause the diaphragm in the microphone

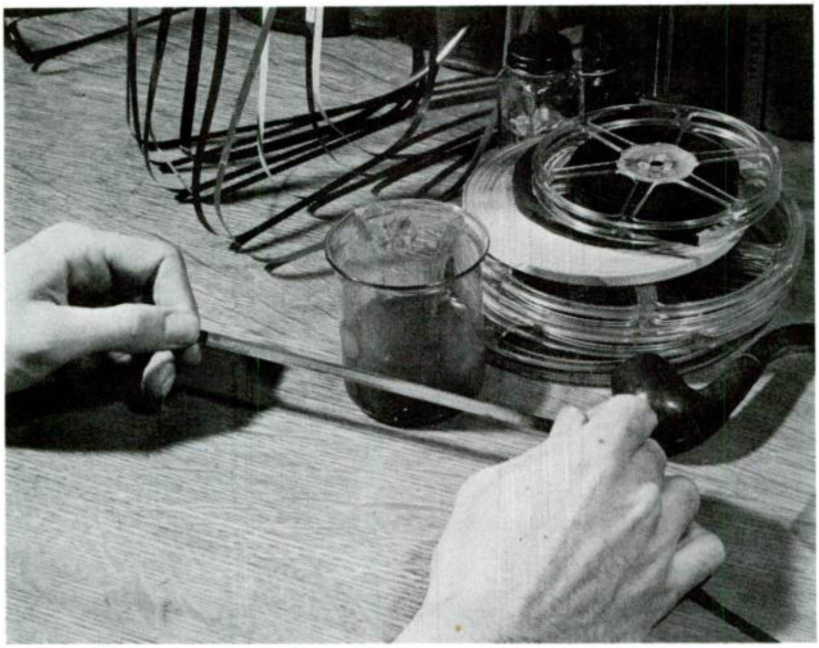


Figure 13 — Using a solution of lighter fluid and carbonyl iron on tape to make the tracks visible to the naked eye.

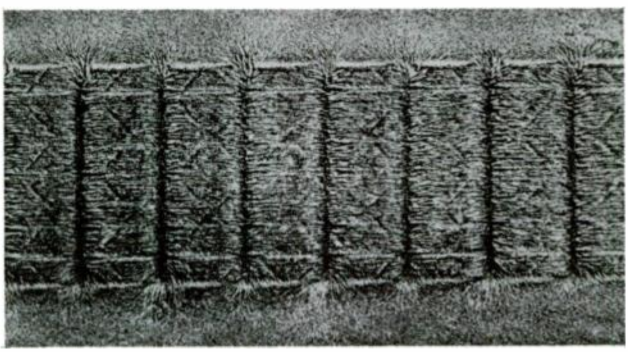


Figure 14 — Microscope enlargement of visible magnetic tracks.

to vibrate accordingly. This produces corresponding electrical pulsations in the microphone which are boosted in strength by an amplifier. The amplified pulsations are then fed into the recording head where corresponding magnetic fields are created, which, in turn, leave their magnetic patterns on the tape.

The Playback Process

In playing back a recorded tape, the recording process is more or less repeated, only in reverse. During the recording process, an electric current in a coil was used to create a magnetic field. In playback, a magnetic field moved through a coil is used to create an electric voltage.

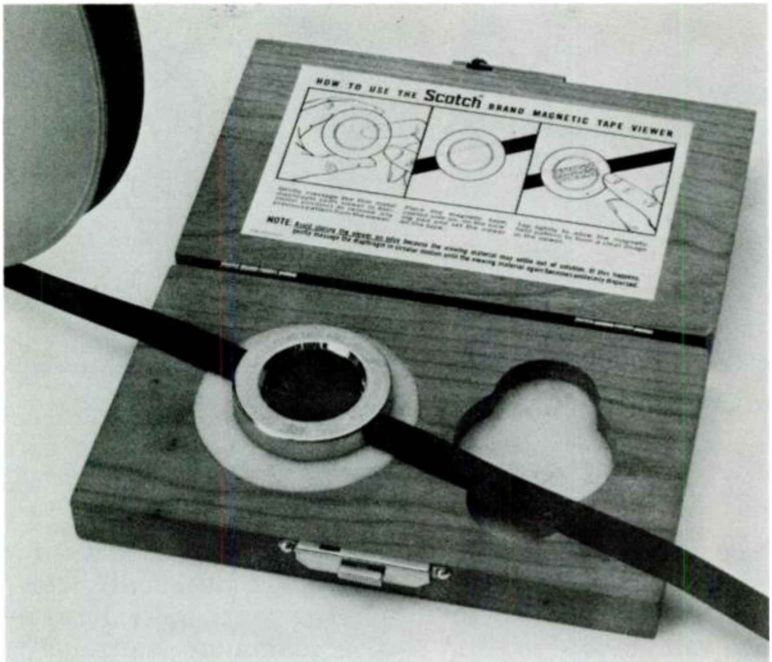


Figure 15 — Magnetic-tape viewer.

A basic principle of electricity is that a surge of electrical voltage can be generated by moving a bar magnet (or its surrounding magnetic field) through a coil. By moving a series of magnets of opposite polarity (or their fields) through a coil, an alternating electrical voltage will be produced. In the recording process, the tape was figuratively broken up into just such a series of short, permanent bar magnets.

What actually produces the voltage is the change in the magnetic field from positive to negative. The peak surge of current comes at the moment the polarity of the field is changing most rapidly. Therefore, when the magnetic force in the head is maximum, no voltage is produced. See point A in Figure 16. At the point where the polarity of the head is reversing, the maximum voltage is produced as shown at point B in Figure 16.

In the playback process, the bar magnets on the tape are not actually moved through the coil of the electromagnet; however, part of the magnetic field of each bar magnet is. What happens is that the iron ring of the electromagnetic playback head temporarily routes the bar-magnet field through the coil.

In Figure 16 at point A, it can be seen that a north pole and a south pole are on either side of the gap. Normally, the lines of magnetic force stay close to the tape, but because it is easier for the magnetic field to follow the iron ring (a much better conductor) than jump the air

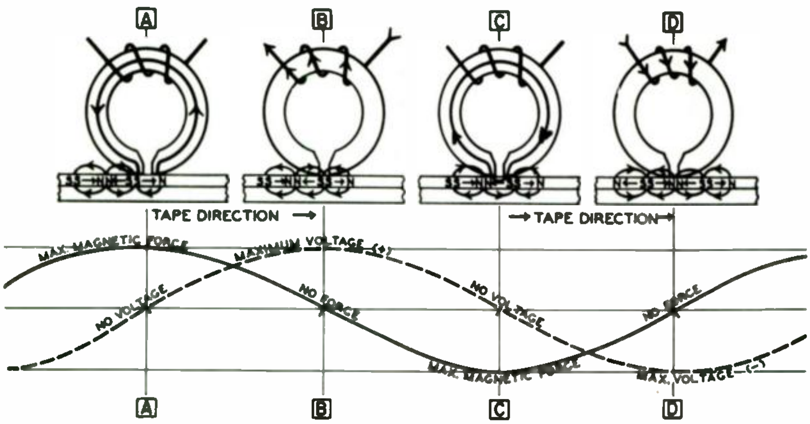


Figure 16 — The playback process.

spaces at the gap, it does just exactly that. At point A, therefore, the magnetic force in the head is maximum but the voltage is zero.

When the tape has moved a fraction of an inch farther, as at point B, a strongly magnetized line, a south pole this time, is at the gap. The iron ring of the electromagnet serves no useful purpose to the field, so it is ignored, and magnetic strength in the head is reduced to zero. However, since this is the point where polarity of the head changes most rapidly, maximum voltage is produced.

At point C, the situation again occurs where one pole is on one side of the gap, and an opposite pole on the other. As at point A, the magnetic field again takes the easiest route and flows through the soft iron ring. Maximum magnetic strength is produced in the head, but no voltage, since this is the point of alternation of the magnetic field where the rate of change is zero.

At point D, the polarity of the head is again at the point of reversal, and consequently this sudden change in magnetic force results in the maximum surge of voltage. Since the surges of voltage alternate between positive and negative with the same frequency as that which was recorded on the tape, they can be amplified and fed through an amplifier to a speaker to once again produce the original sounds.

THE MOTORBOARD

The tape recorder operates on basically simple mechanical concepts. Most people with mechanical ability can study the mechanism and determine how it works and what each part is supposed to do. In many cases tape recorders are less complicated than record changers since there are no critical trip or cycling adjustments. However, many more stringent requirements are made on the tape mechanism.

The job of a record player is to rotate a disc, while the job of a tape recorder is to pull a tape; although both are designed to operate at a constant speed, the problem of pulling a tape past a magnetic head at a constant speed is considerably more complex than rotating a turntable. The disc player turntable serves as a flywheel, providing excellent instantaneous speed characteristics. A tape has very little inertia and its stabilization must come from an external flywheel.

A disc player turns only a single shaft at one, or at the most, three or four speeds. In contrast, the tape-recorder capstan must often be able to operate at one of two different speeds. The take-up reel operates at an infinite number of speeds within a given range. The supply-reel spindle must both rotate freely during certain operations and supply back tension during others, while having the ability to operate at high speed during rewind. All the shafts must be controlled by a system of clutches and brakes to facilitate rapid changes in tape direction and speed, still providing sufficient tension to avoid tape slack. The drawing in Figure 17 illustrates a typical two-speed tape recorder with its principal features pointed out.

Primary Function of the Motorboard

The motorboard is the actual mechanism of the tape recorder. The motorboard moves the tape past the magnetic head at a uniform rate of speed, winds it on a take-up reel, rewinds it, and has the ability to go fast forward. The fast forward and rewind functions enable the rapid location of any desired portion of the recording within the reel. The top view of a typical motorboard is shown in Figure 18.

Capstan Drive

The capstan drive is the very heart of a tape recorder. The tape is

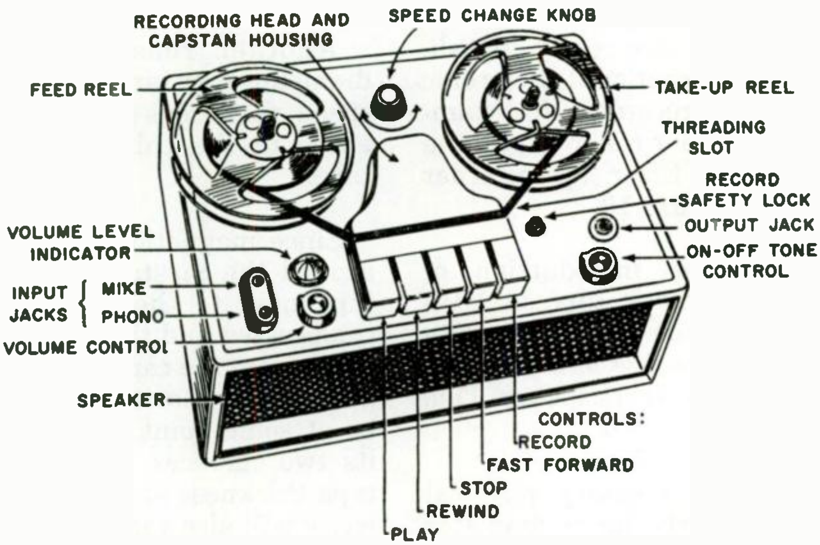


Figure 17 — Typical two-speed recorder with principal features indicated.

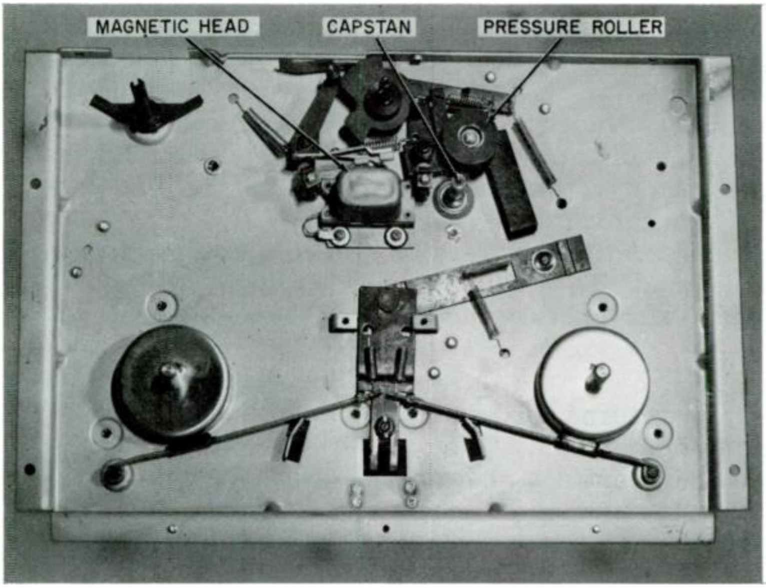


Figure 18 — Top view of a typical motorboard of a modern recorder

pulled by a roller pressing the tape against a rotating shaft. The rotating shaft is known as the capstan. In many older machines rubber or composition covered shafts were employed to pull the tape. The rubber capstan was attached to a common shaft with a flywheel and was motor driven. The early Brush, Eicor, and International Electronic Company tape recorders, for example, used a rubber roller to pull the tape. The early Eicor tape recorder is shown in Figure 19.

However, the introduction of lubricated magnetic tape in 1949 necessitated a more positive drive and required the use of a pressure roller against a steel capstan. This is shown in Figure 20.

Because of necessary physical stability, a fairly large diameter capstan is required. If the capstan is at all eccentric it will pull the tape faster at one point in its revolution than at another, introducing serious wow and flutter. A small capstan will also have a tendency to whip. To obtain the required rigidity, it is generally necessary to use large diameter capstans.

Another reason for a large diameter capstan is to minimize speed variations caused by differences in the caliper of magnetic tape.

Since magnetic tape is wrapped around the capstan, the portion of tape next to the capstan will be compressed and the portion of tape away from the capstan will be elongated. The velocity of the tape will be at some point midway between its two surfaces. Therefore, if the tape thickness should vary, its velocity will also vary. But if the capstan is large in comparison to the tape thickness, variations in tape

Figure 19 — An early Eicor tape recorder.

thickness will be, for all practical purposes, negligible.

However, large capstans have one main disadvantage. If the capstan size is increased, the flywheel size must also be large, since more inertia is needed to stabilize a large slow-speed capstan than one that is small but high speed. The capstan size of most recorders varies from slightly under an eighth of an inch to approximately five-eighths of an inch.

Drive Methods

In order to stabilize the capstan rotation and provide the most uniform tape speed possible, a flywheel is attached to the capstan shaft. The motor then drives the flywheel by either a puck-, belt-, or direct-drive system.

Puck Drive. The high speed of the motor shaft requires that some method of speed reduction be incorporated into the drive system. The puck drive is a method of driving the rim of the flywheel by a friction process. In some mechanisms, the flywheel is equipped with a rubber tire and is driven directly by the motor shaft as in Figure 21A. Another type of puck drive is shown in Figure 21B. This method, which is used by many home-type recorders, employs an intermediate-puck roller which in turn drives the flywheel.

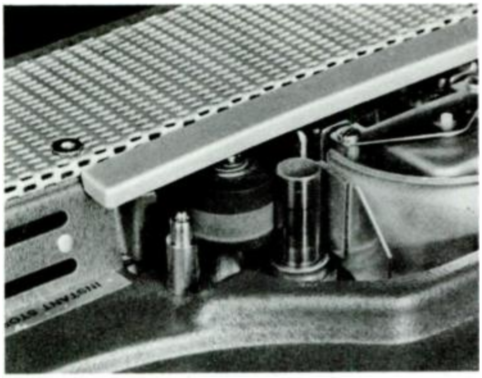


Figure 20 — Tape is held by pressure roller against steel capstan.

For the intermediate-puck drive system a rubber-tired wheel, called the idler wheel (See Figure 22), is mounted so that the motor pulley will drive it. The idler wheel, in turn, will drive the capstan flywheel rim. The center bearing of the idler wheel is mounted on a plate. Although there are design variations in the mounting of this bearing, the purpose of each is threefold: (1) To insure a correct wedge angle of the idler wheel between the flywheel rim and the motor pulley, exerting enough traction to transmit the torque and yet not stall. (2) To keep the idler wheel horizontally movable so that spring tension may be applied to the bearing mounting in the direction of the wedge angle while providing constant pressure of the idler wheel against both the flywheel rim and the drive pulley. (3) To maintain alignment of the idler wheel in a vertical plane with the motor pulley and the flywheel rim. An exploded view of a typical bearing mounting system is shown in Figure 23.

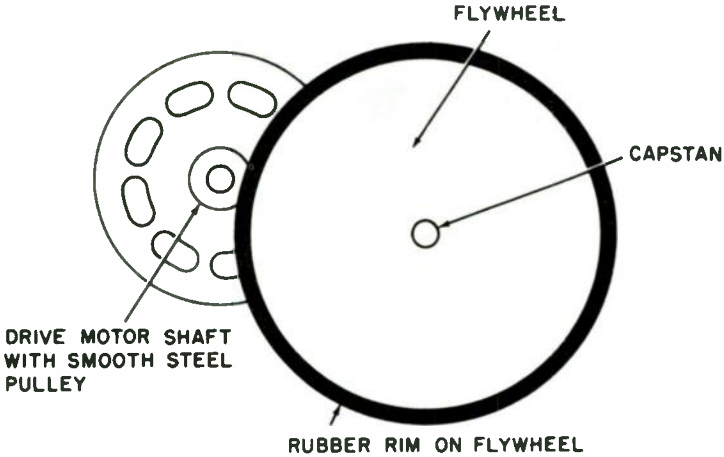
The diameter of the motor pulley is determined by the diameter of the flywheel, the speed of the motor shaft, the capstan diameter, and the loss in working the rubber of the drive tire. The diameter of the idler wheel does not affect the speed ratio but is selected and designed according to the curvature which will best deliver the torque required.

Belt-Drive Systems. The second major drive system is the belt drive. Two types of belts are employed: composition and rubber.

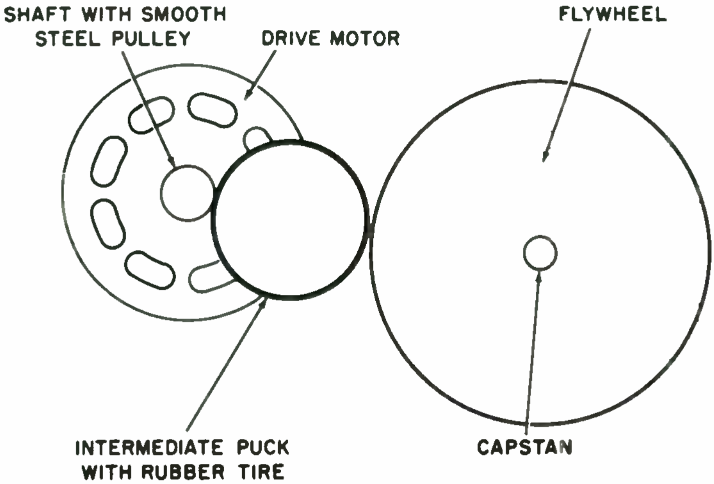
The composition belt is flat in construction, running between the motor and the flywheel. Generally, a tension roller arm is also employed to keep the belt taut. This is a comparatively expensive drive because an extra idler roller is required. However, it is fundamentally a good drive system, making for excellent speed stability. The composition belt is used in some professional recorders.

The other type of belt is a round rubber belt, also linking the motor to the flywheel. The use of a rubber belt means that an idler is not needed because the rubber has enough tautness to remain tight. However, the rubber belt in time will become loose and cause slippage. Hard spots may develop, also introducing wow. When slippage develops, the rubber tends to wear away and fills the recorder with rubber shavings. The round rubber belt was used to drive the capstan on the Brush *Soundmirror* and is also used in some current models.

Direct-Drive Systems. The third type of drive system, becoming increasingly popular in pro-



(A) Rim drive to flywheel.



(B) Intermediate-puck drive.

Figure 21 — Two methods of capstan drive.

fessional recording equipment, employs the motor shaft as the capstan shaft. If there is a flywheel in the system, the flywheel is attached directly to the motor shaft. This drive, operating directly from the motor, has many advantages since there is only one rotation shaft with no transmission of power from one shaft to another. Therefore, there is no need for rubber puck rollers, which may become dented and introduce wow. There are no belts to stretch and develop hard spots.

Motor Types

Any drive system can use two types of motors: induction or synchronous. A conventional induction motor usually has a fairly stable

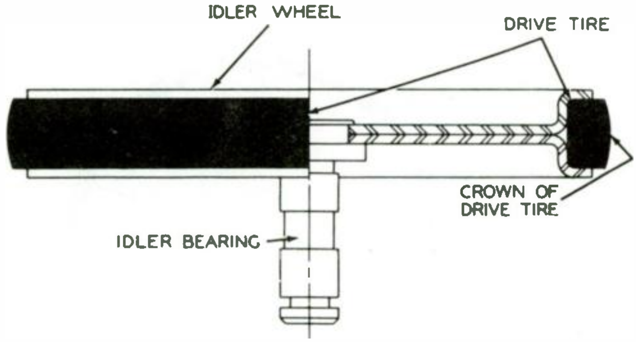


Figure 22 — Detail of an intermediate-puck wheel.

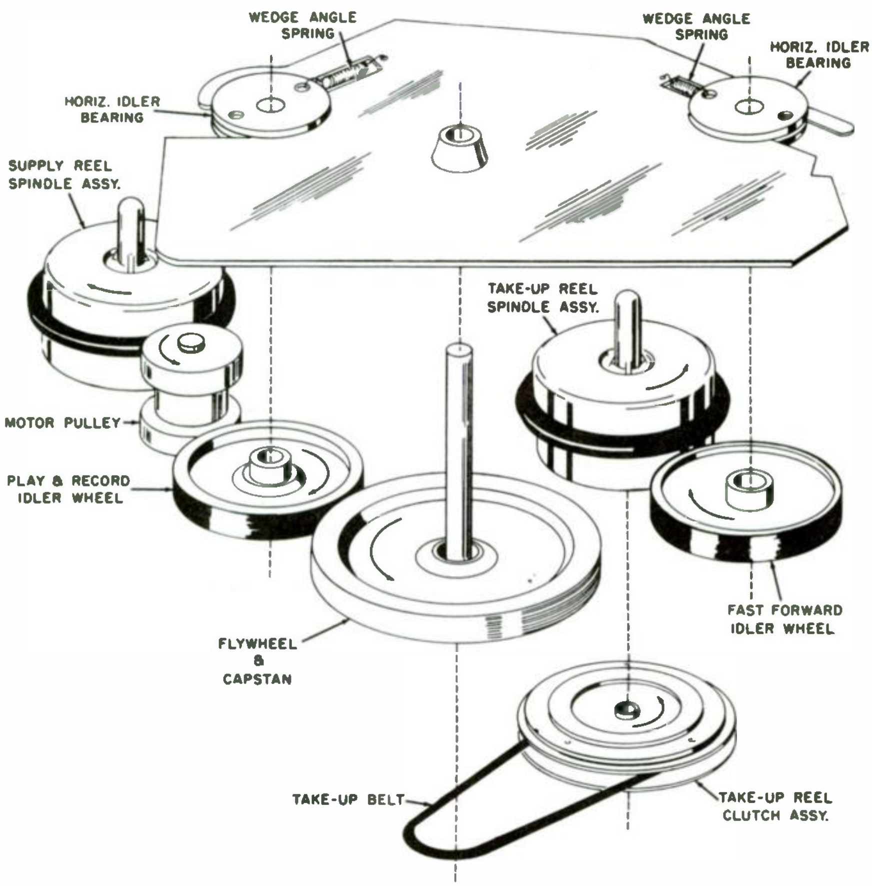


Figure 23 — Exploded view of a typical bearing mounting.

speed characteristic. It has good instantaneous speed regulation, including very little flutter and wow. It is inexpensive, compact, runs relatively cool, and gives a lot of power for its size. Nonsynchronous or induction motors, however, are subject to speed variations caused by changes in load and line voltage.

The other type of motor, used on some equipment, is a synchronous motor. The synchronous motor has absolutely perfect long-time speed regulation since its speed is controlled by AC power alternations. However, it tends to introduce a certain amount of instantaneous speed variation during its rotation, resulting in some flutter. It is an expensive motor, runs quite hot, and is large for a given amount of power.

Take-up Reel Drive

The capstan, of course, is used to pull the tape at a constant speed past the magnetic head. However, tape moving at a constant speed must then be spooled onto a take-up reel. Because the tape goes from a small diameter at the beginning of the reel to a large diameter at the end, the reel speed must change since the tape speed remains constant. The rpm of the reel changes considerably from a large to a small diameter. Therefore, all recorders employ some type of variable-speed drive.

The slipping clutch is a common variable speed drive. Generally, the clutch consists of a rotating disc that is driven at a constant speed, often by the same motor that drives the capstan. Next to this disc is placed a piece of felt. The felt slips on the disc and drives another disc which, in turn, drives the reel shaft.

Rewind and Fast-Forward Mechanisms

The remainder of the motorboard mechanism is designed to rewind the tape. In addition, practically all tape recorders incorporate a fast-forward speed, enabling the tape to move at a higher than operating speed, facilitating rapid location of selections within the reel of tape. During both fast forward and rewind, very little back tension is applied to the feeding reel. This allows the tape to be moved at a high speed with a minimum of mechanical power.

In home recorders, generally a mechanical linkage shifts the reel shaft or puck shaft into position to be driven by the motor. By using a minimum amount of mechanical power with little back tension, a "soft" tape wind is achieved. It is essential that tapes are softly wound to prevent physical distortion in which one edge of the tape is stretched.

Two-Speed Drive

In the professional field, two tape speeds are becoming standardized throughout the industry. The 15-IPS speed is being widely used for original recording where the highest possible fidelity is desired. However, with the tremendous improvement in performance at 7.5 IPS, this speed has been widely accepted as standard for the bulk of broadcast work. Therefore, the professional machine should have both speeds.

In most professional equipment the speed change is now accomplished by means of switching the fields in the synchronous drive motor. Since most professional machines use this type of motor, it is possible to change from a four-pole motor, running at 1,800 rpm, to an eight-pole motor, running at 900 rpm. A synchronous drive motor with six poles, running at 1,200 rpm, can be changed to a twelve-pole motor running at 600 rpm. The speed change is simply accomplished by flipping a switch which connects the proper number of motor fields in the circuit.

By contrast, the speed of some makes of professional recorders can be changed by the physical transfer of capstans as shown in Figure 24. A removable pressure roller and/or capstan of different diameter is used for different speeds. This method, while perhaps bothersome and time-consuming, serves the purpose. A well-machined shaft is used, making the removal and fitting of the capstan easy. However, the pressure of dirt on the capstan shaft will make the capstan eccentric with resulting wow and flutter.

Among the home recorders, both the 7.5- and 3.75-IPS speeds are of vital importance. The 7.5-IPS speed is generally used for higher quality musical recordings, while the 3.75-IPS speed serves primarily for voice applications. It is true that some recorders operating at 3.75 IPS give better performance than others operating at 7.5 IPS, but this depends on the design and precision of the recorder itself.

It is more difficult to obtain good performance at slower tape speeds for two reasons: First, the high-frequency response is limited and the output is reduced. This subject will be fully treated in the chapter on magnetic heads. Second, the wow and flutter are increased since there is less inertia in tape systems

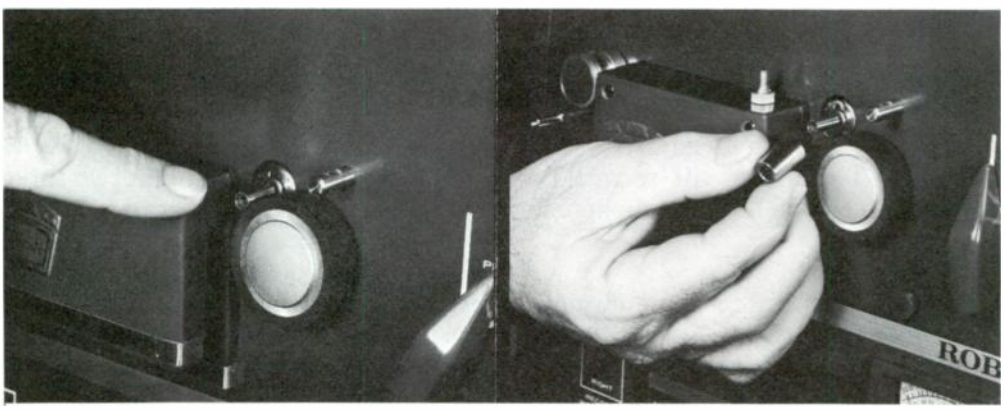


Figure 24 — The Roberts Model 330 changes speed by physical transfer of capstan and pressure roller.

operating at slower speeds. Also, any minute variation in tape speed has a tendency to adversely affect the recording when the tape is traveling at slow speeds.

In the home-recorder field, the majority of recorders change speed by changing the position of the intermediate puck from one diameter on the motor shaft to another as illustrated in Figure 25. Generally, the intermediate puck is moved between two steps of different diameters on the motor shaft.

While this system works very well as a speed-changing device, the method of shifting the pulley is of great importance. On some recorders the pulley is actually forced over the edge of the step. If the recorder is in a neutral or off position, the speed change can be easily and safely accomplished. However, if the recorder is running, the pulley will severely nick the intermediate puck roller. The nicked edge will result in serious wow and flutter.

The more desirable method of speed change used in many of the newer home recorders is accomplished by actually removing the intermediate puck from both the motor drive shaft and the flywheel. The intermediate puck is then shifted to its new position and is re-engaged, eliminating any possibility of nicking its edge.

In most home recorders the intermediate puck roller is the heart of the drive system. The smoothness and consistency of the surface about its center axis are all important in keeping wow and flutter

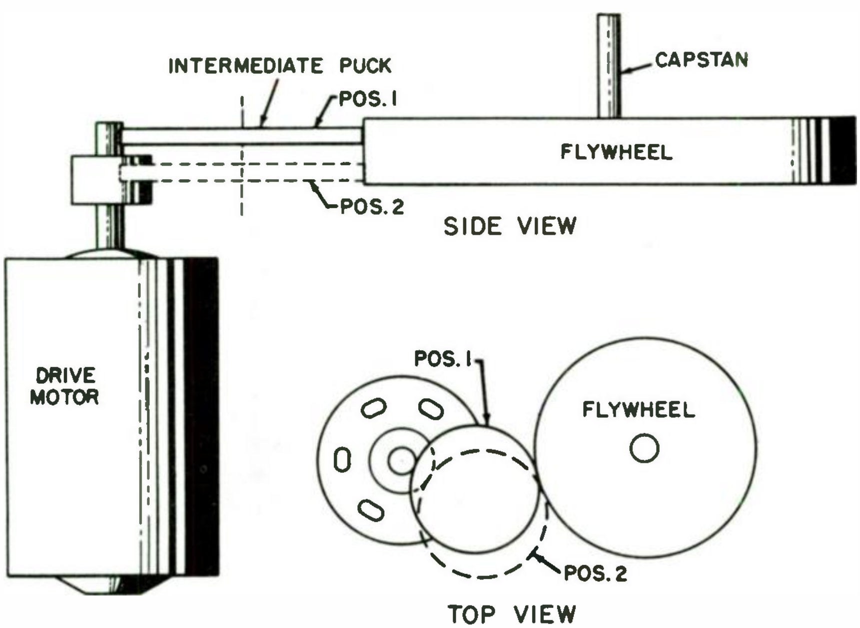


Figure 25 — Changing speed by changing puck position.

to a minimum. Care must be exercised in operating those machines which, in changing speeds, do not remove the intermediate puck from the shaft, motor pulley, and flywheel. It is a wise precaution to check the types of speed change used by the recorder before attempting to change the speed.

Several of the older home machines change speed by varying the capstan size. However, this method is gradually being discarded. Because of cost considerations, in home machines a tapered shaft, precision-machined, cannot be used. Consequently, if the capstan fits well it is difficult to remove and put on. If the capstan is easy to remove, the fit is so poor that the capstan will be eccentric and wow and flutter will develop.

Dual-Direction Mechanism

A number of recorders are specially designed for longer playing time, continuous operation, repetitive loops, etc. One very popular home machine, the Concertone Series 800 recorder (Fig. 26), incorporates a dual-direction design which permits operation in both directions.

In dual or half-track stereo recording, as used on this machine, one pair of stereo tracks is recorded in one direction, the other pair in the opposite direction. This eliminates turning over the reel when the end of the tape has been reached as is customary in other recorders that operate in only one direction. The tape changes direction automatically at the end of each track.

Figure 26 — The Concertone Series 800 recorder incorporates a dual-direction recording and playback mechanism.

Braking Mechanisms

When the recorder is put in the stop position the reels must brake as rapidly as possible without causing damage to the tape. Generally, the brakes consist of a metal wheel which engages a rubber rim on the reel shafts. Also, a rubber or felt pad can be used which rubs on a metal disc on the reel shafts.

In normal operation the brakes are removed, but in the stop position they are suddenly released and applied to the revolving reel spindle shafts, causing them to abruptly halt. The brake mechanism of the Wollensak Model T-1570 is shown in Figure 27. It is important that the feeding reel, the reel from which the tape is being drawn, be stopped first. Otherwise tape spillage will result.

The adjustment of the brakes is critical in many machines to prevent tape spillage and still not cause physical damage or stretching of the tape. Several machines use no brake action whatsoever. The tape is braked only by reversing the direction of drive on the reel spindles. An interesting approach to braking is also used which applies braking pressure toward both reel spindles while stalling the motor, rapidly halting the tape with no danger of spilling or breaking the tape.

Figure 27 — Brake mechanism of the Wollensak Model T-1570

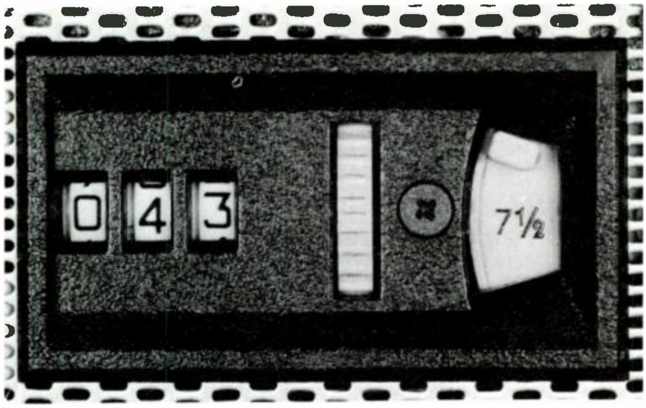


Figure 28 — Position indicator used on the Wollensak Model T-1400.

Position Indicators

Position indicators are almost universally included. They are counters that are driven by the feed or the take-up reel and count the revolutions of the reel. This feature enables rapid location of selections within a reel of tape. Figure 28 shows the position indicator on the Wollensak Model T-1400 recorder.

SUMMARY

The history of magnetic recording began in 1898 when Valdemar Poulsen built the first magnetic recorder. The *telegraphone* closely resembled the modern magnetic recorder. Poulsen's telegraphone had limited frequency response and the output was extremely low. Dr. Lee de Forest applied the vacuum tube amplifier to the telegraphone to amplify the recorded output.

Magnetic tape allowed for longer recording times and reduced the cost of recording. In magnetic recording a magnetic field is induced into the tape by a magnetic recording head. When the tape is played back the magnetic fields recorded on the tape induce a voltage into the playback head and an output is produced.

The mechanical concept of the magnetic recorder drive system is simple. The drive system must be capable of pulling the tape past a magnetic head at a constant speed without stretching or breaking the tape. The drive system must be capable of changing direction and speed, still providing sufficient tension to avoid tape slack. There are many motorboard configurations capable of this task.

TEST
Lesson Number 74

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-074-1.

1. **High quality tape recordings are superior to disc records because tape**
   A. is cheaper.
   B. has less distortion.
   C. mechanisms are less expensive.
   D. recorder electronics is simpler.

2. **Competence in tape recorder servicing can be acquired more easily than in color TV because**
   A. tape recorder service information is more readily available.
   B. tape recorders are totally mechanical.
   C. less theory is involved.
   D. tape recorder service involves less mechanics.

3. **Early magnetic recording was done with steel**
   A. wire or tape.
   B. drums.
   C. discs.
   D. coated paper.

4. **The first magnetic recorders were not successful because of limited recording time and**
   A. they were spring drive.
   B. they had a low noise level.
   C. they could not be erased.
   D. they lacked amplification.

5. **The method/methods used to drive the capstan in tape recorders is/are**
   A. puck-drive.
   B. belt-drive.
   C. direct-drive.
   D. all of the above.

6. **The first successful recording tape was made by depositing __________ on paper tape.**
   A. iron oxides
   B. adhesives
   C. ground carbon
   D. steel plating

7. **The playing time of taped recordings has been extended by using thinner tape with more on a spool and by**
   A. using more involved electronics.
   B. reducing tape speed.
   C. using stereo recording techniques.
   D. multiplexing.

8. **Nearly all tape recorders use capstan drive which means that the driving power is applied to the**
   A. tape.
   B. take-up reel.
   C. supply reel.
   D. none of the above.

9. **Most tape recorders can operate at __________ speed(s).**
   A. one
   B. three
   C. four
   D. two

10. **Many home tape recorders are designed to operate at two speeds. A speed of 3.75 IPS is intended for voice recording with _________ IPS being used for music.**
   A. 15/16
   B. 30
   C. 7.5
   D. 15

Portions of this lesson from
Tape Recorders-How They Work (2nd Edition)
by Charles G. Westcott and Richard F. Dubbe
Tape Recorder Servicing Guide
by Robert G. Middleton
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Notes

Notes

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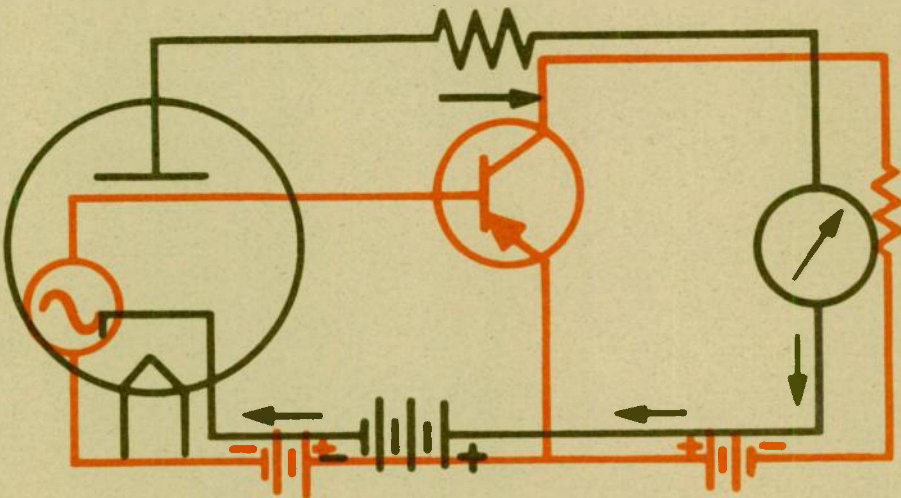
S. T. Christensen

LESSON NO. 75

TAPE RECORDERS PART 2



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-075

407

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

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Contents

TAPE RECORDERS PART 2

MAGNETIC-RECORDING HEADS

The magnetic-recording head is the most critical and precision device in the entire recording mechanism (Fig. 1). Built to a tolerance as close as 1 millionth of an inch, the magnetic head requires an exceptionally high degree of precision in its construction.

Good fidelity in record operation, at the present-day speed of 3.75 IPS, has been achieved. This, in large measure, has been made possible through basic improvements in magnetic heads. Magnetic heads not only determine the low- and high-frequency response of a recorder but also help to establish the signal-to-noise ratio.

Some two-head recorders have a combination erase and record/playback head mounted in a single case, giving the appearance of only one head, although these are actually two separately operating heads. Also, some monaural tape recorders use a permanent-magnet erase head which is mechanically moved into contact with the tape during recording.

In most discussions it is common to speak of three magnetic heads. First, the erase head, which has the
4 function of obliterating or "wiping" off any signal on the tape, leaving the tape in a completely demagnet-
2 ized condition. Second, the record head which serves to place a signal in the form of magnetic impulses on the tape. And third, the reproduce or playback head which has the function of converting the
3 stored magnetic impulses on the tape into electrical energy to be amplified for reproduction.

In respect to design, the record and reproduce heads are practically

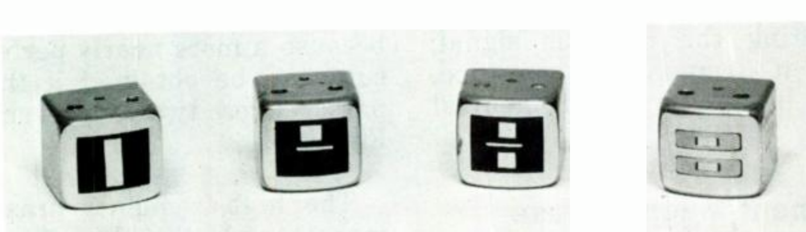


Figure 1 — Modern heads.

identical. In the majority of machines, especially home-type tape recorders, the same head is used for both record and playback functions. This is accomplished by merely switching the head from the output of the amplifier during the recording process to the input of the amplifier during the playback process. Therefore, only the erase head and the record-reproduce head will be discussed.

The Erase Head

As previously mentioned, the first function of the erase head is to completely obliterate any signal on the tape from the prior recording. The second function is to leave the tape in a completely neutral or demagnetized condition. To completely wipe off any previous signal from the tape is, of course, important since an echo or background of the previous recording would disturb the new recording. The tape must also be left in a completely neutral or demagnetized state in order to eliminate all distortion and noise.

To accomplish both objectives in tape erasure, a magnetic field which is considerably stronger than the strongest signal on the tape is needed. This field must be designed in such a manner that it will highly magnetize the tape in one direction obliterating the previous signal; and then demagnetize the tape, leaving it in a completely neutral state.

Permanent-Magnet Erase

Many early recorders and some present-day machines use what is known as permanent-magnet erase. This is a permanent magnet generally made of *Alnico* material that is so constructed that one pole completely magnetizes the tape, saturating it to a higher magnetic state than the strongest previous signal. Thus, the permanent-magnet erase serves to obliterate any signal on the tape. Then either a second magnet, a series of magnets, or a diagonal magnetic gap is used to demagnetize the tape and leave it in a neutral state.

High-Frequency Erase

The high-frequency erase head is a head with a rather wide gap that uses a very high frequency, generally the bias frequency, to erase the tape. The source for the current in this case is the bias oscillator. In the high-frequency erase process, as the tape passes over a wide gap (Fig. 2), a series of reversals takes place in the magnetic field on the tape. When the tape leaves the gap, it is in an essentially neutral or demagnetized condition.

Some erase heads are constructed exactly as a recording head except for a wider gap (about .004 inch or 4 mils) and an increased track width. However, most are of "double-gap" construction because a more nearly perfect erasure can be obtained if the tape passes across two gaps as shown in Figure 3.

The high-frequency erase head makes an ideal method of tape erasure. If the signal is strong enough and if the head is correctly designed, the high-frequency erase method will completely obliterate any previous signal, leaving the tape in a completely neutral condition.

The Record-Reproduce Head

Since the record-reproduce head is generally the same head in most machines, serving a dual function, this discussion will cover the general design of only one head.

In general, the magnetic record-reproduce head is a closed magnetic circuit with a gap at one point. The physical configuration is the reason why it is sometimes called a ring head (Fig. 4). On the ring is wound a coil to which the electrical signal is applied during record, and during playback the signal is drawn from the same coil.

Frequency Response

During the playback operation, the high frequencies on the tape are generally limited in reproduction by the width of the gap. That is, as the recorded wavelengths on the tape approach the physical size of the head gap, the signal becomes greatly attenuated. In simpler terms, a 7,500-hertz wave recorded

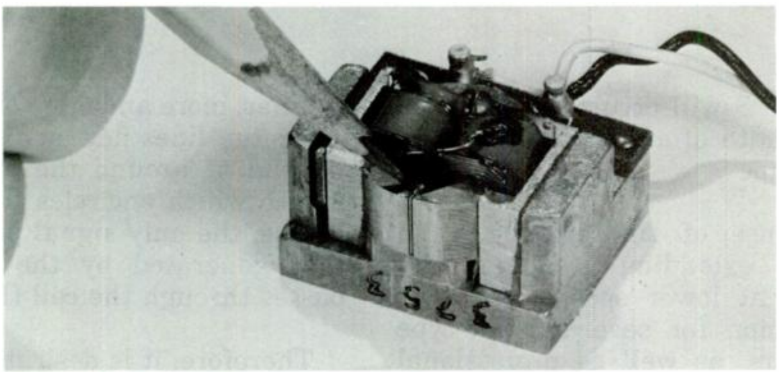


Figure 2 — Long-gap erase head.

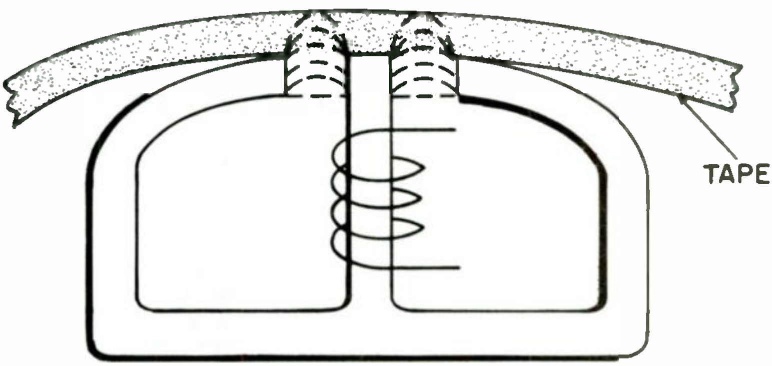


Figure 3 — Double-gap erase head.

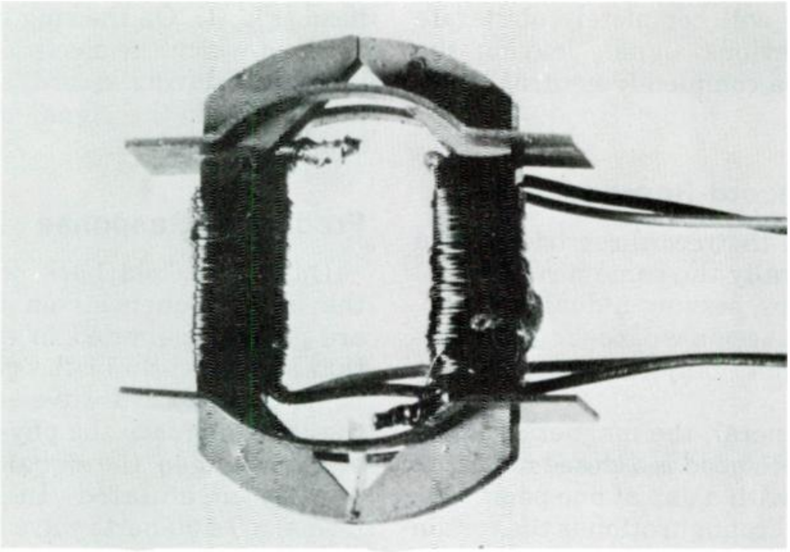


Figure 4 — The ring head is a closed magnetic circuit with a gap at one point.

at 7.5 IPS will occupy a space of a thousandth of an inch on the magnetic tape.

Because of the present trend toward extending frequency response at lower speeds, it is not uncommon for several home-type recorders, as well as professional machines, to go up to 15,000 hertz at 3.75 IPS. This means that the gap length must not be longer than about .00028 inch long. It is obvious that extreme precision is required in the manufacturing process in order to make a gap of the required narrow width.

One might logically reason: Why not make the gap as short as possible to record the highest frequency possible? The disadvantage of a short gap is that the available signal energy is reduced as the gap length is shortened. In other words, as the gap becomes smaller and smaller, more and more of the magnetic-flux lines flow across the gap instead of around the entire core length which encircles the coil. Of course, the only signal produced is that generated by the flux that passes through the coil (Fig. 5).

Therefore, it is desirable to have a wide gap for maximum signal. However, it is desirable to have a narrow gap for maximum high-frequency response. Generally, the gap length is made as narrow as possible to a point where the desired signal output is still obtained. Present gap lengths generally range between 40 millionths and 5 ten-thousandths of an inch long.

The shape of the head at the gap is an important consideration. From the standpoint of wear, the gap should be as deep as possible. Thus, when the tape passes over the head, wearing it down as any

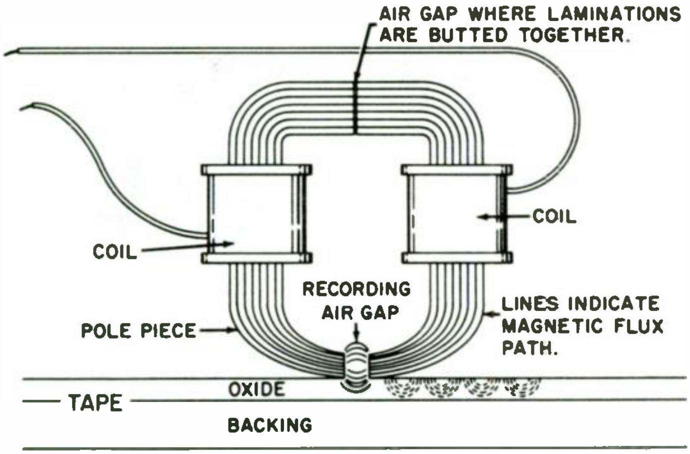


Figure 5 — Diagram showing flux through the ring.

sliding friction inevitably will, there should be a good depth of metal before the gap length becomes longer, ruining the high-frequency response. The effects of poor head contact with the tape are shown graphically in Figure 6.

It is obvious that when the head has been worn down as shown in Figure 7, the high-frequency response will be greatly impaired. Therefore, it is desirable to have a deep gap to prolong head life. A deep gap, however, is undesirable from the standpoint of output. A deep gap has the same effect as a narrow gap in that it prevents all the flux from going through the coil, but rather shorts out the flux through the air gap. Again, a compromise is reached in head design between long wear and high output.

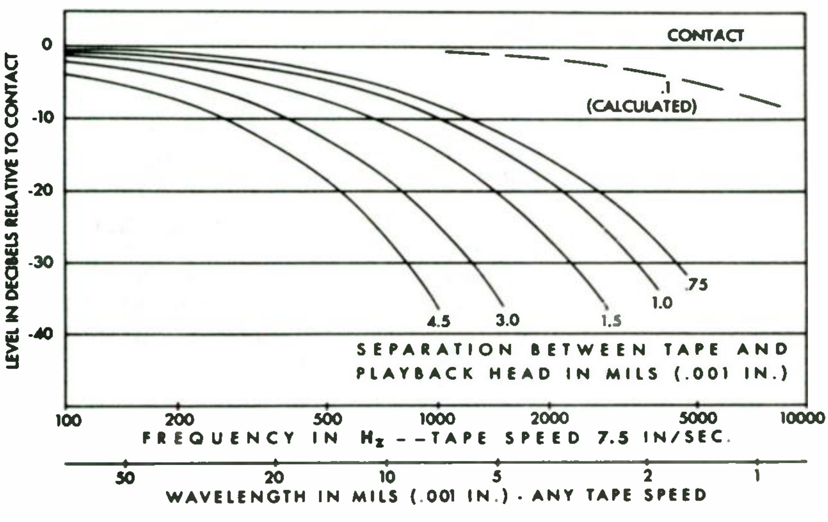


Figure 6 — Attenuation caused by poor contact in playback.

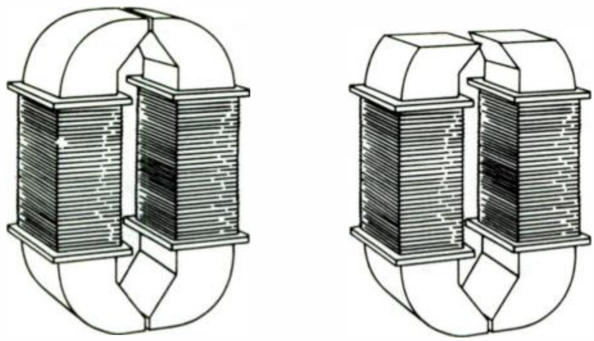


Figure 7 — Lengthening of gap due to head wear

ELECTRIC MOTORS

An electric motor is defined as a device which converts electrical energy into mechanical energy. A tape recorder contains some device which furnishes the mechanical force necessary for operation. Electric motors are universally used for this purpose.

Magnetic and Electromagnetic Principles

A discussion of the basic principles of operation of the ELECTRIC MOTOR involves a review of magnetism and electromagnetism.

The space surrounding a magnet where magnetic forces act is known as the magnetic field. This field is usually indicated by lines which are called flux lines or magnetic lines of force. These lines of force are assumed to leave the north pole of a magnet, pass through the surrounding space, and enter the south pole as shown in Figure 8. The lines of force then travel inside the magnet from the south pole to the north pole thereby completing a closed loop.

There are several characteristics of magnetic lines of force which must be mentioned:

1. Magnetic lines of force are continuous and will always form closed loops.
2. Magnetic lines of force never cross.
3. Magnetic lines of force traveling in the same direction repel one another. Magnetic lines of force traveling in opposite directions tend to attract each other and combine.
4. Magnetic lines of force tend to shorten themselves. Therefore, the magnetic lines of force existing between two unlike poles cause the poles to be pulled together.
5. Magnetic lines of force pass through all known materials—magnetic or non-magnetic.

When a current is passed through a conductor, a magnetic field is formed around that conductor as shown in Figure 9. The

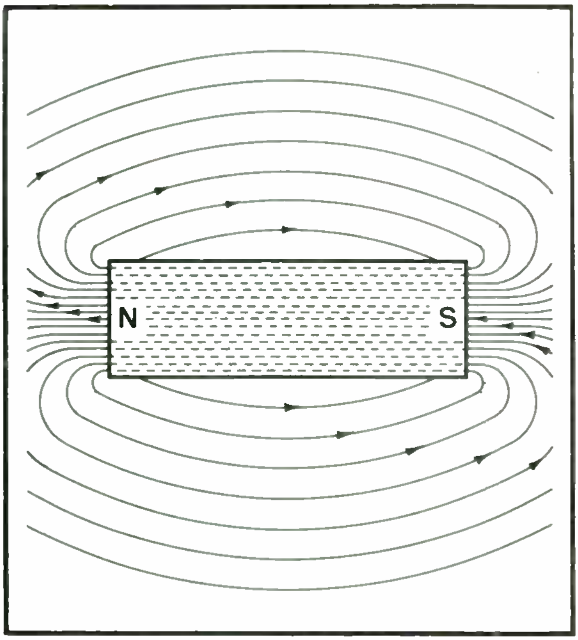


Figure 8 — Fields about a bar magnet.

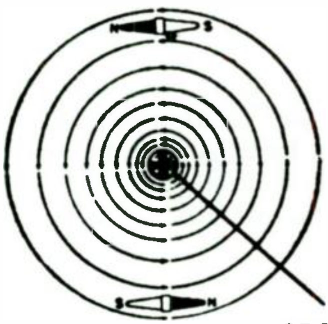


Figure 9 — Flux lines around a conductor.

direction of these lines of force may be determined by the left-hand rule. This rule is stated as follows:

"Grasp the conductor with the left hand so that the thumb points in the direction of current flow. The fingers will wrap around the conductor in the direction of the magnetic lines of force."

If the current carrying conductor is placed in a magnetic field as shown in Figure 10, motion of the conductor will be produced. The direction of motion may be determined by referring to the rules governing the action of lines of force. The rule of interest here states that magnetic lines traveling in the same direction repel one another, and lines of force traveling in opposite directions attract and combine with one another.

Figure 10A shows the field about the conductor aiding the field at the bottom of the magnet and opposing the field at the top. This means that the conductor will be repelled from the bottom of the magnet and attracted toward the top. Figure 10B shows the current reversed through the conductor. This means that the fields will oppose at the bottom and

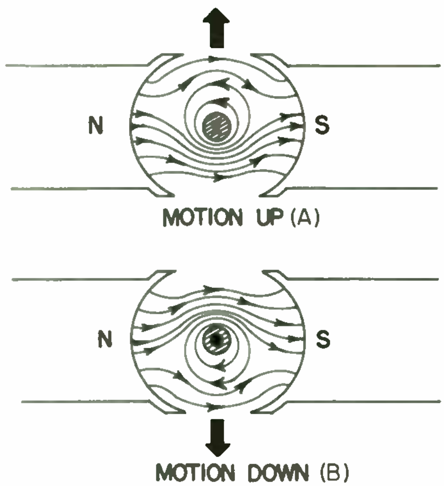


Figure 10 — Motion of a current carrying conductor in a magnetic field.

aid at the top. This will result in a downward motion of the conductor. This is the underlying principle of motor action.

Perhaps the action of the basic motor can more easily be seen by using the diagram in Figure 11. Figure 11 shows a loop of wire suspended in a magnetic field. The loop of wire is also called an ARMATURE. The loop is connected to a COMMUTATOR-BRUSH assembly. The purpose of the commutator-brush assembly is to provide a contact area between the movable loop and the stationary DC source. Notice that one portion of the loop is connected to the commutator segment designated segment X, and the other portion of the loop is connected to the commutator segment designated segment Y. The commutator segments are insulated from one another. Segment Y is connected to brush A. Brush A, in turn, is connected to the negative terminal of the battery. Segment X is connected to brush B which is connected to the positive terminal of the battery. As the commutator segments turn, they will each be in contact with one of the brushes. Assume the starting position illustrated. Commutator segment Y is in contact with brush A, and the other segment, X, is in contact with brush B. When current is permitted to flow in the direction indicated, fields are established about both sides of the loop of wire. The direction of current flow causes a magnetic field to exist in a direction which will cause the loop to start to rotate in a clockwise direction. In the left hand loop the fields are aiding and repelling at the bottom and opposing and attracting at the top. Therefore, the left hand loop will move in an upward and clockwise direction. The current flowing through the right hand portion of the loop causes an opposing and attracting field at the bottom resulting in a downward and clockwise motion. Therefore, the action of the left hand portion is aided by the action of the right hand loop. A shaft is mounted at the axis of the

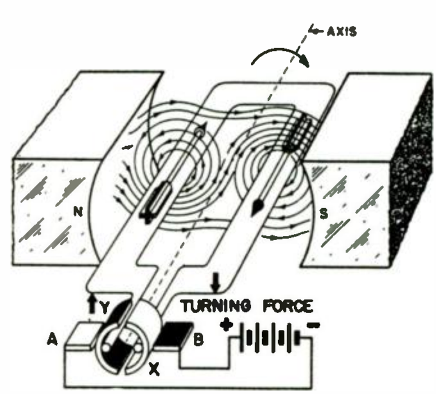


Figure 11 — Basic DC motor action.

loop allowing the loop to rotate freely. Initially when the loop starts to rotate, it does so with a twisting force. This twisting force is known as TORQUE.

The torque will cause the conductors (loop) to rotate in the field. However, when the conductors reach a certain point in their travel (90° after the indicated starting position), they will be parallel to the lines of force established by the magnet. It would seem that at this position all motion would stop. This statement would be true if the conductors did not possess momentum. The actual condition is that the conductors possess sufficient momentum to ride past this point. Notice the position of both the loops and the commutators at this time (Fig. 12). The loop is perpendicular to the lines of flux and the commutator bars are not making contact with the brushes. However, the momentum of the loop will be sufficient to cause the loop to pass through this point and reestablish contact with the commutator bars. Notice also that the commutator bars will now be connected to the opposite brushes, however, current flow will still be INTO brush A and OUT at brush B.

The direction of this current flow will establish fields that will continue the clockwise rotation. Figure 13 shows the loop moved to a position where it is again parallel to the field. The action will continue for the next 180° as it did for the first 180°. It is because of the switching action of the commutator that 360° of rotation of the armature can be achieved.

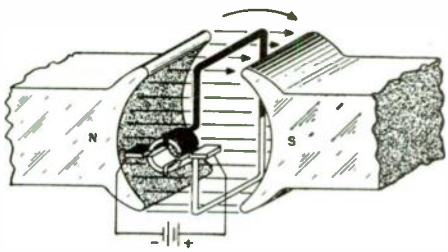


Figure 12 — Position of no apparent motion.

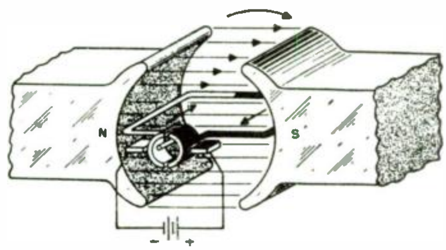


Figure 13 — 180° of rotation.

An armature composed of one loop of wire is used to explain the basic operation of a DC motor. A practical DC motor has many coils of wire in the armature winding. The armature has many slots into which are inserted many turns of wire. This increases the number of armature conductors and thus produces a greater and more constant torque because the magnetic field is acting on a greater number of conductors at any given instant of time.

AC MOTOR PRINCIPLES

Although commutator-brush motors are used with AC as well as DC, most small commercial AC motors employ another principle. An arrangement is used whereby additional phases of current exist in the pole pieces. The magnetic fields resulting from the reaction of initial phase plus the introduced phase causes a rotating magnetic field that revolves about the pole pieces. This revolving field acts on the armature causing it also to revolve. Several different methods are used to produce this action and the two most commonly used for tape recorder motors will be discussed in the following sections.

Shaded-Pole Motor

The shaded-pole motor employs a salient-pole stator and a cage rotor. The projecting poles on the stator resemble those of DC machines except that the entire magnetic circuit is laminated and a portion of each pole is split to accommodate a short-circuited copper strap called a SHADING COIL (Fig. 14). This motor is generally manufactured in very small sizes, up to 1/20 horsepower. A 4-pole motor of this type is illustrated in Figure 14A. The shading coils are placed around the leading pole tip and the main pole winding is concentrated and wound around the entire pole. The 4 coils comprising the main winding are connected in series across the motor terminals. An inexpensive type of 2-pole motor employing shading coils is illustrated in Figure 14B.

7

During that part of the cycle when the main pole flux is increasing, the shading coil is cut by the flux, and the resulting induced EMF and current in the shading coil tend to prevent the flux from rising readily through it. Thus, the greater portion of the flux rises in that portion of the pole that is not in the vicinity of the shading coil. When the flux reaches its maximum value, the rate of change of flux is zero, and the voltage and current in the shading coil also are zero. At this time the flux is distributed more uniformly over the entire pole face. Then as the main flux decreases toward zero, the induced voltage and current in the shading coil reverse their polarity, and the resulting magnetomotive force tends to prevent the flux from collapsing through the iron in the region of the shading coil. The result is that the main flux first rises in the unshaded portion of the pole and later in the shaded portion. This action is equivalent to a sweeping movement of the field across the pole face in the direction of the shaded pole. The cage rotor conductors are cut by this moving field and the force exerted on them causes the rotor to turn in the direction of the sweeping field.

Most shaded-pole motors have only one edge of the pole split, and therefore the direction of rotation is not reversible. However, some shaded-pole motors have both leading and trailing pole tips split to accommodate shading coils. The leading pole tip shading coils form one series group, and the trailing pole tip shading coils form another series group. Only the shading coils in one group are simultaneously active, while those in the other group are on open circuit.

The shaded-pole motor is similar in operating characteristics to the split-phase motor. It has the advantages of simple construction and low cost. It has no sliding electrical contacts and is reliable in operation. However, it has low starting torque, low efficiency, and high noise level.

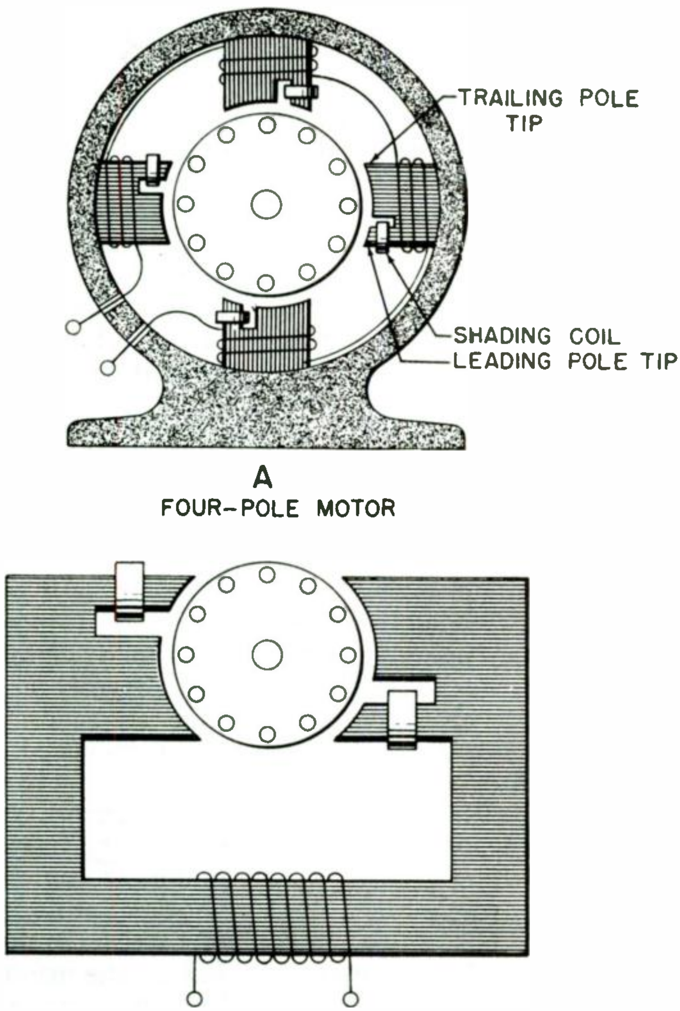


Figure 14 — Shaded-pole motor.

Shaded-pole motors are the most frequently used kind in home style recorders. They are simple to make and have a long, trouble free life.

Capacitor Motor

The capacitor motor is a modified form of split-phase motor, having a capacitor in series with the starting winding. The capacitor produces a phase displacement of currents in the starting and running windings. The starting winding is made of many more turns of larger wire and is connected in series with the capacitor. The starting winding current is displaced approximately 90° from the running winding current. Since the axes of the two windings are also displaced by an angle of 90°, these conditions produce a higher starting torque than the shaded-pole motor. The starting torque of the capacitor motor may be as much as 350 percent of the full-load torque.

If the starting winding is cut out after the motor has increased in speed, the motor is called a CAPACITOR-START MOTOR. If the starting winding and capacitor are designed to be left in the circuit continuously, the motor is called a CAPACITOR-RUN MOTOR. Electrolytic capacitors for capacitor-start motors vary in size from about 80 microfarads to 400 microfarads for large motors. Capacitor motors of both types are made in sizes ranging from small fractional horsepower motors up to about 10 horsepower. The direction of rotation of the capacitor motor may be reversed by interchanging the starting winding leads.

Synchronous Motor

The second type of motor used in tape recorders is the synchronous motor. In the synchronous motor the armature rotor travels at exactly the same rate of speed as the magnetic field. With the exception that the shaded-pole principle is not used (either the series capacitor or high inductance winding is common), the stator or pole structure is exactly the same as in an induction motor. The difference lies in the speed of the armature.

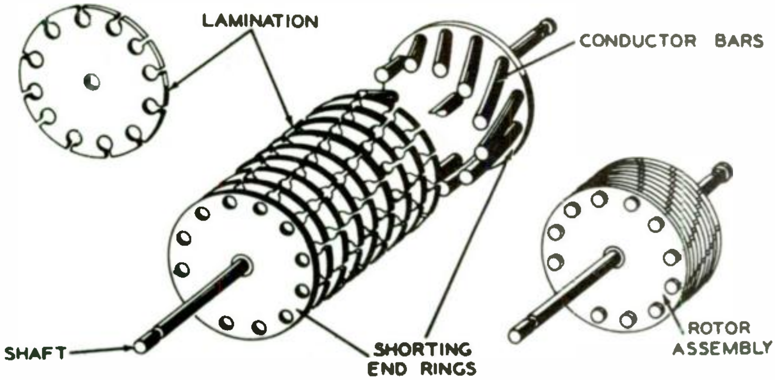
A synchronous motor, true to its name, runs at an exactly synchronous speed. If the magnetic field of the stator is rotating at 1,800 rpm, the armature also will rotate at exactly 1,800 rpm.

Synchronous armature speed is achieved by two methods. In the salient-pole synchronous motor illustrated in Figure 15B the armature is exactly the same as in an induction motor, using the same type of core structure that supplies torque. However, as shown in the comparison of the two armatures in Figure 15A and B the armature is milled with flat spots on it. As the motor comes up to speed, these flat spots will lock into the rotation of the magnetic field. Thus, an easier path for the magnetic field is supplied through one side of the armature than the other. The armature will tend to follow the magnetic field exactly rather than slip behind it, thereby running at synchronous speed.

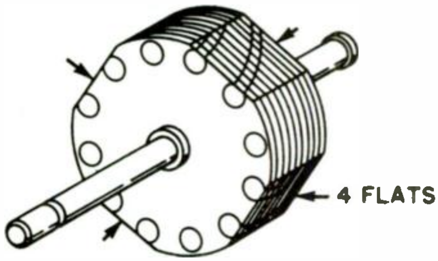
The other type of synchronous motor, the hysteresis synchronous
10 motor, is commonly used in present-day professional-type recorders. In a hysteresis synchronous motor, the armature is surrounded by a thin ring of magnetically hard material (Fig. 16), which becomes highly magnetized. As the motor comes up to speed, the rotating flux of the last cycle, before locking into synchronization, will magnetize one end of the armature north and one end of the armature south. These poles will lock in with the rotating magnetic field, and the motor will run at synchronous speeds.

CARTRIDGE TAPE

The cartridge tape player has become popular in automobiles for



A - Induction motor.



B - Salient-pole synchronous motor.

Figure 15 — Construction of rotors.

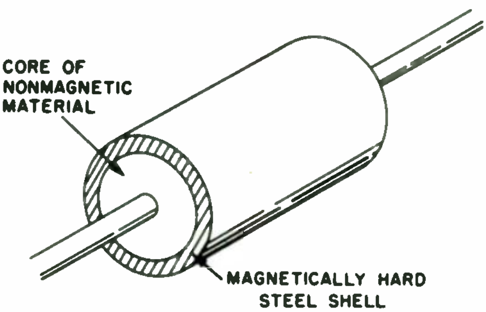


Figure 16 — Rotor of a hysteresis synchronous motor.

the person who wants to choose the music he listens to (Fig. 17). The cartridge player uses a continuous tape and may have 4 or 8 recorded tracks. An automatic track shift is normally a part of the tape machine so that the music is continuous from one set of tracks to the next. Two tracks are required for each pass in order to have stereo reproduction.

Continuous-Loop Cartridge

A continuous-loop cartridge is a tape container in which the tape is removed from the center of a roll (Fig. 18), fed past the tape head, and then taken up on the outside of the same roll. This eliminates the need for takeup and feed reels and makes it unnecessary to rewind the tape for reuse. After the tape plays through once it is ready to start at the beginning again.

When power is applied to the cartridge player, the motor starts turning. A pulley on the motor

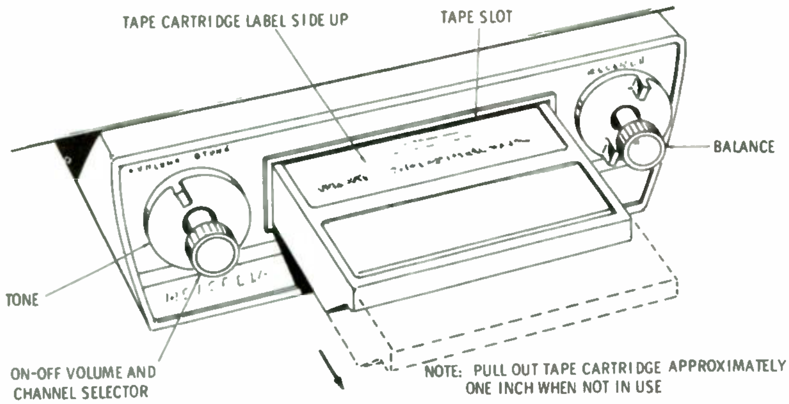


Figure 17 — Tape player with motor actuated by plug-in cartridge.

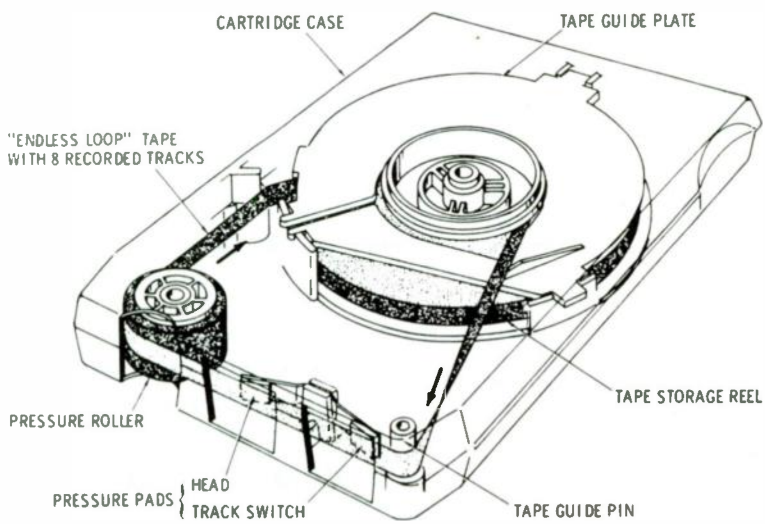


Figure 18 — An 8-track cartridge with pressure roller built into cartridge.

shaft runs a drive belt (sometimes a double one). The drive belt turns a large speed-damping flywheel. And, usually, on top of that is a shaft called the *capstan*. The pressure roller holds the tape in contact with the capstan; as the capstan turns, the tape is pulled from the cartridge.

Operation of the tape cartridge is sketched in Figure 18. The tape unwinds at the center, next to the hub of the cartridge. The capstan and pressure roller pull it around the guide and past the pickup head. Pressure pads keep the tape held smoothly against the head. The magnetic gaps and pickup coils inside the head sense the magnetization on the oxide of the tape.

As the hub of the cartridge turns, unwinding the tape, it also turns the whole spool of tape in the cartridge. The circular motion winds the tape up again on the outside of the spool. That continuous movement of the tape, cartridge, and hub suggest why the cartridge is called an endless-loop or continuous-loop type. As fast as the unplayed tape is unwinding from the hub, the played tape is rewinding onto the spool. There's no end.

TAPE AMPLIFIERS

There are two ways to have tape music in an automobile. One is to have the tape player built into a radio as an integral part of the radio. In this method the radio is usually a multiplex-FM unit which already has two sets of amplifiers and speakers. The other method is to have a separate tape transport and twin amplifiers with speakers.

Tape Preamps

Figure 19 shows one type of preamp that can be used in an auto radio to amplify the magnetic tape head output sufficiently to drive the audio circuits of a radio. This preamp uses NPN silicon transistors in a direct-coupled circuit. One feedback circuit is used for bias stabilization and another audio feedback circuit for tilting the response of the amplifier to compensate for frequency losses in the tape head.

The DC bias stabilization is provided by the connection between the emitter of Q2 through the 270K resistor to the base of Q1. Audio degeneration is prevented because of the 30-mfd emitter bypass capacitor for Q2.

The audio feedback circuit for proper tilt of the amplifier amplification curve is the 4.7K resistor from the collector of Q2 back through the .022-mfd capacitor to the emitter of Q1. This is a degenerative circuit providing apparent

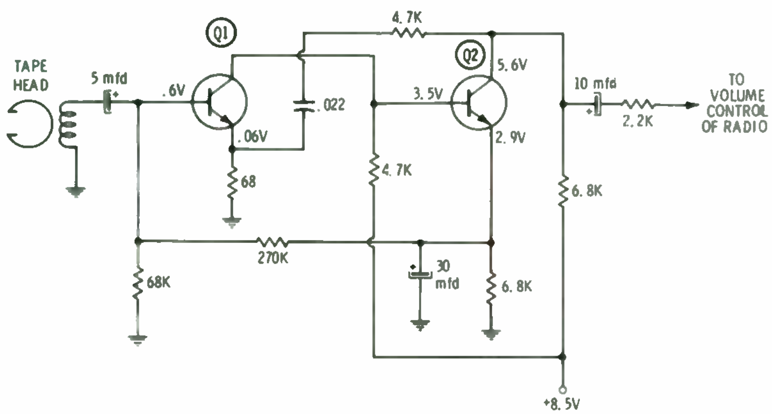


Figure 19 — A preamp used on radio and tape player combination.

improvement in low-frequency response by reducing the high-frequency response of the amplifier.

A COMPLETE TAPE AMPLIFIER

Figure 20 is a complete tape amplifier. Two of these amplifiers, almost always identical, are used in complete cartridge stereo playback units. There is usually some interconnections between the two amplifiers such as a balance adjustment to make sure that the volume of both amplifiers is the same. There may also be some interconnected stabilization circuits. Sometimes a "neutralizing" circuit, which helps to cancel crosstalk (or apparent crosstalk), is included between the two amplifiers.

The amplifier in Figure 20 is all germanium transistors. It could just as easily be all silicon or part silicon and part germanium. Whatever kind of transistors are used the essential theory of operation is about the same.

This amplifier uses a preamp similar to the one discussed earlier, which was a direct-coupled driver amplifier driving a transformerless output circuit. Thermistors are used in the output transistor bias circuit to compensate for changes in heat. The speaker is coupled to the output circuit through a 1000-mfd capacitor. Small 0.33-ohm resistors in the emitters of the output transistors are "safety valves" that will open up should either of the output transistors short or the current becomes excessive for any other reason.

CASSETTES

Modern tape recorders use various types of magnetic-type packages. The conventional reel-to-reel arrangement has been supplemented by cartridges and cassettes that simplify machine operation. Cartridges and cassettes are also more compact than the reel-to-reel method. Although the terms are often used interchangeably, a cassette is a tape package that contains a compact reel-to-reel assembly, while a cartridge is a tape package that employs a single reel. The basic features of these arrangements are shown in Figure 21.

Figure 22 shows the main technical features of a cassette. As the tape leaves the reel which is operating as a supply reel, it travels past a tape guide, or idler, and then proceeds past the pressure pad and the tape head. The tape continues between the capstan and pinch roller, over the second tape-guide idler, and then to the second reel, which is acting as a take-up reel. At the end of play, the cassette is flipped over to complete the other two tracks. Cassettes have a safety feature consisting of a pair of plastic tabs on the rear of the package. After these tabs are removed, the tape cannot be erased because a safety interlock is automatically activated. However, if it is desired to erase the tape and record it over, the openings can be covered with adhesive tape or equivalent to defeat the interlock. Cassette tapes are merchandised in 300-, 450-, and 600-foot lengths. A 300-foot tape provides an hour of playing time—30 minutes on each side. The longer

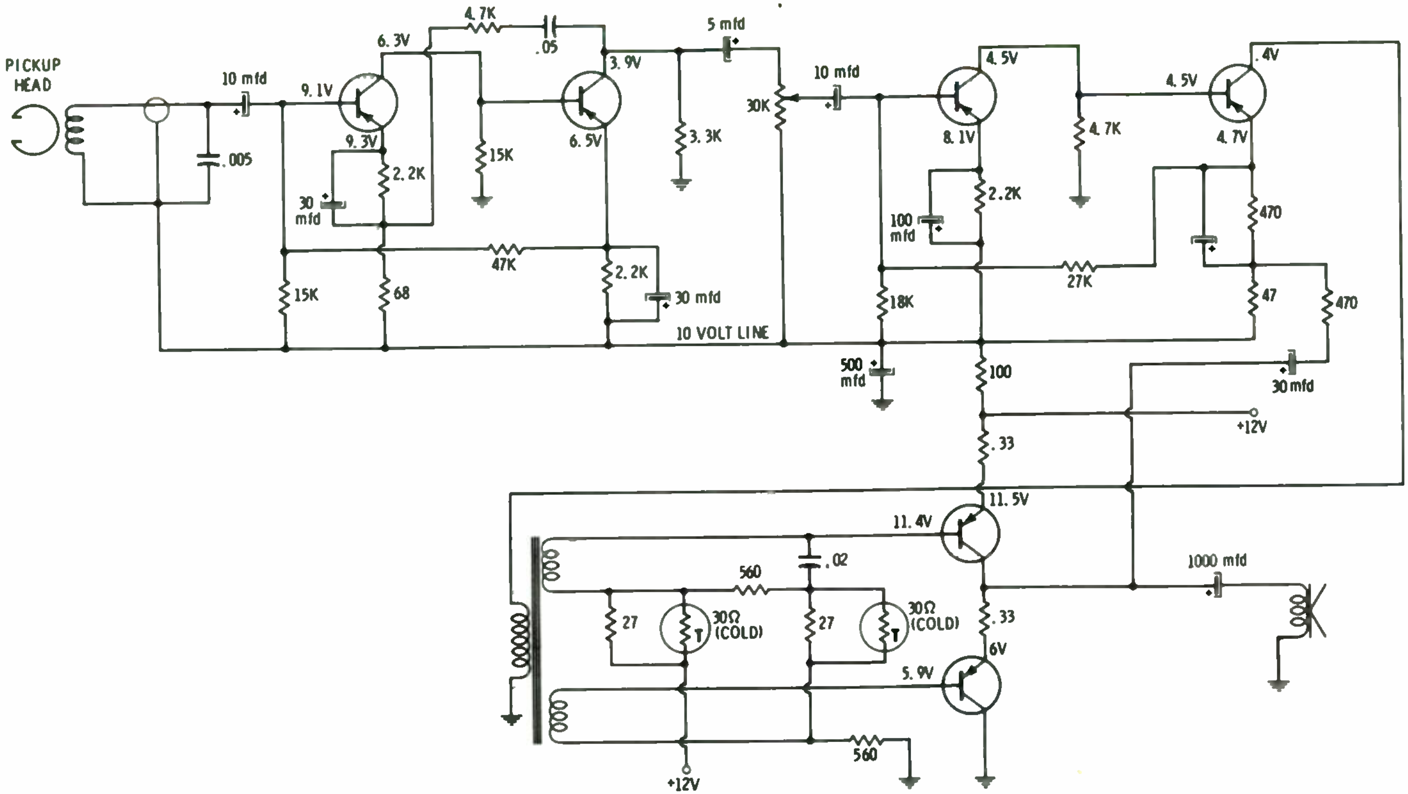
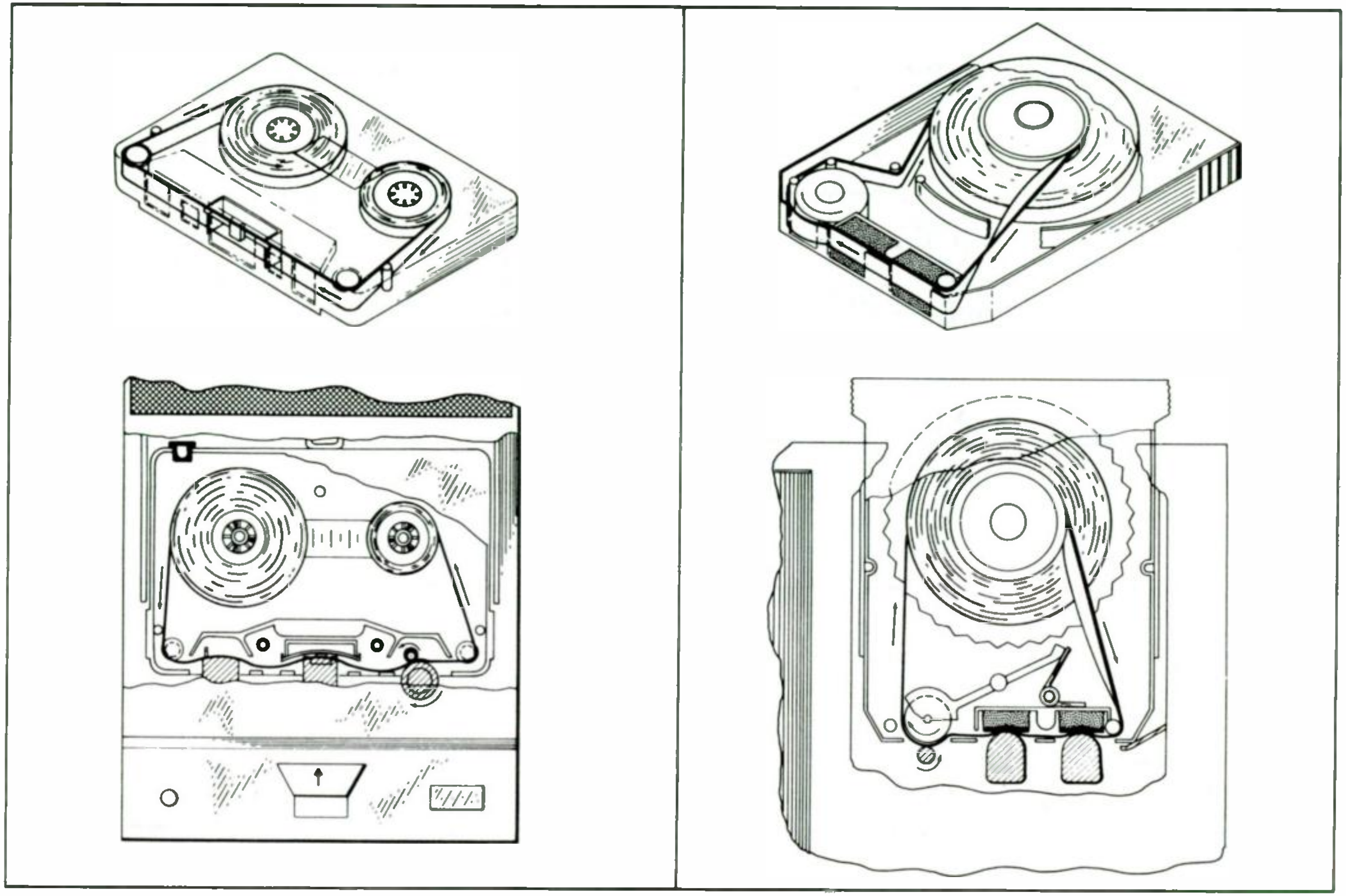


Figure 20 — Schematic of one channel of auto stereo system.



A A cassette is a unitized reel-to-reel tape package.

B A cartridge contains a single reel with specialized construction.

Figure 21 — Cassette and cartridge construction.

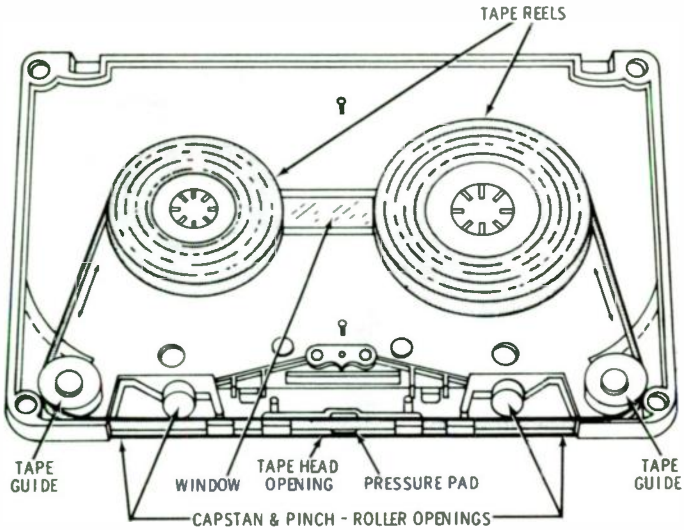


Figure 22 — Principal features of a cassette.

tapes provide proportionally longer playing times.

BASIC RECORDER CIRCUITRY

A microphone provides a comparatively weak signal—in the order of a few millivolts—so an amplifier is required to step up the microphone signal before it is fed to the recording head. Similarly, a playback head provides a comparatively weak signal—in the order of 8 millivolts (0.008 volt). Accordingly, an amplifier is required to increase the reproduced signal before it is fed to a speaker. In the case of a stereo unit, two identical amplifier channels are provided.

The lowest-priced tape recorders employ from three to five transistors. The most common troubles in these units are distortion, low volume, or no sound. Low volume can be the result of a weak power supply, leaky capacitors, or defective transistors. If a push-pull output stage is used, one defective transistor will cause low volume and/or distortion.

The most widely used arrangement employs a record/playback head and an erase head. Professional recorders, however, may employ separate record, playback, and erase heads. In turn, the electronics are necessarily elaborated to accommodate the separate record and playback heads. In any arrangement, stereo facilities almost double the number of electronics components, compared with a mono unit. There is a trend to the employment of combination heads, such as illustrated in Figure 23. This design is also called a triple-action head. It contains record/playback and erase facilities in a single housing; the unit illustrated is designed for a stereo recorder.

Figure 24 shows the bias-oscillator, and power-supply schematic

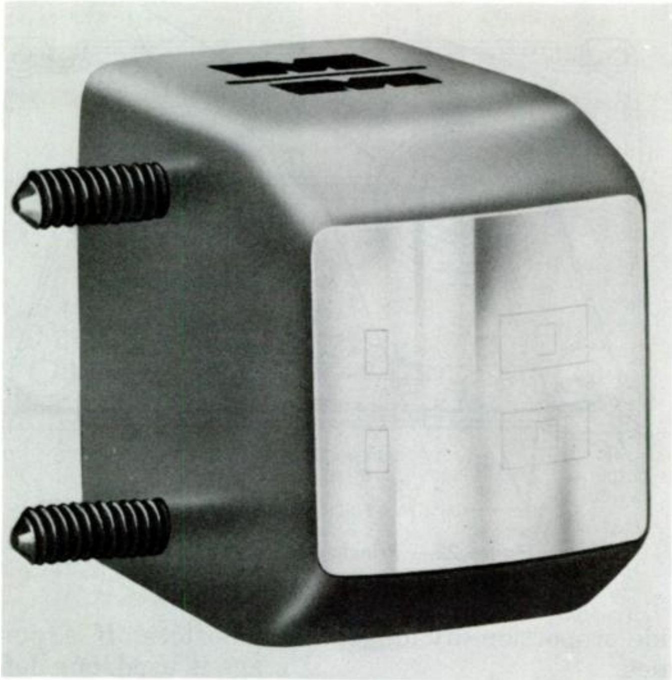


Figure 23 — A combination head that records, plays, and erases.

for a comparatively elaborate recorder that employs a combination head. This machine uses a total of 14 transistors and 7 diodes. There are many more adjustments provided on this type of recorder than on an economy-type. Details of basic adjustment procedures are covered in a later lesson.

In this arrangement, after the end of the tape passes the head, the unit will automatically reverse the direction of tape travel. This action occurs when the sensing foil reaches the left sensing poles (S14). The unit will automatically shut off when the sensing foil at the beginning of the tape reaches the right sensing poles (S13).

The oscillator in the recorder (Fig. 24) is a push-pull circuit with a tapped transformer. The collectors of Q13 and Q14 are connected to opposite ends of transformer L1 while their bases receive feedback from taps 2 and 4. A separate winding (the secondary winding 6, 7, and 8) supplies bias signal to the heads.

Many other circuit configurations are used for bias oscillators. Some employ only one transistor or tube while others may use two transistors or tubes in a cross coupled, multivibrator arrangement.

TAPE RECORDER ELECTRONICS

The electronics associated with different tape recorders may have vast differences in circuitry but

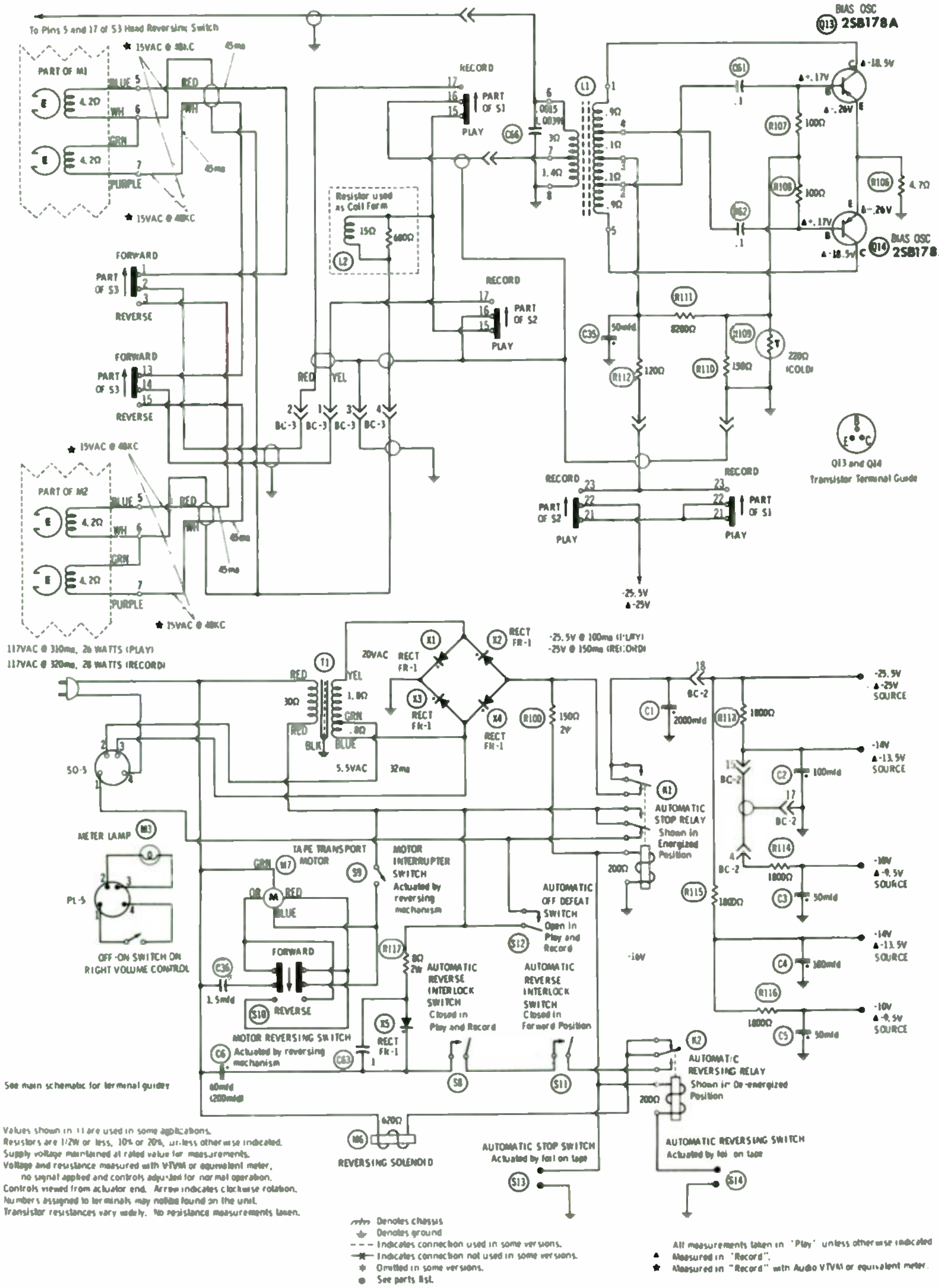


Figure 24 — Bias-oscillator and power-supply for a recorder with a combination head.

they will have many similarities in function.

All tape machines will play back information that is recorded at their speed capability on compatable tape. For this function a high gain amplifier is required to increase the small signal from the playback head to the level required to operate a speaker. If the playback machine is a stereo unit, a dual channel amplifier is then required; one channel each for the right and left channel information.

Playback/record machines require the addition of a bias oscillator. An ultrasonic signal is generated by the bias oscillator and mixed (in the record head) with the audio signal being recorded. The presence of this bias signal is necessary on the tape to provide the correct amount of magnetic intensity for the different levels being recorded.

Diagram 1 from your *Diagram Envelope* is the schematic of a high quality tape recorder manufactured by 3M Wollensak. All circuitry shown in red with associated voltages apply during the record mode.

Blue line sections and components are active during playback. The black line portions apply to both functions.

The bias oscillator section appears in the lower right of Diagram 1. It consists of transistors Q_7, Q_8, and associated components. Capacitors C_{18} and C_{20} provide the cross coupling to sustain oscillation. Signal from the collectors is applied to transformer T_1. This transformer supplies bias signal to both the record and erase heads. Bias is interrupted in the playback mode. This is accomplished when voltage to the bias oscillator is interrupted through switch contacts 10 and 11.

The final stage of the amplifier (Q_5 and Q_6) drives the speaker during playback. During record this stage supplies amplified audio to the record head. The following description of the amplifier's function is reprinted through the courtesy of 3M Wollensak from their service manual.

AMPLIFIER CIRCUIT DESCRIPTION

The amplifier is conventional except for the transformerless output which is a complementary symmetry system. It also includes an Automatic Record Level section. The amplifier contains the following stages:

Q1	1st Preamplifier
Q2	2nd Preamplifier
Q3	Pre-driver
Q4	Driver
Q5	Output
Q6	Output
Q7	Oscillator
Q8	Oscillator
Q9	Detector Stage
Q10	ARL Control
Q11	ARL Preamplifier

The first two stages, Q1 and Q2, are conventional stages of preamplification with Q3 as a pre-driver stage. Q4 is a driver for the output stage. The Q5, Q6 pair are the complementary symmetry push-pull output which uses neither a driver transformer nor an output transformer. The output from Q4 is fed to the bases of Q5 and Q6 (thru a 39 Ω resistor to Q5). Q5, being an NPN and Q6 a PNP transistor, allow only one transistor to conduct at one time depending upon the polarity of the half cycle signal from Q4. The positive half cycle signal at the collector of Q4 causes Q5 to conduct and Q6 to turn off. The negative cycle half cycle signal at Q4 collector causes Q6 to conduct and Q5 to cut off.

The Automatic Record Level Circuit consists of Q9, Q10, and Q11. The signal from the second preamplifier stage feeds Q9 and Q11 (Q11 thru a voltage divider formed by R44, 45, and CR5). The signal from Q9 emitter follower is rectified by CR4 and charges up C26. The voltage of C26 controls the DC current thru Q10 and CR5. This DC current thru CR5 controls the dynamic resistance of CR5 which maintains a constant AC across CR5 over a wide range of input voltage to the recorder. Q11 is a preamplifier for the small AC signal across CR5.

Playback is possible in the ARL position by means of R54 and R52. However, it is at a fixed volume level.

The following specifications and instructions are reprinted through the courtesy of 3M Wollensak to acquaint you with the actual specifications and instructions applied to a good quality, general purpose tape machine.

SPECIFICATIONS

Supply Voltage	105-120v 60 hertz AC only		
Power Consumption	55 watts (maximum output)		
Tape Capacity/Playing Time	Two track monophonic		
	Tape Length	3-3/4 IPS	7-1/2 IPS
	600'	1.0 Hrs.	0.5 Hrs.
	900'	1.5 Hrs.	0.75 Hrs.
	1200'	2.0 Hrs.	1.0 Hrs.
	1800'	3.0 Hrs.	1.5 Hrs.
	2400'	4.0 Hrs.	2.0 Hrs.
Fast Forward Wind Time	93 seconds 1200'		
Fast Rewind Time	135 seconds 1200'		
Recorder Weight	17.5 pounds		
Output Power	8 watts continuous into 8 ohm resistive load less than 5% total harmonic distortion.		
Frequency Response	40 - 15000 Hz ±3db		
Signal to Noise Ratio	50db ±4db with respect to 3% distortion 1 kHz tape.		

Wow and Flutter	0.25% RMS
Amplifier	Completely solid state
Amplifier Input Sensitivity	0.3 mv 1 kHz mike input = 0 VU 58 mv 1 kHz tuner = 0 VU
Earphone or Extension Speaker Output Load Impedance	4 ohms min - 8 ohms design for maximum efficiency.
Bias and Erase Frequency	95 kHz
Microphone Sensitivity	1 millivolt/millibar 1000 Hz
Microphone Input Impedance	27 k ohms
Tuner Input Impedance	470 k ohms

EQUIPMENT DESCRIPTION

The Wollensak 1520AV is a recorder designed for audio visual use and is suited to all heavy duty applications in education, business, industry, and government. The all solid state half track records at speeds of 7-1/2 and 3-3/4 IPS. This reel to reel recorder uses the full 7 inch reel size with automatic tape shut off. The features of the recorder are the automatic record level on record. The safety features are the circuit breaker and the 3-terminal grounded power cord.

CONTROLS AND CONNECTIONS

Play Key. Starts tape and activates playback circuit.

Record Key. Starts tape and activates recording circuit. Record Lever must be held in while pressing RECORD key to engage circuit.

Stop Key. Stops tape travel from PLAY or RECORD modes, automatically disengaging recording circuits.

High Speed Search Lever. Rapidly moves tape forward or back to rewind or locate a previously recorded portion of tape. Move lever in direction you wish tape to move. To stop, return lever to center position. Lever can be operated from any recorder mode, and moving lever automatically releases PLAY or RECORD keys.

Volume/ARL Control. Controls both recording and playback volume; numbers allow presetting to previously determined level. When set to AUTO, Automatic Recording Level is activated, eliminating need for further adjustment during recording. Control may be left in AUTO position for playback. For manual control of volume, turn dial past AUTO position.

Tone Control/On-Off Switch. Turn clockwise past "click" to turn recorder on, full counterclockwise to turn off. When recorder is off, mechanism cannot be engaged. BASS position of dial provides a mellow tone, cutting highs to minimize any noise, hiss, record scratch.

TREBLE position of dial provides high frequency boost, bringing out musical overtones. Center position provides flat response; this is preferable for playback through auxiliary sound equipment. During recording the Tone Control is inoperative.

Recording Level VU Meter. The VU meter is used in setting optimum recording level when not using the ARL circuit. Best recording results when the Volume Control is adjusted so that the meter needle just touches the red area of the meter on the loudest sounds. If the needle goes into the red area too often, the recording level is too high, producing distorted sound. If the level is too low, playback volume will be limited. When the Volume Control is set on AUTO, the meter only indicates that a recording is being made.

Digital Index Counter And Reset. Counter enables you to quickly locate any point on a tape. When beginning a recording on a new reel of tape, set the counter to "000" by pushing the reset wheel back. As you record various selections, note the counter number at the beginning and end of each selection and keep it on file (the back of the tape box is ideal). To play a particular portion of the tape, thread recorder, set the counter to "000" and using the High Speed Search Lever move the tape until the counter registers the previously noted number.

Instant Stop/Record Lever. During recording or playing, pulling this lever forward instantly stops tape travel. When released, tape instantly starts. Use this lever for noiseless, click-free stops and starts during recording, to momentarily stop the tape during transcribing, or to stop tape for precise editing. This lever is also a safety interlock preventing accidental erasure of previously recorded tapes. It must be held in while pressing RECORD key to engage recording circuits. Lever also provides capability for use of accessory foot control.

Speed Selector. Push selector back for 7-1/2 IPS, toward front for 3-3/4 IPS. For speech recording and the majority of music, 3-3/4 IPS will provide excellent results, as well as maximum time from a given length of tape. The 7-1/2 IPS speed is recommended for the highest fidelity and widest frequency response, particularly for music to be played back through an auxiliary sound system. Use of the 7-1/2 IPS speed will also speed up rapid forward winding.

Automatic Tape Shutoff. Automatically shuts off recorder when end of tape passes out from between post and pin. To operate, thread tape between post and pin with pin in threading position, then gently push pin against tape. To turn recorder on after automatic shutoff, pull pin away from post and latch into open position. To operate tape without automatic shutoff feature, pull pin back away from post until it latches.

Microphone Storage. New 1520AV lid design provides improved microphone storage. Place dynamic microphone in the lid support.

All *input and output* jacks accept standard phone plugs.

Radio-Phono Input. For recording high-level signal from radio, phono, TV, P.A. or Hi-Fi Amplifier, etc.

Microphone Input. For hi-impedance dynamic microphone.

Accessory Amplifier Output. Applies signal from recorder playback preamp to an auxiliary amplifier (P.A., Hi-Fi, etc.)

Earphone-Speaker Output. Supplies signal from recorder amplifier to 8-ohm extension speaker or to any type of headphones for private monitoring. A plug in this output automatically silences the speaker in the 1520AV.

Speaker Switch. Controls output of recorder's speaker during recording only. OFF position disconnects speakers, preventing acoustic feedback during microphone recording. ON position allows you to monitor recording being made through recorder's speaker. During playback switch is inoperative.

Reset Button. The 1520AV has a circuit breaker instead of a fuse. If an abnormal power line surge causes the recorder to become inoperative, push button in to restore circuit. If electrical trouble persists, determine source of trouble before continuing operation.

AC Connection. For 3-wire grounded power cord. Operates on 105-120 volts, 60 hertz, AC ONLY.

Figure 25 shows path of tape for

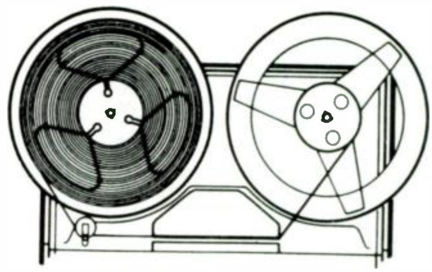


Figure 25 — Tape threading procedure. Courtesy of 3M Wollensak.

recording or playback. Always place full reel on left spindle, empty reel on right. Tape must be threaded so that duller, oxide-coated side faces in and contacts the heads. To thread recorder, place a full reel of tape on the left spindle, a matching size empty reel on right spindle. Set Automatic Shutoff Pin in THREADING position. Place tape between post and pin of Automatic Shutoff and hold taut in line with threading slot, then lower into place.

Included with your tape recorder is a "Scotch" Brand Self-threading Reel for use as a take-up reel (Fig. 26). Simply place tape alongside the reel hub, start recorder, and reel threads automatically.

NOTE

For continued cool operation of recorder, be sure unit is placed on hard flat surface when operating so that air passage is not blocked.

Make desired playback hookup as illustrated.

Turn on recorder.

Thread recorder.

Set proper tape speed.

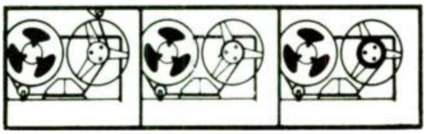


Figure 26 — Attaching tape to reel. Courtesy of 3M Wollensak.

Set Index Counter to "000" by turning Reset wheel.

Begin playback by pressing PLAY key firmly until it engages.

Adjust Volume and Tone controls for desired sound (Volume Control may remain in AUTO if desired).

When finished, press STOP key.

Playback Through Recorder. Your recorder is completely self-contained for playback, and no additional equipment or hookups are required. The solid-state 9-watt amplifier and wide range speaker provide sufficient volume for a large classroom or meeting room.

Playback Through Headphones. Any monophonic headphone with a standard phone plug may be used. Any impedance headphone is satisfactory, although 600-ohm is most satisfactory. The Wollensak Headphone A-0483 is ideal. Plug phone jack into Earphone-Speaker output automatically silencing recorder's speaker. Control volume and tone with recorder's controls.

Playback Through Extension Speaker. Connect alligator clips of Attachment Cord to terminals of extension speaker (nominal impedance is 8 ohms; 4 or 16 ohm speakers may be used with slight loss of efficiency). If clip cannot be held firmly, tape over each clip to prevent their accidentally touching. Plug Attachment Cord phone plug firmly into Earphone-Speaker Output: this automatically silences recorder's speaker. Control volume and tone with recorder's controls.

Playback Through Radio-Phono. Using a Hi-Fi Cable, connect the phone plug to the recorder's Accessory Amplifier output. Connect the other end of the auxiliary input jack of the radio or phono (if jack requires a different plug, accessory jack converters are available). Set recorder's Tone Control to center position and use volume and tone controls on radio or phono to adjust final sound. Recorder's speaker output can be controlled independently by recorder's Volume Control, allowing it to be turned all the way down or to play along with the radio-phono speaker.

Using a Hi-Fi Cable, connect the phone plug to the recorder's Accessory Amplifier output. Connect the other end to the "Tape", "Aux", "Spare" or other high-level input of the amplifier (if jack requires a different plug, accessory jack converters are available). Do *not* plug into a "Tape Head" input. Set recorder's Tone Control to center position and use volume and tone controls on amplifier to adjust final sound. Recorder's speaker output can be controlled independently by recorder's Volume Control, allowing it to be turned all the way down or to play along with the auxiliary system speakers. Playback through a quality sound system provides the fullest response, lowest distortion and highest fidelity sound your tape recordings are capable of reproducing.

RECORDING

Make desired recording hookup as illustrated.

Turn on recorder.

Thread recorder.

Set to desired recording speed.

Set Index Counter to "000" by turning Reset wheel.

Pull and hold in Instant Stop/Record Lever, then firmly press RECORD key until it engages.

Set Volume Control to AUTO or adjust to proper meter level, then release Record Lever to begin recording.

When finished, press STOP key, automatically taking recorder out of record mode.

You can monitor your recording through the recorder's speaker with the rear panel Speaker Switch in ON position (do not monitor through speaker during microphone recording).

NOTE

Previously recorded tapes are automatically erased as a new recording is being made. Tape can be erased and recorded indefinitely without any loss of quality. Erasing occurs only when the RECORD key is depressed, erasing the signal as the tape passes the heads.

Your 1520AV has an Automatic Recording Level feature which allows the production of high-quality, low-distortion recordings without any Volume Control adjustments. To activate the ARL circuit, turn the Volume Control counterclockwise so that it "clicks" into the AUTO position. For manual volume control, turn dial clockwise past the "click" and adjust for optimum recording level using the Record Level VU Meter. During playback control may be left on AUTO or turned past "click" to adjust for desired volume.

Inexperienced users will normally make better recordings by using the Automatic Recording Level feature rather than the manual volume control. The experienced recordist may choose between ARL and manual control, depending upon the material being recorded. When recording live, unfamiliar program material,the ARL will adjust for program peaks more quickly and accurately than any operator can do manually. When recording material with a pre-established sound level (radio programs, records, etc.) manual volume control is preferred to keep the quiet passages in the proper relationship to loud passages. The expert recordist will normally use manual volume control when possible, and will find the ARL feature a definite aid to better quality recordings when the machine must be used unattended.

Two-Track Recording

Your 1520AV is a two-track monophonic recorder allowing you to record on both the top and bottom halves of the tape. Note that "Scotch" Brand reels are marked Side 1 and Side 2. When you are recording on a new reel of tape, place both the full and empty reels with Side 1 up. After you have completely recorded on this half of the tape, interchange the reels so that the empty reel is on the right spindle and the full reel is on the left spindle, with Side 2 of the reels up. Thread tape as instructed on page 26, and you can now record on the other half of the tape. Follow the same procedure for playing back two-track recordings.

Recording From Microphone

Insert Microphone plug firmly into Microphone Input jack. Set Speaker Switch to OFF to disconnect recorder's speaker and prevent acoustic feedback. Set Volume Control to AUTO to utilize Automatic Record Level circuit. For manual volume control, turn dial past AUTO and adjust using VU meter. If you wish to monitor a microphone recording, connect headphones to the Earphone-Speaker output and place Speaker Switch in ON.

Recording from Radio/Phono TV Speaker

CAUTION

If appliance from which you intend to record is of the enclosed "hot" chassis AC-DC type, or has an interlocked panel, plug the appliance into an isolation transformer to avoid possibility of shock.

Using Attachment Cord, insert phone plug into Radio-Phono Input. Connect alligator clips to speaker terminals. Adjust volume of appliance to normal listening level, then make final adjustments with recorder's Volume Control. If appliance loses volume, reverse clips on speaker terminals.

Recording From Amplifier or Tuner

Using a Hi-Fi Cable, connect the phone plug to the Radio-Phono Input of the recorder. Connect other end to Tape Output jack of amplifier or tuner. Adjust amplifier or tuner volume to normal level and any tone control to center, then switch to AUTO or make final recording level adjustments with recorder's Volume Control.

Recording From Another Tape Recorder

To duplicate tapes, use a suitable cable to connect the Accessory Amplifier (preferable) or Extension Speaker output of the playing recorder, such as a 1520AV, to the Radio-Phono Input of another 1520AV. Adjust the volume on the playback recorder to a normal listening level, set tone control to center, then make necessary recording level adjustments with the Volume Control of the 1520AV or set to AUTO.

SUMMARY

In the two lessons relative to tape recorders a brief history of magnetic recording has been presented along with the basic principles of recorder functions. You have learned that tape recorder repair is less involved than color TV and in many instances B/W repair because recorders are basically simple machines.

A tape recorder functions when coated plastic tape is pulled past record, playback and erase heads. The coating consists of magnetic oxides. The assembly responsible for this action is called the tape transport mechanism. This mechanism is in turn a part of the motorboard which comprises all mechanical and power functions.

The heads in a tape recorder serve three purposes. They interpret magnetic variations on the tape, record magnetic impression onto the tape and erase existing information.

An amplifier (similar to a Hi-Fi amplifier) boosts feeble audio signals before applying them to the head. The same amplifier also boosts the signal from the playback head before presenting it to the speaker.

A high frequency AC bias signal is applied to the tape during recording to normalize nonlinear response to different frequencies. The same bias frequency is also used to demagnetize and erase the tape.

Cartridge and cassette machines were developed to ease the loading operation. The development of these machines made tape recording and playing a pop-in operation.

Cartridges are single reel packages that feed from the outside of a spool and wind to the center during playing of a set of tracks. The process is then reversed for playing the next set. Cartridge players are widely used in automobiles.

Cassettes consist of two reels contained in a drop-in package. They are widely used in steno work and in education. The market for tape machines is constantly expanding as new uses are being found. In tape recorder servicing, profitable opportunities are almost unlimited for the alert service man with good mechanical aptitude and some electronic knowledge.

TEST

Lesson Number 75

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-075-1.

1. **The most critical part of a tape recorder is/are the**
   A. motor.
   B. drive assembly.
   C. amplifier.
   D. heads.

2. **The head that magnetizes audio information onto the tape is called the __________ head.**
   A. playback
   B. record
   C. erase
   D. stereo playback

3. **The head that causes magnetic impulses on the tape to become audio signal currents is called the __________ head.**
   A. playback
   B. record
   C. erase
   D. stereo record

4. **The head that removes unwanted information from tape is called the __________ head.**
   A. playback
   B. record
   C. erase
   D. stereo record

5. **Electric motors operate from**
   A. electromagnetic attraction and repulsion.
   B. heat generated from an electromagnetic field.
   C. electrostatic attraction and repulsion.
   D. heat generated from an electrostatic field.

6. **DC motors contain**
   A. shaded poles.
   B. a capacitor for starting.
   C. brushes and a commutator.
   D. four shaded poles.

7. An AC motor that uses a copper ring around a portion of a pole piece is called a __________ motor.

A. synchronous
10 B. shaded-pole
C. brush-commutator
D. capacitor-start

8. An electric motor that relies on line frequency rather than voltage for speed is called a __________ motor.

A. synchronous
B. shaded-pole
C. brush-commutator
D. variable speed

9. The most commonly used motor in home tape recorders is the __________ motor.

A. synchronous
11 B. shaded-pole
C. brush-commutator
D. variable speed

10. Professional grade tape recorders use mostly __________ motors.

A. hysteresis-synchronous
12 B. shaded-pole
C. brush-commutator
D. multiphase

Notes

Notes

Portions of this lesson from
Tape Recorders How They Work
by Charles G. Westcott & Richard F. Dubbe
Auto Radio Servicing Made Easy
by Wayne Lemons
1-2-3-4 Servicing Automobile Stereo
by Forest H. Belt & Associates
Tape Recorder Servicing Guide
by Robert G. Middleton
Courtesy of Howard W. Sams, Inc.

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YOUR STUDY HABITS

Find the time and place that work best for you . . . and then study on a *regular* schedule. Two hours of serious, concentrated study are worth more than four hours of study with one eye on the television set.

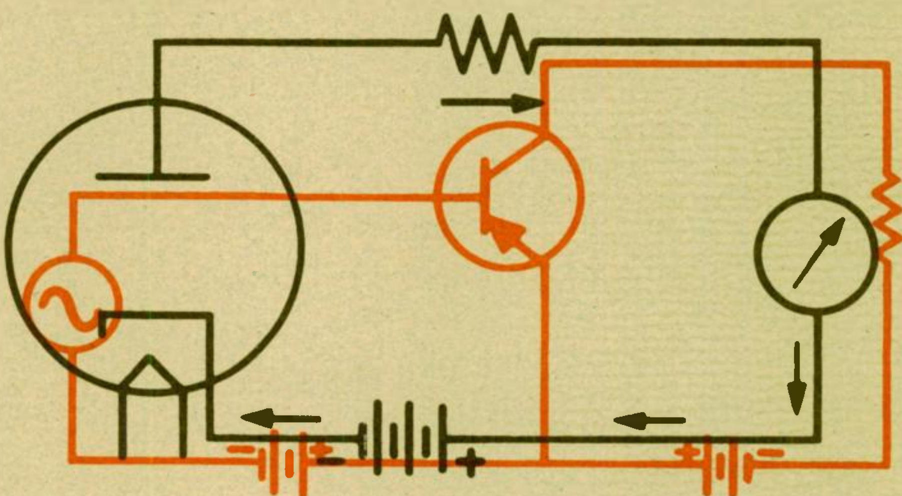
When you study also makes a difference. Some students prefer to study in the early evening hours; others study in the late evening when it is quieter and there are less distractions. If you are too tired at night to really work on your lessons, try getting up an hour or two earlier in the morning to do your studying when you are fully refreshed.

Plan ahead so that you will get maximum benefit from the time you spend on your lessons. Remember, study time is always time well spent, as YOU are the one who benefits from it. The knowledge you gain is yours and can never be taken from you.

S. T. Christensen

LESSON NO. 76

TAPE RECORDER REPAIR



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-076
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Contents

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52-076

TAPE RECORDER REPAIR

RECORDER CIRCUITRY

A microphone provides a comparatively weak signal—in the order of a few millivolts—so an amplifier is required to step up the microphone signal before it is fed to the recording head. Similarly, a playback head provides a comparatively weak signal—in the order of 8 millivolts (0.008 volt). Accordingly, an amplifier is required to increase the reproduced signal before it is fed to a speaker. Figure 1 shows a block diagram of the electronics for a typical tape recorder. This arrangement is for a monaural unit. In the case of a stereo unit, two identical amplifier channels are provided.

Figure 2 shows a complete amplifier and bias oscillator schematic for a small recorder. Although the tape-transport motor is DC operated in this example, many recorders use AC operated motors. The lowest-priced tape recorders employ from three to five transistors. The most common troubles in these units are distortion, low volume, or no sound. Low volume can be the result of a weak power supply, leaky capacitors, or defective transistors. If a push-pull output stage is used, one defective transistor will cause low volume and/or distortion.

The configuration of Figure 2 employs a record/playback head and an erase head. This is the most widely used arrangement. Professional recorders however, commonly employ separate record, playback, and erase heads. In turn, the electronics are necessarily elaborated to accommodate the separate record and playback heads. In any arrangement, stereo facilities almost double the number of electronics components, compared with a mono unit. There is a trend to employment of combination heads, such as illustrated in Figure 3. This design is also called a triple-action head. It contains record/playback and erase facilities in a single housing; the unit illustrated is designed for a stereo recorder.

Diagram 2 (from your *diagram envelope*) shows a complete amplifier, bias-oscillator, and power-supply schematic for a comparatively elaborate recorder that employs a combination record/play head. This machine uses a total of 19 transitors and 5 diodes. Many more adjustments are provided on

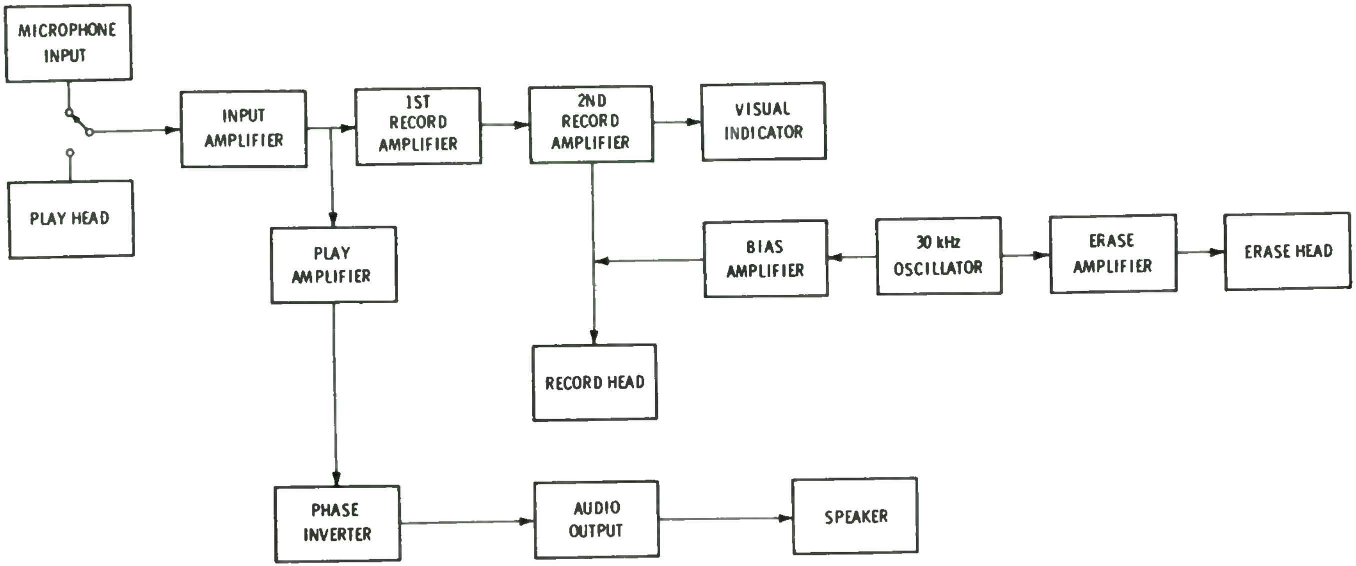
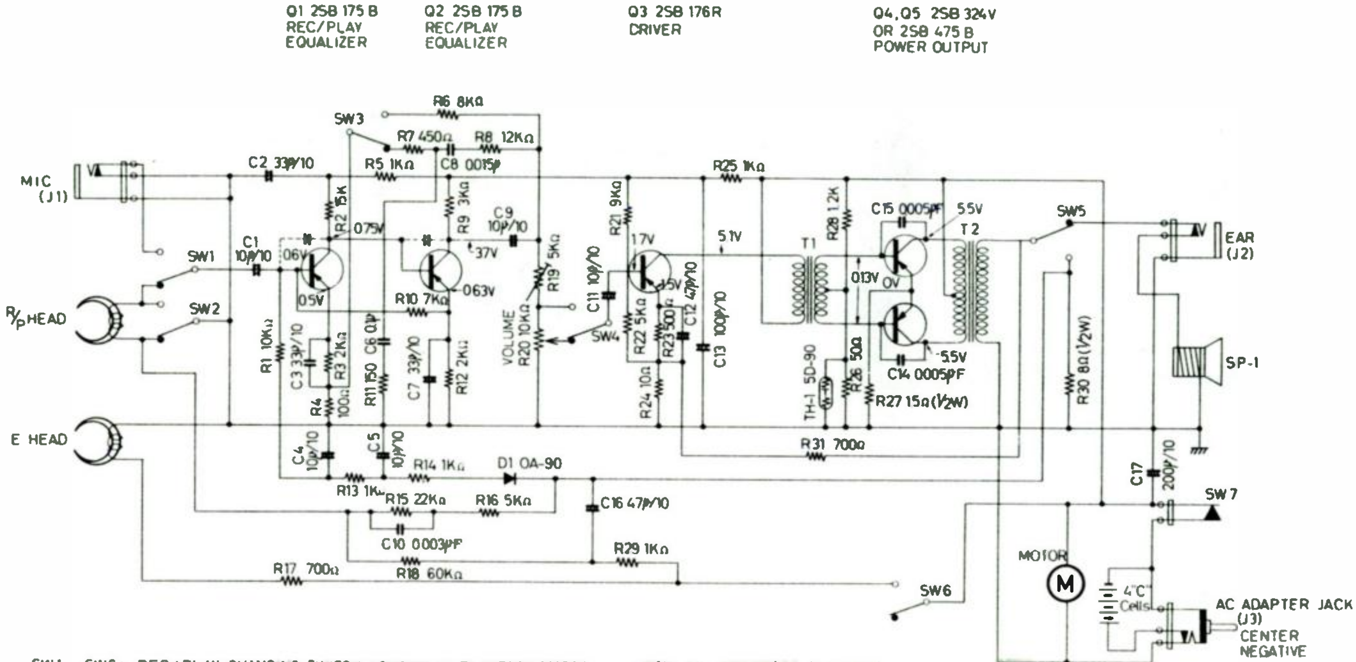


Figure 1 — Block diagram of tape-recorder electronics.



SW1 – SW6 REC/PLAY CHANGING SWITCH (SHOWN IN PLAYBACK MODE)
SW7 LEAF SWITCH (ON - OFF)

NOTE: ALL RESISTORS ⅛ W ±10% UNLESS OTHERWISE NOTED.
VOLTAGES TAKEN WITH DC VTVM AND IN PLAYBACK MODE.

Figure 2 — Amplifier section of a popular portable tape recorder.

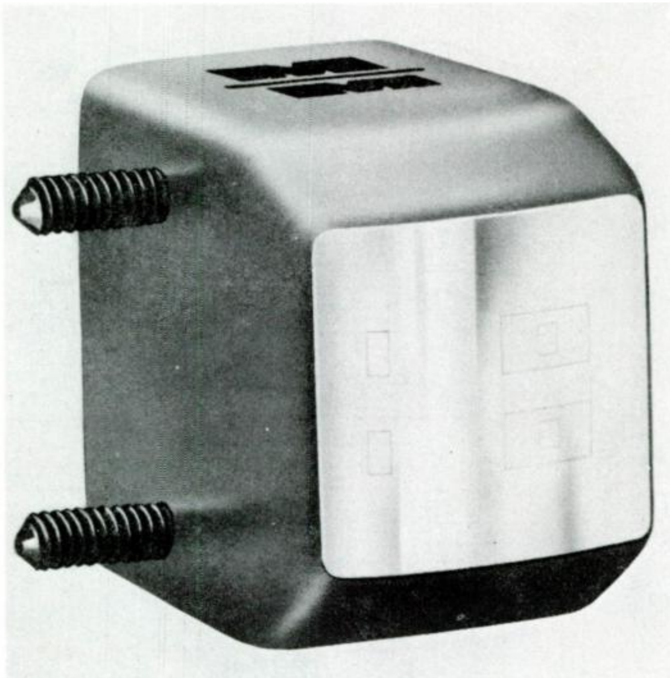


Figure 3 — A combination head that records, plays, and erases.

this type of recorder than on an economy-type machine.

The amplifier shown in Diagram 2 is from a stereo record/playback machine. Combination R/P heads are used for each channel with separate erase heads.

The single-transistor (Q_{11}) bias oscillator uses a tapped winding on transformer (T_4) to supply feedback to sustain oscillation. Its secondary (1,5) supplies bias signal to the record and erase heads.

A dual channel amplifier with transformerless output is used for audio. The output stages are driven from dual secondary interstage transformers T_2 and T_3.

Speakers and phone jacks are coupled to the amplifier through capacitors C_{74} and C_{75} during playback. In the record mode the amplifier boosts audio signals from microphones, phono cartridges, a radio or other source and applies them to the record heads.

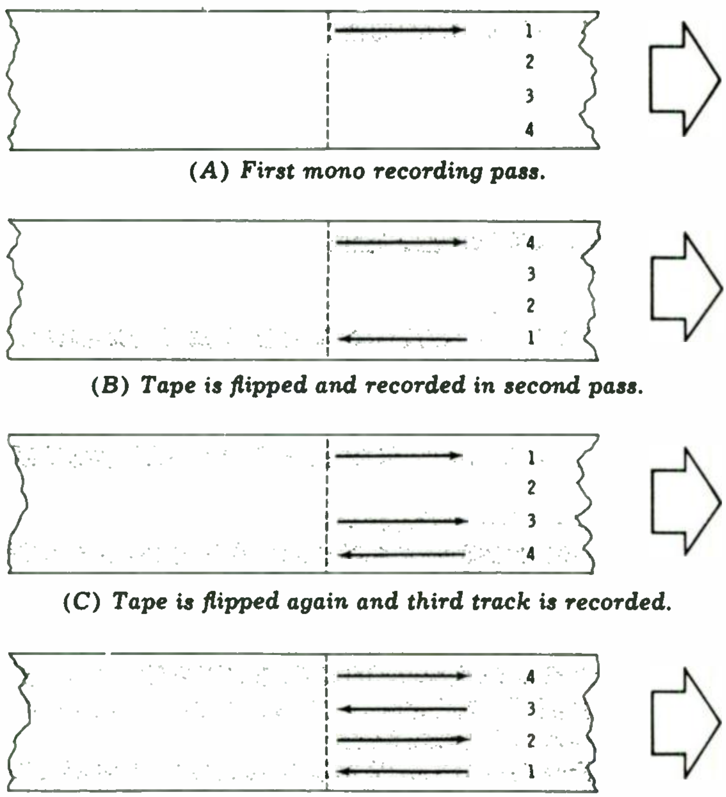
A VU meter is included in each channel as a recording level indicator. (VU is short for volume units). They indicate the amount of signal being presented to the heads during the record mode and are necessary aids in setting controls for the correct recording levels.

A single knoo volume control is used to control loudness in both channels. The addition of a *balance* control is necessary to provide adjustment for equal amounts of signal in each channel.

MONAURAL, BINAURAL AND SOUND-ON-SOUND RECORDING

In a two-track system, the tracks may be used for L and R stereo signals. If a monaural head is used, and the reels are flipped, the playing time is doubled, compared with that of a full-track recording. A four-track system doubles the playing time of a two-track stereo recording, or quadruples the playing time of monaural recordings. This quadrupling is accomplished in the system illustrated in Figure 4. Note that the associated L or R input must be used for monaural recording on a given track. This extension of monaural playing time can be doubled by using a similar technique with an eight-track system. The cartridge type of package is not flipped, of course, and all eight monaural tracks will run in the same direction.

Various "stunts" are also possible, such as sound-on-sound, sound-with-sound, and sound-over-sound. The sound-on-sound technique exploits erase-head defeat. That is, the erase head is switched off, or its magnetic field is "killed"



(A) First mono recording pass.

(B) Tape is flipped and recorded in second pass.

(C) Tape is flipped again and third track is recorded.

(D) Tape is flipped a final time, and remaining track is recorded.

Figure 4 — Four-track monophonic recording.

when the second recording is superimposed on a previously recorded track. This technique is less than perfect, in that the volume of the first recording is reduced to some extent, due to a noticeable erasing effect of the bias current. If the same recording level is used, the second "pass" tends to dominate the first, and the reduction in volume of the first recording is associated with a high-frequency loss.

If a recorder does not provide a means for disabling the erase head during recording, you can simply wind a strip of photographic film around the erase head, so that the tape is kept from contacting the head. Sound-on-sound is often used to insert sound effects into a previous recording. This technique can be used with any recorder, regardless of the number of tracks. Next, the sound-with-sound technique is utilized with stereo recorders; it exploits the possibilities of playing back on one track while simultaneously recording on another track. For example, records are available that have one part missing, such as a soloist, or one of the instruments. You can complete the record by means of the sound-with-sound technique. Thus, the record can be copied on one track of the tape, as you fill in the missing part while listening to the playback.

The sound-over-sound technique is also called multiple recording. For example, a song may be recorded, and then the recording can be copied while blending in a second part. This method originally employed more than one mono recorder; however, a stereo recorder that provides simultaneous recording on one channel while playing back on the other channel is a more elegant approach. Stereo recorders are available that have built-in sound-over-sound mixing facilities. Alternatively, a stereo recorder that has separate level controls for microphone and phonograph inputs may be used. You can provide a mixing system by using a patch cord to link the preamp output of one channel with the phono input of the other channel.

In some cases, it is necessary to use an accessory mixer. The essential requirement in any case is to employ an arrangement that permits you to monitor the recording on each "pass." Headphones are normally used for monitoring. You can then check the blending of the new material with the previously recorded material and make the necessary adjustments. Speakers are not satisfactory for monitoring in many cases, due to feedback from the speaker to the recording microphone. Many special sound effects and audio "stunts" can be employed, in addition to those that have been noted. Readers who are interested in this field are referred to specialized books on these techniques.

QUADRAPHONIC TAPE CARTRIDGE PLAYERS

You may occasionally encounter a quadraphonic tape-cartridge player. Although the terminology sounds formidable to the beginner, the same general troubleshooting principles used to locate defects in conventional cassette players are applicable. True four-channel sound denotes four distinct sound sources at the tape-recording and at the tape-play-back portions of the system. That is, the so-called true quadraphonic sound requires four audio signals, with four channels of reproduction (four amplifiers and four speakers).

On the other hand, synthesized four-channel sound denotes a method whereby conventional two-channel stereo is reprocessed to apparently make each of four speakers reproduce different audio signals, in order to simulate a four-channel effect without employing four channels (different sound sources), and without four channels of amplification. In the early days of hi-fi, only monophonic sound was utilized. Conventional stereo systems employ two-channel sound in order to exploit the binaural hearing characteristics of the listener. Quadraphonic sound adds a new dimension of realism.

One of the more popular quadraphonic systems is compatible with conventional stereo systems. The basic additions to an ordinary stereo system are another two-channel (stereo) amplifier and two additional speakers. These are driven by a four-channel adapter, as shown in Figure 5. This type of quadraphonic system can use four-channel tapes, or it can be used to synthesize four-channel sound from two-channel stereo tapes.

REPAIR PROCEDURES

When a tape recorder or player is brought in for adjustment or repair, the customer usually provides some information of value. He may state whether the trouble developed gradually or suddenly, and he may give certain technical details

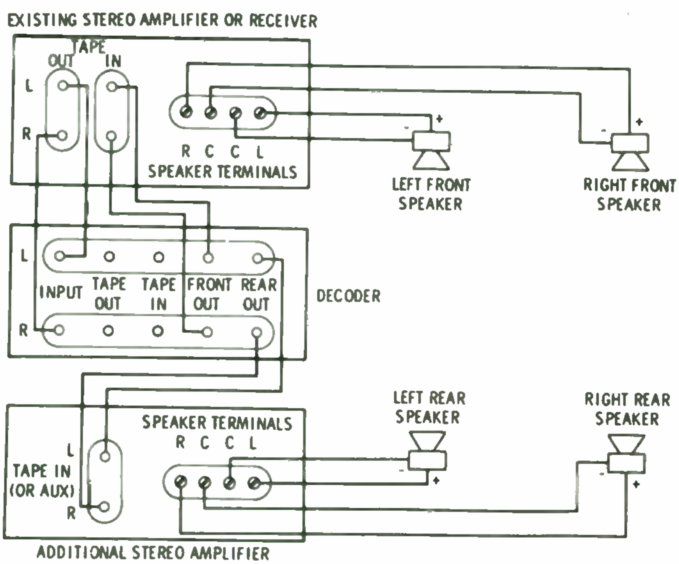


Figure 5 — Connections for a popular four-channel system.

from his own point of view. Most customers believe that they know the cause of the trouble. In turn, the technician must guide the conversation toward any pertinent facts of the matter, insofar as the customer is able to recognize and recall the facts. This preliminary information can often be helpful, and may save time in "sizing up" the job.

The value of a thorough visual inspection cannot be overemphasized. In many cases, a careful inspection and cleaning of the mechanism will turn up the defect by the time that this part of the troubleshooting procedure is completed. Experienced technicians know that the majority of service jobs involve contaminated grease or oil, lack of lubrication, loose nuts or screws, a broken belt, etc. Therefore, always look for the simple and obvious troubles first. Sometimes a trouble situation is caused by defective tape, instead of a defective machine. For example, gummy tape can produce misleading symptoms. Always remove the reels or cartridge from the machine, and make preliminary tests with a tape that is known to be good.

Systematic Checkout

You may decide to make a systematic checkout of the machine at the outset. In any event, good practice requires that a systematic checkout be made before the recorder leaves the service bench. The basic mechanical checks are:

1. **Tape speed.** This test is made to best advantage with a tape strobe. Wow or flutter will show up as failure of the segmented bars to stand still (or a failure to rotate steadily in a clockwise or counterclockwise direction). If the bars appear to stand still briefly and then to start rotating in one direction, and vice versa, wow or flutter is present. Special tapes are available for this test, in addition to a rotary tape strobe. Check each speed that is provided.
2. **Brake action.** In a reel-to-reel recorder, with the tape stopped, neither of the reels should turn freely in a manual check. Unless there is significant resistance to turning, a defect is indicated in the braking mechanism. The next test is applicable to both reel-to-reel and cartridge-type machines. With the tape winding rapidly on the take-up reel, press the stop button and observe whether the tape stops rapidly and smoothly. If the braking action is defective, a maintenance adjustment may be all that is required. (It is assumed that the mechanism has been cleaned previously.) With reference to Figure 6, the braking torque in this example is determined by the condition of clutch (19) for the supply spindle and clutch (6) for the take-up spindle.
3. **Rewind and fast-forward action.** If the rewind and/or fast-forward functions are erratic, slow, or otherwise abnormal, the drive system falls under suspicion. For example, a rewind belt might be defec-

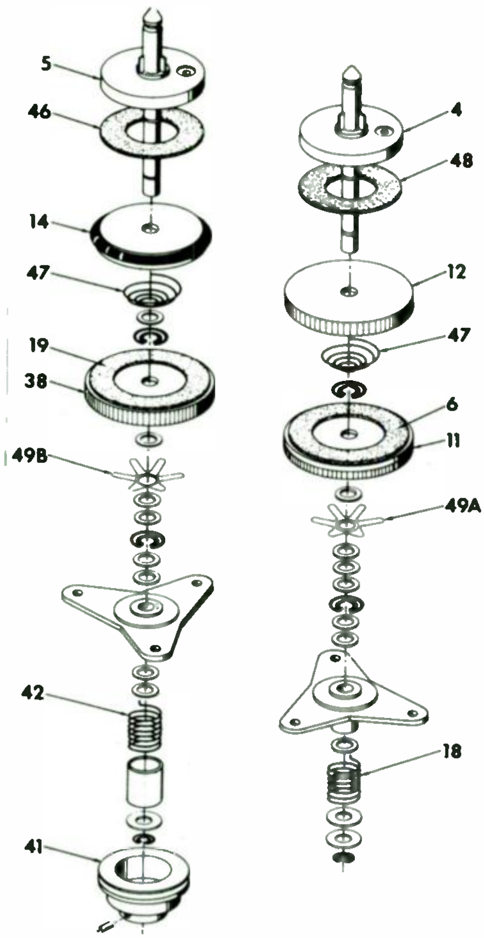


Figure 6 — Typical brake assembly.

tive or an idler wheel might be glazed.

4. **Automatic stop action.** Figure 7 shows the tape path on a typical recorder of the reel-to-reel type. Note the automatic shut-off sensor between the left-hand tape guide and the erase head. If the recorder does not stop automatically when all of the tape has been wound on the take-up reel, the sensor and its associated assembly should be checked.

5. **Tape alignment.** Observe whether the tape is in proper mechanical alignment with the take-up reel. In case of poor alignment, check the tape guides for correct positioning. The trouble could also be due to a misaligned capstan.

Although a recording head normally has no residual magnetism, it can become magnetized if the bias oscillator is turned off suddenly. The head may also be magnetized in the course of electrical testing procedures. For example, if the resistance of the coil winding in the head is checked with an ohmmeter, residual magnetism will be induced. If the head is touched with a magnetized screwdriver, some magnetism may result. Manufacturers often recommend that record/playback heads be systematically demagnetized after each 24 hours of normal recorder operation. The reason for this is that magnetic fields in a head tend to introduce distortion and noise.

A magnetized recording head first becomes apparent as excessive tape hiss. The subsequent trouble is poor high-frequency response. Unless a head is properly degaussed (professional head degaussers are available from good parts houses) permanent damage will result to any recording played back on the machine. A head demagnetizer is similar to a bulk-type eraser in that it employs an AC magnetic field. The demagnetizer should be plugged into an outlet before it is brought near a tape head; then, the tip is moved slowly across the gap in the

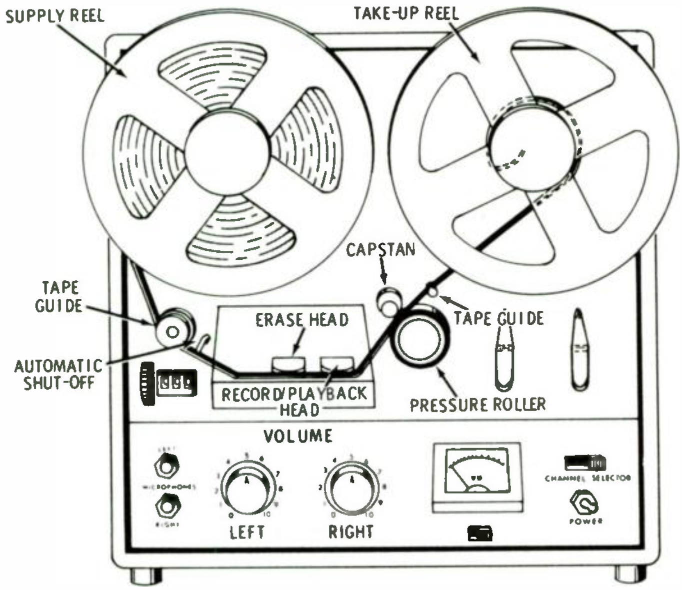
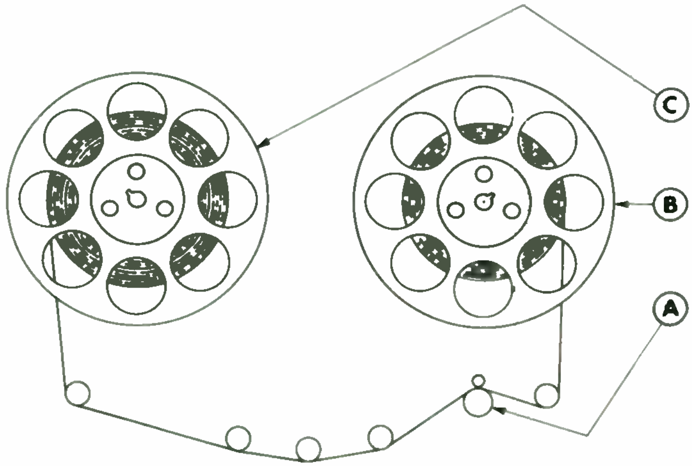


Figure 7 — Tape path on a typical recorder.

head, being careful to avoid scratching the head. A plastic sleeve, or transparent tape placed over the pole tips will minimize the danger of scratching the highly polished surface of the head. The demagnetizer is gradually withdrawn from the vicinity of the head, and is not turned off until it is at least two feet away. Do not leave a demagnetizer energized indefinitely, or it will overheat and burn out.

Check the record action by placing a known good tape on the machine and recording some musical passages at various levels. It is desirable to use a Hi-Fi source in this test. The highest level should not overdrive the recording-level indicator on the recorder. Next, rewind the tape and play it back. If the reproduction is unsatisfactory, try playing the same tape back on a tape player known to be good. This cross-check serves for preliminary trouble localization. The precaution of recording at several levels avoids the possibility of misinterpreting an improperly adjusted or defective recording-level indicator.

In the case of a stereo unit, each channel should be checked separately. When a test tape is used, no crosstalk should be audible in the L channel when the R channel is played back and vice versa. Crosstalk is most likely to result from capstan or tape-guide defects. (See Figure 8.) Eight-track machines are more likely to develop crosstalk, because the tracks are closely spaced. However, crosstalk can also be caused by defects in the electronic circuits that permit signals from one channel to couple into the other channel. Details of amplifier troubleshooting are reserved for subsequent discussion.



1. DRIVE (A) MUST BE SMOOTH AND CONSTANT.
2. TAPE MUST MOVE SMOOTHLY PAST ALL GUIDES AND HEADS, WITHOUT SNATCHING OR CHATTERING.
3. PULL OF TAKE-UP REEL (B) MUST BE GENTLE AND SMOOTH.
4. DRAG OF FEED REEL (C) MUST BE LIGHT AND SMOOTH.
5. PATH OF TAPE MUST PROVIDE STEADY UNWOBBLING MOTION.
6. PRESSURE OF TAPE AGAINST HEADS MUST BE FLAT, UNIFORM, AND STEADY (WHETHER OR NOT PRESSURE PADS ARE USED).
7. GUIDES A FOR TAPE MUST ENSURE ACCURATE LOCATION OF PATH BY HEADS, IN CORRECT POSITION, AND IN CORRECT ALIGNMENT.

Figure 8 — Basic requirements for a tape transport.

The basic importance of thorough cleaning has been noted previously. The capstan, heads, and tape guide may be cleaned with alcohol, or with a special cleaning fluid. Solvents should not be permitted to drip into bearings because normal lubrication may be impaired. Alcohol or other suitable solvents may be applied sparingly to the rubber pinch roller (pressure roller) and other rubber surfaces. A swab, is helpful in this procedure. Pressure pads may tend to develop slick and hardened surfaces. It is helpful to roughen the surface slightly with a nail file. Remember to allow sufficient time for solvents to evaporate before running the transport.

Routine cleaning procedures include the motor pulleys. Wow and other symptoms of incorrect tape movement may be caused by contaminated pulleys and belts. If a belt has absorbed oil, due to careless lubrication, it will be advisable to replace the belt, after thoroughly cleaning the pulleys. Tape-transport difficulties are often caused by brake or clutch defects (Figure 6). In many cases, operation is restored to normal after the friction surfaces have been properly cleaned.

Although the service data for a recorder is the final authority, a standard preventive-maintenance cleaning procedure may be noted:

All head faces should be cleaned with a suitable solvent to remove dust and accumulated oxide. An applicator may be fashioned from absorbent cotton. Avoid using a screwdriver or other metallic object near the head faces. As a cautionary note, be careful to keep cleaning solvents from all plastic surfaces. The cleaning schedule should include the capstan, pressure roller, pressure pads, and all tape guides. A lint-free cloth moistened with alcohol may be used to remove oil or grease from drive belts, idler wheels, brake drums and shoes, and all other driving surfaces.

Head Alignment

Misaligned heads cause defective recording and playback action. If a commercially recorded tape is reproduced by a misaligned playback head, the listener reacts with the typical criticism that the sound is "dull." However, if a tape is recorded and played back on a two-head machine (record/playback and erase heads), and the head is misaligned, the sound impairment may pass unnoticed. That is, the recording head is misaligned in this example to the same degree that the playback head is misaligned. The same observation applies to a machine that employs a combination head (record, playback, and erase structures in a common housing). It is evident that if either the recording head or the playback head is misaligned in a three-head machine, tapes recorded and played back on the same machine will be reproduced deficiently. In this situation, if a commercially recorded tape plays satisfactorily, we know that the recording head is misaligned.

The necessity for precise head alignment is evident from the track dimensions shown in Figure 9. Obviously, if the recording head is too high or too low with respect to the playback head, or if the playback head is too high or too low with respect to the tracks on a commercially-recorded tape, faulty reproduction is inevitable. Moreover, a head must be oriented exactly at right angles to the tracks; otherwise, the information at the bottom of the track will be out of phase with the information at the top of the track. The critical aspect of head orientation can be easily recognized when we note that the gap width may be as narrow as 0.00015 inch. In most designs, head height is adjusted by a screw or a pair of screws, and the angular orientation (azimuth) is adjusted by a separate screw or pair of screws.

Head alignment requires the use of special test tapes. A tape suitable for azimuth alignment has a high audio-frequency signal such as 10 kHz or 15 kHz recorded on the tape at a precise 90° angle. It is essential to employ a high test frequency in this portion of the procedure, because azimuth-alignment errors affect high-frequency reproduction more than low-frequency reproduction. A VTVM is ordinarily used as an indicator, and the output from the playback amplifier is monitored as the azimuth adjustment is made. Correct alignment produces a maximum output amplitude. Note that a lesser peak occurs on each side of the maximum-peak adjustment.

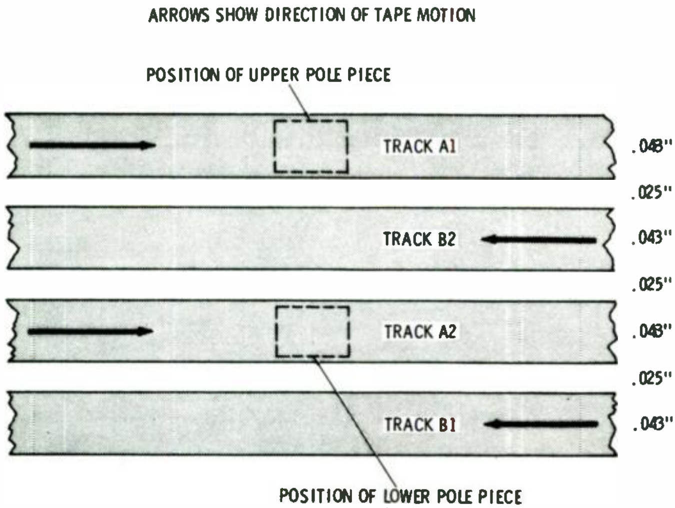


Figure 9 — Position of four tracks on tape.

Many lower-priced recorders omit head-height and azimuth adjustment facilities. It is good practice to consult the service data for a particular recorder, because specified procedures vary. For example, a manufacturer may direct that the pole piece in the head be positioned 0.002 inch below the edge of a properly threaded tape. Elaborate machines, such as eight-track stereotape players, require that the head height be adjusted on the basis of response to a specified type of tape test. The adjustment is made for maximum output from the playback amplifier. Test tapes are available for reel-to-reel, cassette, and cartridge machines. If a technician desires to make his own test tapes, it is advisable to make the recordings with new machines, to minimize the chance of inaccuracies. An audio oscillator may be used to feed a sine-wave signal of chosen frequency into the recorder.

Lubrication Procedures

Lubrication is an essential part of preventive maintenance. Although procedures vary, and the service data is the final authority, a standard lubrication procedure may be noted: Clean all surfaces before lubricating. Apply a few drops of No. 20 machine oil to all bearings and rotating bushings. Apply a thin film of nonhardening grease to all sliding surfaces and detent rollers. Always wipe excess oil or grease from parts that have been lubricated. A cautionary note: oil and grease must be kept off all driving surfaces as well as any parts which may transfer oil or grease to them.

Bearings should be lubricated with grease or oil as specified by PHOTOFACT or the manufacturer's service data. Pivot points and similar areas where metal slides against metal should be lubricated with medium-heavy high-temperature silicone grease, or equivalent. Note that lubricants become much heavier at low temperatures. In turn, a recorder that has been transported or stored in cold weather may not operate normally until it has warmed up to room temperature. Contamination of lubricants by dust or grime can also defeat normal operation. A thorough cleaning followed by proper lubrication will usually cure the trouble.

MECHANICAL ADJUSTMENTS AND REPAIRS

Although a simple maintenance procedure such as head demagnetization can often be accomplished by the owner of a tape recorder, the services of a technician are required to make head-height and azimuth adjustments. Similarly, the cleaning and lubrication of the mechanism is a professional technician's job. During preventive maintenance and evaluation procedures, worn and/or damaged mechanical parts may be found. In turn, disassembly is required so that defective parts can be repaired or replaced. In most situations, it is not expedient to repair a defective mechanical component, and the technician usually makes a replacement.

Belt-Type Clutch

The belt-type clutch is in very wide use. It employs a pulley driven by a slipping belt. Its chief advantages are simplicity and low manufacturing cost. Figure 10 shows a belt-type clutch which employs a grooved pulley with a rubber belt, and provides a constant-torque. This type of clutch has no adjustment, and its operation depends upon the condition of the belt and pulley. In most cases, subnormal torque is traced to a defective belt. After extensive service or excessive aging, a rubber belt tends to lose its tension and to stretch. Note that a glazed and hardened surface will result in subnormal torque, even if the belt tension is normal. The belt should be replaced routinely, when the take-up torque problems are encountered. Belt replacement may require minor disassembly, as seen in Figure 11.

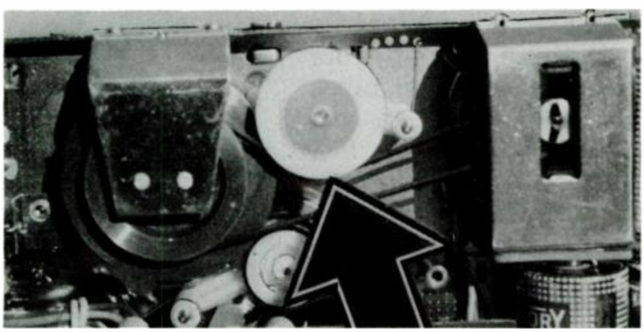


Figure 10 — A belt-type clutch.

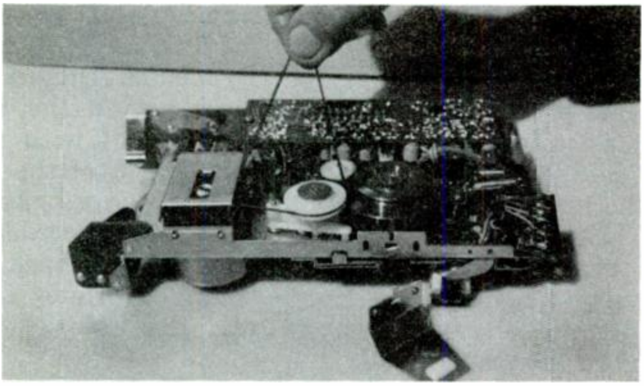


Figure 11 — Bearing bracket removed to permit belt replacement.

When the take-up torque is subnormal, the tape is not reeled in as fast as it is reeled out by the capstan assembly. Also, the customer complains that the tape "piles up" between the take-up guide and reel, or that the tape is pulled out of a cassette. Note that a new belt will not cure the trouble unless the pulley grooves are clean and free from oil or grease. It bears repeating that the value of a thorough inspection and cleaning procedure cannot be overemphasized. The technician can be misled by confusing clutch trouble with cassette defects. It is good practice to lay the original cassette aside, and to make the preliminary evaluation of trouble symptoms using a test cassette that is known to be good.

Figure 12 illustrates the meaning of torque,or twisting force. Torque values are measured in ounce-inches, ounce-centimeters, gram-inches, or gram-centimeters. Conventional procedures usually specify ounce-inch measurements. For example, if the radius of the hub in Figure 12 is one inch, the value of force F in ounces is also the value of the torque in ounce-inches.

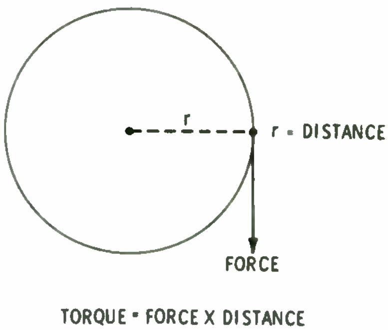


Figure 12 — Definition of torque.

Torque measurements are usually specified at a certain speed setting, such as $1^7/_8$ in/s. Note that there are 28.35 grams in an ounce; this is the conversion factor used to convert grams to ounces. Although take-up torque specifications vary, values from $^1/_2$ to 1 ounce-inch are quite common. Some inexpensive recorders do not have specified take-up torque values. The procedure for torque measurement is as follows:

1. With reference to Figure 13, a standard plastic reel (or a measuring hub) may be employed. If the hub diameter is exactly 2 inches, the spring scale will read directly in ounce-inches of torque. Reels with smaller hubs can be brought up to 2 inches diameter by winding on sufficient tape. However, if a diameter other than 2 inches is utilized, multiply the spring-scale reading by the hub radius to find the torque value in ounce-inches.
2. A piece of string 30 inches long is used. A loop is tied in one end for securing the hook on the spring scale.
3. Take-up torque is measured on the driven reel; hold-back (drag) is measured on the supply reel.
4. To measure take-up torque, wind a few turns of string around the hub, and hook the spring scale into the loop at the end of the string. Start the recorder and observe the scale reading.
5. To measure hold-back torque (drag), wind the hub of the supply reel with nearly the full length of the string and attach the spring scale. Do not start the recorder; instead, pull the scale back so that the string unwinds slowly and read the scale.

As would be expected, values specified for rewind and fast-forward torques are several times as great as for take-up torque. These increased torques are commonly obtained by throwing a planetary drive-disc arrangement into contact between the flywheel and the reel turntables. The torque values are determined by spring tension, and an adjusting screw may be provided. Otherwise, the torque spring must be replaced when its tension becomes incorrect. Note that a planetary train will fail to provide normal torque, even if the spring tension is correct, in case the tires are worn, glazed, or contaminated with lubricant. Clean or replace, if necessary.

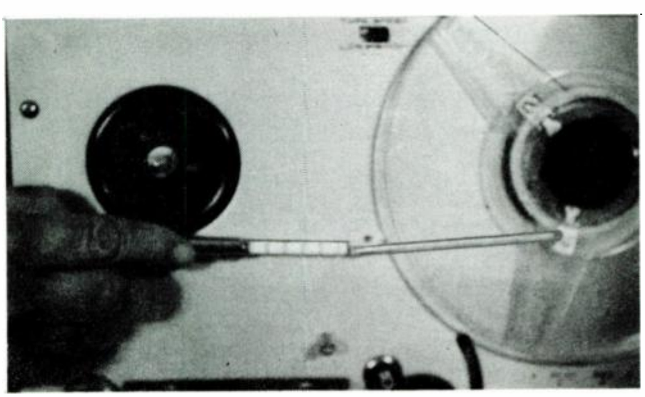


Figure 13 — Torque measurement.

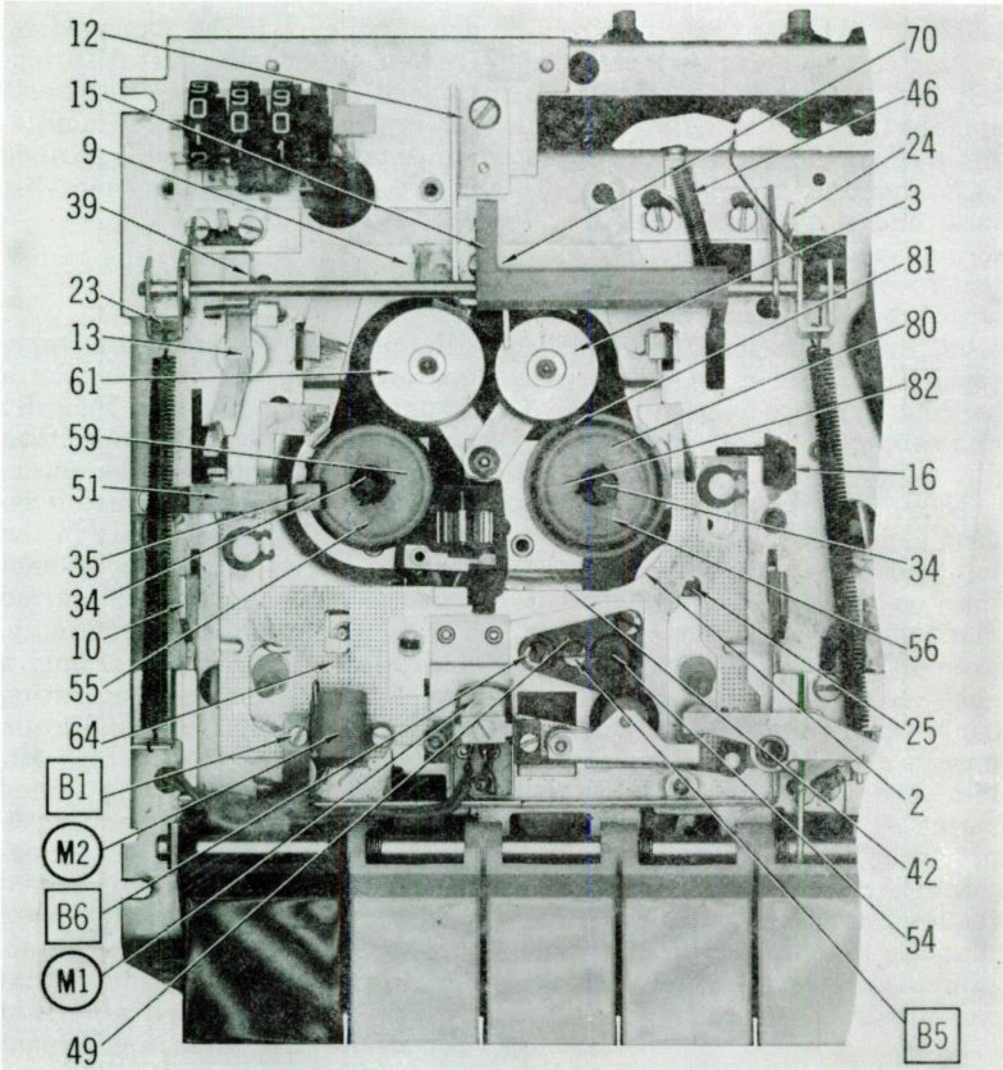


Figure 14 — Recorder with disc-type clutches.

Disc-Type Clutch

The disc-type clutch is also in wide use. This type of clutch generally employs a rotating disc that is driven at constant speed. In most recorders, the clutch disc is driven by the same motor that turns the capstan. The clutch disc may be fabricated either from metal or from plastic. A felt surface is provided on a second disc, which provides frictional torque between the two discs. The amount of torque may be adjustable by means of a spring assembly, or the torque may be fixed in the simpler recorders. When the torque value is not adjustable, normal operation depends upon the condition of the felt surface in the clutch assembly.

With reference to Figure 14, the take-up torque in the playing mode is developed by the disc clutch comprising clutch spring (82), reel disc felt (80), clutch disc (81), take-up spindle (56), and spindle cap (34). In this example, the take-up torque has a nominal value of $^1/_2$ ounce-inch, and is not adjustable. If the torque value is incorrect, we look for a worn felt, or contamination with lubricant. If the trouble persists, the clutch spring should be replaced. In rare cases, a defective bearing develops opposing torque and causes defective operation.

Next, note that the supply reel drag is provided by spring (51) and felt (35). This is a pad-type clutch that operates in the same basic manner as a disc clutch. In this example, the supply-reel drag torque has a nominal value of $^1/_4$ ounce-inch. The torque value is determined by the condition of the felt, and by the tension of the spring. Although no adjustment is provided for spring tension, the technician can bend the spring as required to change its tension. Note that the take-up reel drag in this example depends entirely on the cassette drag.

When the supply-reel drag becomes incorrect in this type of transport, the condition of the felt pad should be checked first. If it is contaminated, the pad can be cleaned by washing it in alcohol. Counter drive pulley (59) in Figure 14 should also be cleaned before replacing the clutch pad and spring. If the felt is worn down, it should be replaced, as its remaining life will be short. When a clutch felt is permitted to wear away completely, it is likely that the counter drive pulley will be damaged by friction against the metal spring. In such case, the pulley must also be replaced. Preventive maintenance procedures normally include inspection of clutch components, as well as functional checks.

Magnetic Clutch

In professional recorders, take-up torque may be provided by a magnetic clutch. This is basically accomplished by an induction motor operated in its stalled mode. Note that an induction motor develops its rated torque only in the vicinity of its normal rotational speed. When the motor is started up, it develops starting torque only, and this starting torque is only a small fraction of its rated operating torque. Therefore, if an induction motor is forced to rotate at a low speed, it develops starting torque only, and is said to be operating in its stalled mode. Although a magnetic clutch is much more expensive than a disc-type clutch, or a belt-type clutch, there is a characteristic of the magnetic clutch that is desirable in this application. Let us consider the torque requirement in somewhat greater detail.

In the case of disc-type and belt-type clutches, the torque applied to the take-up reel is practically constant. However, constant torque is not optimum torque in this case. When the reel is nearly empty, the tension on the tape is high; conversely, when the reel is nearly full, the tension on the tape is low. Although the capstan is supposed to maintain a constant tape speed, it operates under difficulties when the tape tension varies over a wide range. If the capstan pressure happens to be subnormal, the tape speed will vary substantially as the tape tension changes. The possibility of this trouble is avoided by a properly designed magnetic clutch, which provides constant tape tension, rather than constant torque.

Another advantage of the magnetic clutch is that its operation is independent of temperature and humidity, and it is not affected by careless lubrication. Therefore, a magnetic clutch is much less likely to cause trouble symptoms than a disc-type or belt-type clutch. In case a magnetic clutch does develop a defect, the troubleshooting procedure is the same as for induction motors.

Friction Brake Maintenance

When a recorder is set to the stop position, the reels must brake as rapidly as possible without damaging the tape. The same requirement applies to the pause operation. A widely used type of friction brake employs a metal brake shoe that is brought into contact with the spindle rim. More braking torque is normally applied to the supply spindle than to the take-up spindle. This ensures that the transport will stop without pulling tape from the cassette. Typical braking-torque values are $1^1/_4$ ounce-inches and $^3/_4$ ounce-inch for the supply and take-up spindles, respectively. Although mechanical details may vary (Fig. 15), the end result is the same.

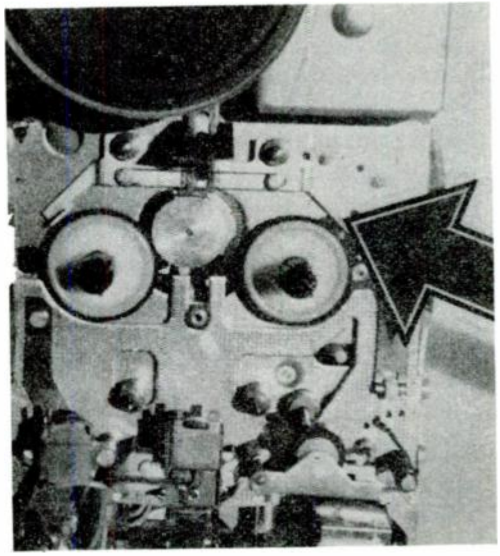


Figure 15 — Another example of a brake assembly.

Thus, in some recorders, a metallic spindle rim is employed with a padded brake shoe. When a metal shoe is utilized, it presses against a rubber or plastic spindle surface. Braking force is determined by spring tension which is adjustable in the more elaborate types of recorders. In an economy-type recorder, the brake spring must be replaced if the braking force is incorrect. This is somewhat of a critical requirement, because faulty brake action can cause tape spillage, tape stretching, or tape breakage. A broken or missing brake spring results in no braking action and the transport then coasts to a stop, often with tape spillage.

Brake shoes and drums should be systematically cleaned in preventive maintenance procedures. As in the case of clutch assemblies, oil, grime, or other foreign matter can seriously impair brake action.

Worn pads should be replaced, as the life expectancy of the brake is short. If pads are permitted to wear away completely before replacement, the brake drums may become badly scored or pitted, and require replacement. Lubrication neglect can also lead to brake trouble symptoms. If the spindle bearing wears excessively, and "wobbles," braking action becomes defective. Alternatively, a dry bearing may seize and jam the mechanism.

In certain types of professional recorders, magnetic braking is employed in combination with friction braking. This design is advantageous in that it provides very rapid brake action without damage to the tape. Magnetic braking is also called *dynamic braking.* Single-phase induction motors, utilized in many machines, provide starting torque by use of shading coils. To employ magnetic or dynamic braking, the AC voltage is switched off from the stator coils, and DC current is switched into the shading coils. Eddy currents in the rotor develop braking torque. As the armature slows down, the braking torque decreases but does not become zero until the rotor stops completely.

As was noted previously, the starting torque is less than the running torque at rated load for an induction motor. The dynamic braking torque is specified in terms of starting torque. To obtain a braking torque equal to 25 percent of the starting torque, a DC current equal to 250 percent of the full-load current must be applied to the motor. Maintenance of the braking system involves attention to the switch and switching circuit. In some cases, the rectifier in the DC-power supply may need replacement. A motor defect is also a possibility, as explained subsequently.

TAPE-RECORDER ELECTRONICS

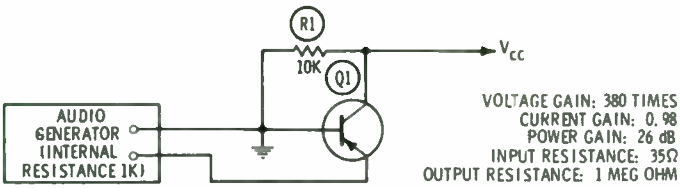
Troubleshooting tape-recorder electronics is basically the same as for other audio systems that have low-level sources. Hi-fi and stereo arrangements call for more knowledge and more elaborate test equipment.

Troubleshooting Techniques

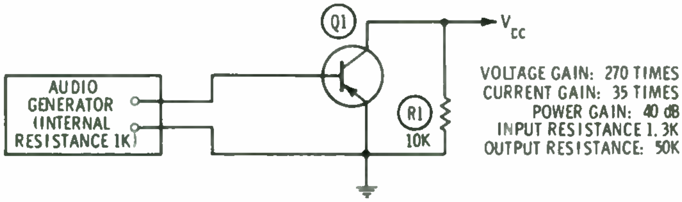
Normal DC terminal voltages are usually specified for each transistor. If a transistor should fail, it can be localized on the basis of abnormal terminal voltages. Capacitor failure may or may not be associated with a change in DC voltage distribution. For example, a shorted coupling capacitor will cause a change in DC voltages, whereas an open capacitor does not alter the DC voltage values. Therefore, signal-tracing procedures are commonly employed to supplement DC voltage measurements. Signal tracing in recorder circuits is easily accomplished with a sensitive oscilloscope. An alignment tape will provide a steady signal source, and if the scope has high vertical sensitivity, a sine-wave pattern display can be obtained at the record/play head terminals.

Some technicians use an audio VTVM instead of a scope for signal tracing. Although the VTVM is somewhat easier to operate, a scope has the advantage that the pattern displayed on its screen provides clear distinction between signal voltage and extraneous voltages such as noise or hum. Hum voltage is usually caused by power-supply defects such as faulty filter capacitors. However, hum can also result from poor ground connections or open high-impedance circuits. In the preamplifier section of a tube-type recorder amplifier, a slight amount of heater-cathode leakage can generate severe hum. Noise voltages are produced by poor contacts, and by various component defects. In a preamp, resistors can produce objectionable noise and worn controls are the most likely culprits. Noise voltages have a random spike appearance on a scope screen and are easily distinguishable from a sine-wave signal voltage.

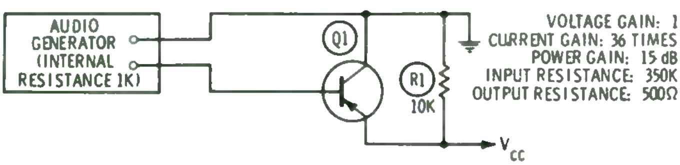
A scope or audio VTVM may also be used for gain measurements. The output level from the playback head is in the order of a few millivolts across 600 ohms, or a power level of a fraction of a microwatt. This low-level signal must then be amplified to a level in terms of watts, such as 3 volts across 8 ohms. Figure 16 shows typical gain figures for transistor amplifier stages. The common-emitter configuration is generally utilized, and a typical stage provides a power gain of 40 db; this is an output/input power ratio of 10,000. The sys-



A Common-base stage.



B Common-emitter stage.



C Common-collector (emitter-follower) stage.

Figure 16 — Comparative voltage-, current-, and power-gain figures for transistor-amplifier stages.

tem must provide a gain of at least 80 db, and reserve gain is provided in all but the lowest-cost units. In turn, three or four stages of amplification are commonly employed.

The gain of a stage, as measured with a calibrated oscilloscope or with an audio VTVM, is evaluated in terms of output voltage vs. input voltage. This is the voltage gain of the stage, and it is related to the power gain in terms of the input and output resistance of the stage. In other words, a basic power law states:

$$P = \frac{E^2}{R}$$

where,
P is the power in watts,
E is the voltage in volts,
R is the resistance in ohms.

In turn, meaningful gain measurements entail not only input and output voltage values, but also input and output impedance values. In case of doubt, the most reliable guide is a comparison test of another recorder which is in good operating condition. The beginner should note that it is quite possible that the ratio of output to input voltage for an audio-output stage might be less than unity. Although there is a signal loss on the basis of voltage values, it is nevertheless a fact that the power gain will be very high, if the ratio of input impedance to output impedance is quite high.

Low gain is often a result of open emitter bypass capacitors, open coupling capacitors, or resistors that have changed in value substantially. Of course, the gain will be low if the power supply voltage is significantly reduced. The base-emitter bias voltage of a transistor may be shifted due to a resistor with an incorrect value. If the transistor is thereby caused to operate near cutoff, or near saturation, the stage gain will be reduced. In the higher-level stages, particularly, this malfunction is likely to be accompanied by objectionable distortion. The technician should be alert to avoid confusing low gain with head defects. That is, it is good practice to start by checking the output signal level of the head. If this is impractical, a substitution test can be made.

Distortion cannot be analyzed effectively by evaluation of scope patterns. That is, if distortion is definitely visible in a sine-wave pattern, the percentage of distortion greatly exceeds high-fidelity, or even good-quality standards. The most practical way to track down distortion in a recorder amplifier is to connect a harmonic-distortion meter in place of the speaker. Then, using a good audio oscillator and a series blocking capacitor of about 10 μ f, proceed to localize the distortion area by signal injection. That is, we proceed back from the output stage and inject a 1-kHz signal at the base of each transistor, step by step. The harmonic distortion meter is operated at each step to determine whether the percentage of distortion has taken a sudden jump upwards.

As we proceed back toward the input stage of the amplifier, the output level from the audio oscillator must be reduced accordingly. Some audio oscillators have an excessive minimum-output level for testing a preamp. In such case, we simply make up a suitable resistive voltage divider to supplement the attenuator of the audio oscillator. It was previously noted that although no industry standards have been established, it is generally agreed that a Hi-Fi amplifier produces no more than 1 percent harmonic distortion at maximum-rated power output. Other amplifiers that develop a harmonic distortion of several percent are regarded as good-quality amplifiers, although they do not qualify in the Hi-Fi category.

The recorder service data will specify the bias voltage that is normally measured across the recording head. This value is usually in the order of a few volts, and will depend considerably on the resistance of the particular head winding. If the bias voltage is incorrect, adjustment may be possible. However, the economy types of machines often have no bias control. Since the bias voltage is generated by a bias oscillator, give first consideration to this section of the electronic system in case of bias trouble. Note that if the playback signal level in an record/playback head is normal, the head does not fall under suspicion. The erase-bias voltage is also specified in the service data and, in most cases, if the recording bias is correct, the erase bias will also be correct. However, a defective erase head will usually show up in this situation in terms of an incorrect erase-bias reading.

Next, let us consider the electronic system for a stereo recorder, such as is shown in Diagram 3 from your *diagram envelope.* We observe that the circuitry is basically a pair of identical amplifiers. Each amplifier section is energized by its associated winding in the playback head. Troubleshooting a stereo system is basically the same as for a mono system, except that we have about twice as many components to contend with. Also, balance and cross-talk are considerations unique to stereo.

With reference to Diagram 3, we observe that each amplifier section has its own volume control. This permits the output levels of the right channel and left channel amplifiers to be equalized, or balanced. The procedure is comparatively simple. If we operate the machine with a mono alignment tape, both the left and right channels will be energized at exactly the same input signal level. In turn, we connect an AC VTVM across the voice coil of the right speaker, and note the output reading. Next, we measure the voltage across the voice coil of the left speaker. If it is not the same as the first reading, we adjust the left volume control as required.

An eight-track stereo recorder may have an automatic-record-level (ARL) circuit. In such case, the ARL balance control should be checked and adjusted, as required. With reference to Figure 17, R1 is an ARL balance control. To adjust the control, we set the machine to the record mode and feed a 1-kHz tone at a level of 0.0006 volt rms from an audio oscillator to the left

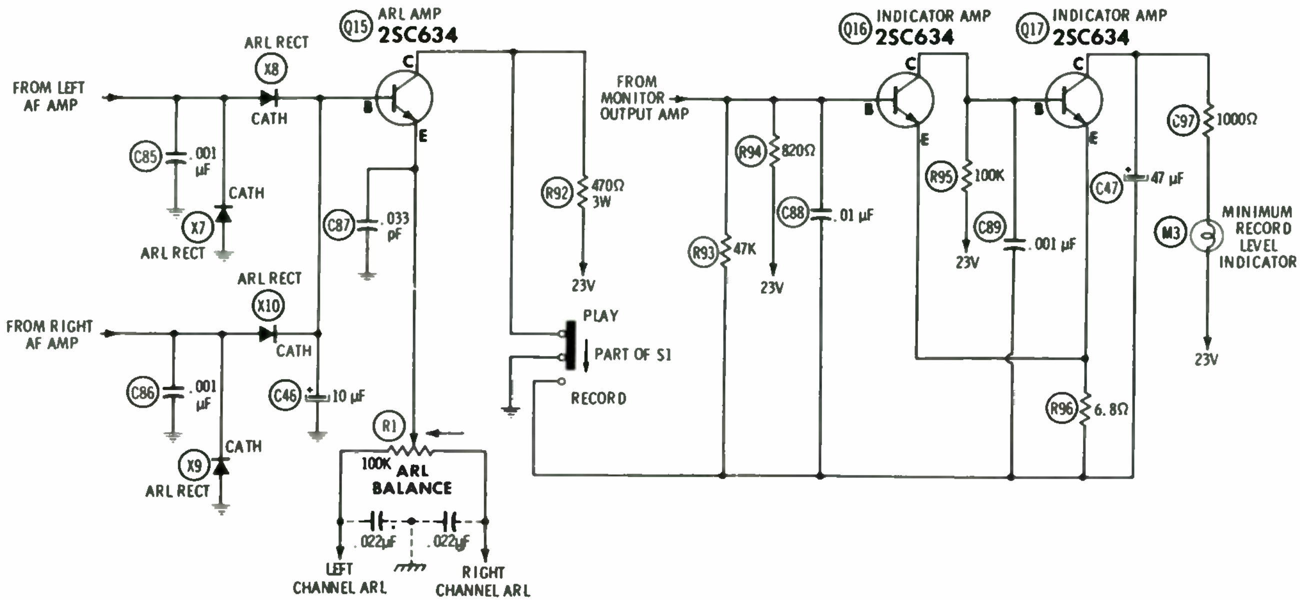


Figure 17 — Automatic-record-level circuit.

and then the right microphone-input jacks in turn. We connect an AC VTVM to the left and right output jacks in turn, and adjust R1 to obtain equal output voltage values. As was noted previously, most audio oscillators cannot supply an output as low as 0.6 mV and, therefore, a voltage divider must be employed at the output of the audio oscillator.

Experienced technicians know that it is difficult to measure a voltage in the order of 0.6 mV with an audio VTVM, because the residual noise level confuses the reading. Therefore, the most practical approach in this situation is to measure the minimum output from the audio oscillator—for example, the minimum output might be 0.1 volt rms. In turn, we can connect a 100-ohm resistor in series with a 0.6-ohm resistor. Then, if we apply 0.1 volt to the divider as shown in Figure 18, the voltage across the 0.6-ohm resistor will be 0.6 mV.

Next, let us consider crosstalk symptoms and cures. Crosstalk in a stereo-tape recorder is defined as interference from one channel of a stereo tape with the other channel. It can be caused by recording or playback defects, or by amplifier trouble. Insofar as tape tracking is concerned, we will find that eight-track tapes are more likely to produce perceptible crosstalk, simply because the tracks are so close together. Slight defects or mechanical wear in the cam assembly that determines head height for the various pairs of tracks can result in crosstalk. However, we are concerned only with the electronic system at this point. We will discuss head-shift troubles subsequently.

To eliminate confusion with possible deficiencies in the mechanical system, a test for amplifier crosstalk should be made with a signal from an audio oscillator, as described previously for the ARL balance adjustment. That is, we feed a suitable low-level signal into the left microphone-input jack, and measure the output (if any) from the right output jack with an audio VTVM. This test should be made with the amplifier set for maximum rated power output. If appreciable crosstalk is detected, the power supply is the prime suspect. When the internal impedance of the power supply increases, there is a signal voltage drop across the power supply and the audio signal from one channel is coupled into the other channel. With reference

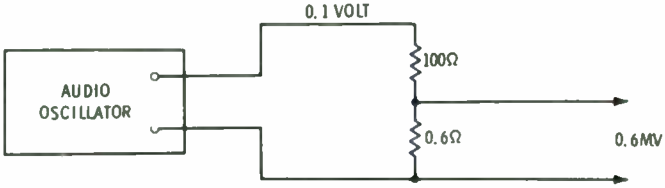


Figure 18 — Voltage divider for balance check.

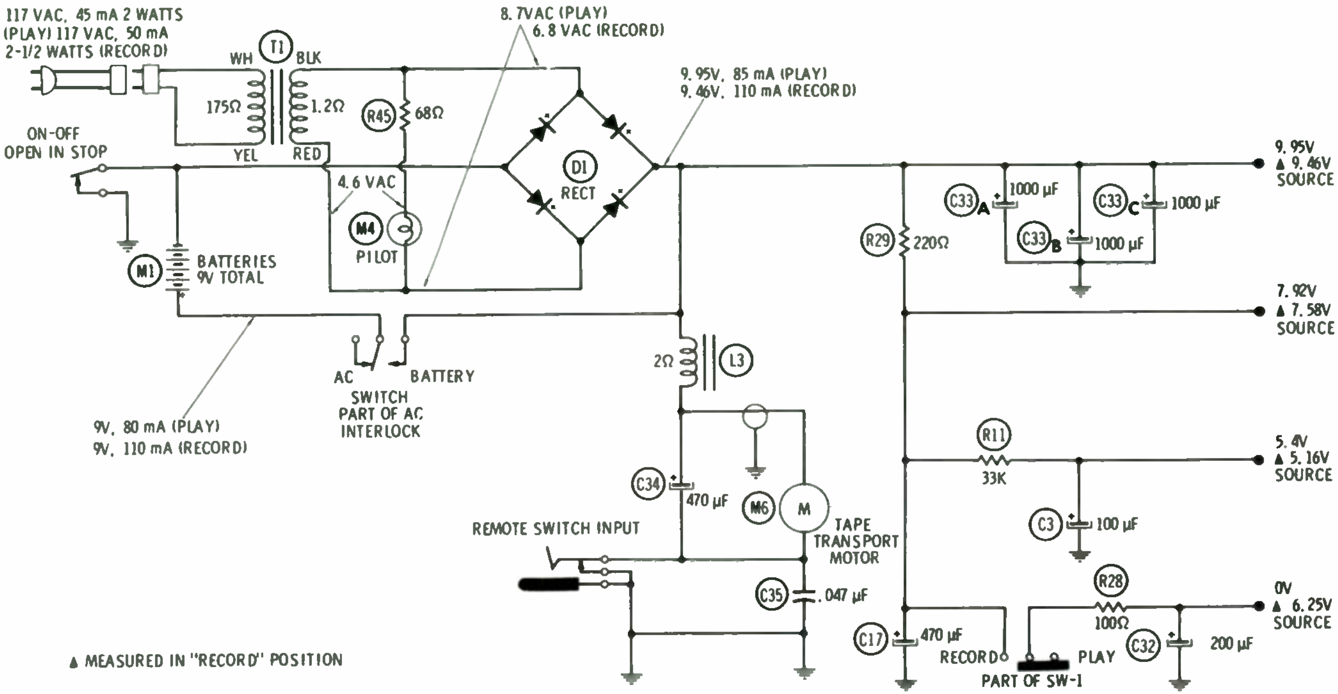


Figure 19 — Power supply for a tape recorder.

to Figure 19, we would check C_{33}, C_{32}, C_{17}, and C_3. This type of crosstalk is most prominent at low audio frequencies.

TAPE TRANSPORTS

The term *tape transport* is a collective name for the parts of a tape recorder that control the movement and handling of the tape. All machines, except those in the toy category, employ a capstan to move the tape past the heads at a precise speed. A capstan is a precision cylindrical drum or spindle against which the tape is pressed in order to maintain a constant tape speed. A pinch roller (pressure roller) holds the tape, by spring pressure, against the capstan. Figure 20 shows a typical capstan, with the pressure roller to the left. The tape transport also provides for fast tape movement forward or backward, so that any desired spot on the tape can be located rapidly. Braking and pause functions, discussed previously, are also associated with the tape transport. Common trouble symptoms are:

1. No movement of the tape.
2. Incorrect tape speed.
3. Defective braking action.
4. Incorrect tape tension.
5. Erratic or no response to control operation.
6. Take-up reel does not revolve in fast-forward position.
7. Supply reel does not revolve in rewind position.
8. Tape rides up and down between capstan and pressure roller.

Sequence of Operation

It is helpful at this point to consider the sequence of operation for a typical cassette transport. With reference to Figure 21, when the function selector is moved to its play position, assembly (19) is slid, thereby pivoting assembly (13) and moving pulley (14) which moves belt (3) from spindle (5). Assembly (19) also actuates switch (S_2),

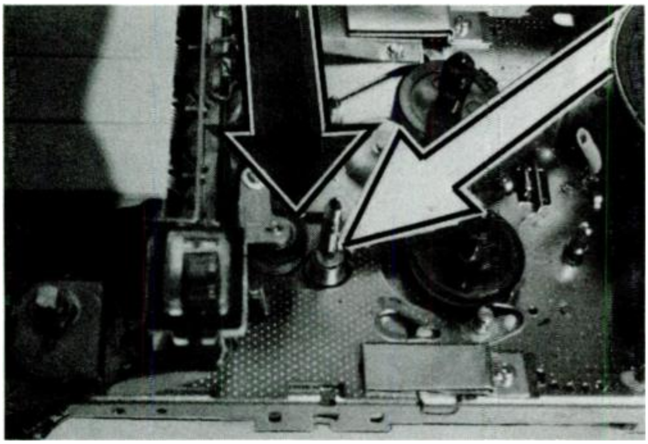


Figure 20 — White arrow points to capstan; black arrow points to pressure roller.

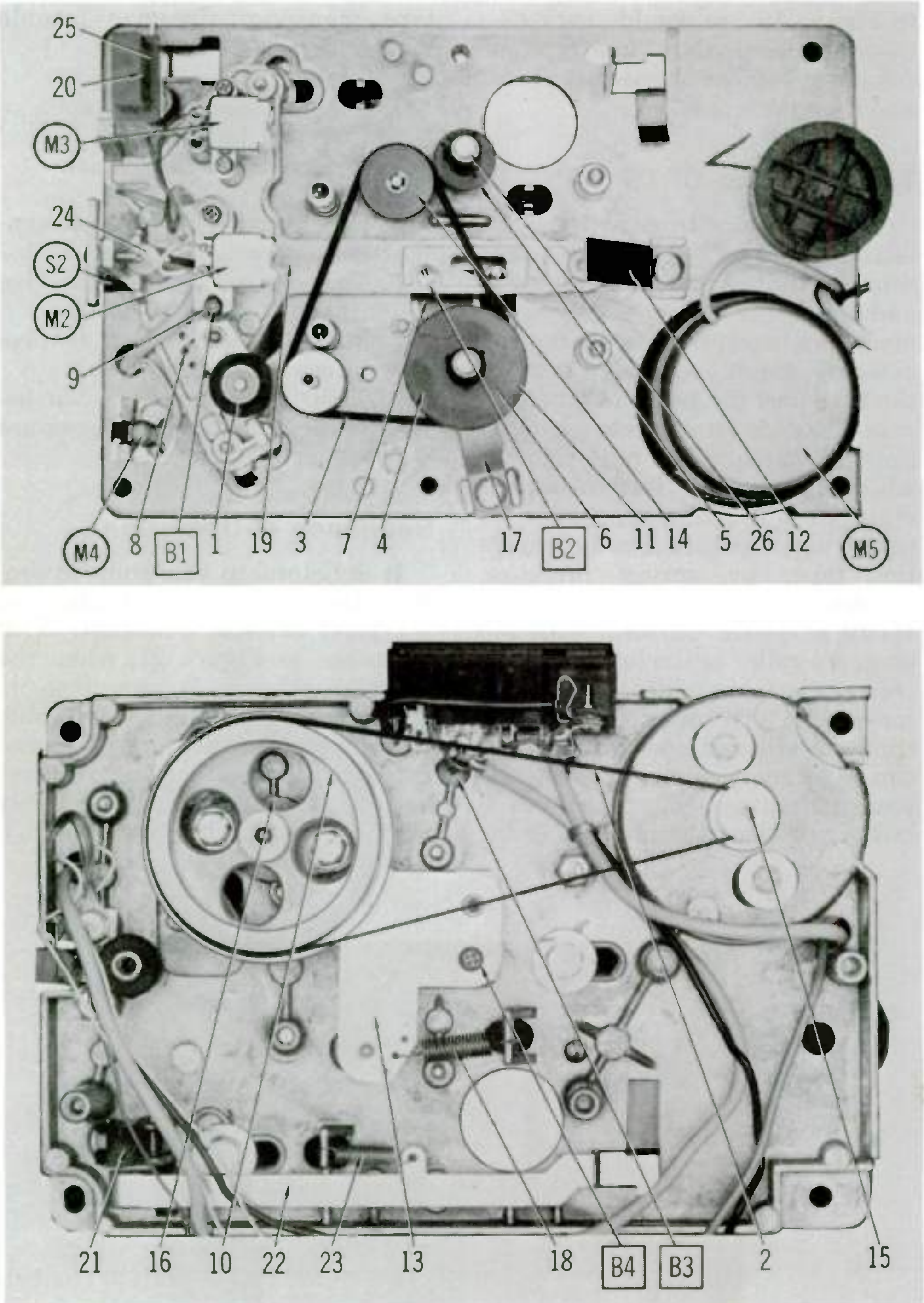


Figure 21 — Mechanical components of a typical tape transport.

moves the head forward, and allows spring (8) to press roller (1) against the capstan. The motor, through pulley (15), belt (2), flywheel (10), belt (3), pulley (11), and clutch (6), drives spindle (4).

When the function selector is moved to its record position, the sequence is the same as explained above. However, if the cassette has moved lever (22), pressing the record button will slide shaft (20) to pivot lever (21), thereby actuating the record/play switch to record mode. Next, when the function selector is moved to its fast forward position, assembly (19) is pivoted, which pivots assembly (13), thereby moving pulley (14) to move belt (3) from spindle (5). Assembly (19) also releases spring (7) to increase the pressure on clutch (6) and actuates switch (S2). The motor, through pulley (15), belt (2), flywheel (10), belt (3), pulley (11), and clutch (6), drives spindle (4).

When the function selector is moved to its rewind position, assembly (19) is pivoted to actuate switch (S_2) and to press spring (7), thereby removing the pressure from clutch (6). The motor, through pulley (15), belt (2), flywheel (10), and belt (3), drives spindle (5). Finally, when the function selector is moved to its stop position, assembly (19) reverses the play or record sequence. The braking torque is provided by the tension of spring (7). With the introduction to the transport mechanism of a cassette-type machine completed, let us observe the sequence of operation for a reel-to-reel machine.

With reference to Figures 22 and Diagram 4 from your *diagram envelope,* pressing the start button moves plunger (29A) to pivot bracket (23), thereby releasing assembly (18). Assembly (18), pulled by spring (70), moves tire (9) against capstan assembly (53). Tire

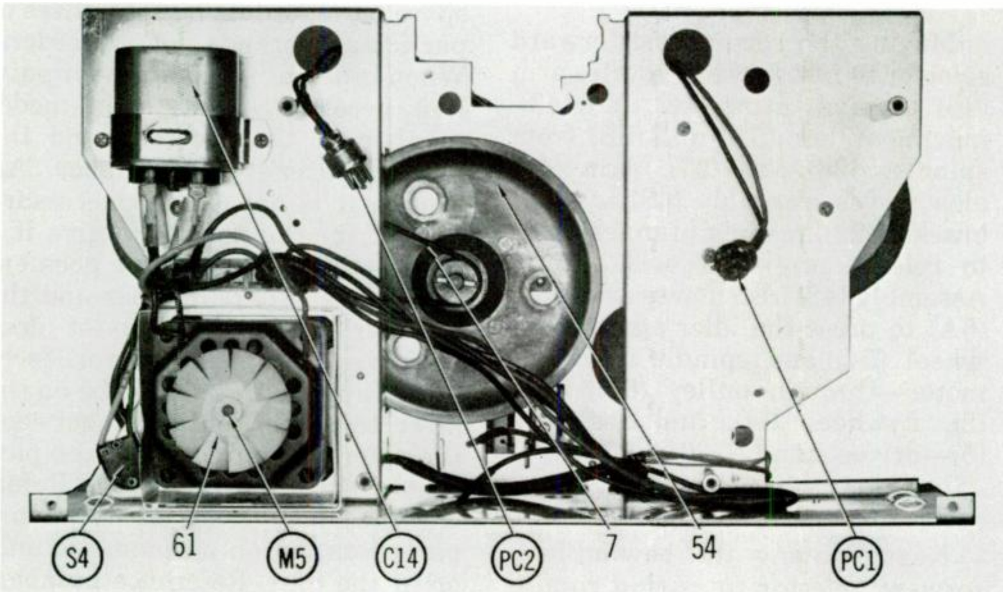


Figure 22 — Partial view of component parts in a reel-to-reel machine.

(9) rotates cam (10), allowing assembly (18) to move forward. Assembly (18) also pivots arm (42) to move roller (6B) from spindle (30). Arm (42) also pivots arm (43) to move roller (6A) from spindle (37). Assembly (18) also pivots assembly (45) to pivot riser (35A), thereby raising pulley (34) to apply pressure to plate (32) and felt (31).

Assembly (18) also moves roller (1) against capstan (53) and moves brackets (16) and (17) forward to allow springs (13) and (14) to press pads (15A) and (15B) against the tape head. The motor—through pulley (62), idler (2), flywheel (54), belt (7), pulley (34), plate (32), and felt (31)—drives spindle (30). The record sequence is the same as play. However, pressing the left and right record button moves plungers (28A) and (28B), thereby actuating the record play switches.

Moving the rewind/fast-forward selector to fast forward rotates arm (46) to pivot arms (42) and (43), moving rollers (6A) and (6B) from spindles (30) and (37). Arm (46) also moves assembly (48) to pivot bracket (22), moving plunger (29B) to release any depressed button. Assembly (48) also moves assembly (5A) to press the idler against flywheel (54) and spindle (30). The motor—through pulley (62), idler (2), flywheel (54), and assembly (5)—drives spindle (30).

Next, moving the rewind/fast-forward selector to rewind rotates arm (46) to pivot arms (42) and (43), moving rollers (6A) and (6B) from spindles (30) and (37). Arm (46) also moves assembly (48) to pivot bracket (22), moving plunger (29B) to release any depressed button. Assembly (48) also moves assembly (5B) to press the idler against flywheel (54) and idler (4), thereby pressing idler (4) against spindle (37). The motor—through pulley (62), idler (2), flywheel (54), assembly (5B), and idler (4)—drives spindle (37). Finally, pressing the stop buttom releases assembly (50), pulled by spring (49), to move cam (10), pressing tire (9) against assembly (53). Assembly (53) drives tire (9) to rotate cam (10), thereby reversing the sequence of the operation in use. Braking torque is provided by rollers (6A) and (6B).

REPLACEMENT PARTS

It is impractical for the technician to stock more than a few spare parts, unless he specializes in particular brands of recorders. When ordering a replacement part, it is necessary to state the model number of the recorder and the manufacturer's part number. Although it is not usually necessary to describe the part or to give it a name—the manufacturer goes entirely by the part number and the recorder model number—it does help to avoid a possible error. Technician apprentices should be on the alert to avoid confusion between the reference number and the part number in the service data. Reference numbers generally refer to a parts location on a schematic and/or in the unit. Reference numbers of this type are, therefore, of in-significant value when ordering replacement parts. Certain notes on a drawing or in a part list however, do have relevance to replacement components. In many instances a series of similar models may be covered in one manual. Although they are basically alike there may be specific differences in some components of one or more of the models. Where a component is different from the one used in the basic family, it will have a different part number. In this case, a note or exception will be placed in the service literature relative to the order number of the part of this type used in the model or models.

Many components are available from sources other than the equipment manufacturer and these alternate sources are frequently stated in the service manual. They are usually listed along with the part name and the manufacturers part number. PHOTOFACT literature, in particular, will often list many commonly available replacements for a part. For example, it is not at all unusual for PHOTOFACT to list six or more recommended replacements for a single transistor. The same availability applies to electrolytic capacitors. Equivalent replacement power rectifiers and signal diodes are also commonly available. We will find that a few parts, such as volume and tone controls, are sometimes specially designed by the recorder manufacturer. Tape heads are often standardized. In any case, the recorder service data is usually the authority for replacement-part information.

SERVICING PROCEDURES

Capstan Replacement

If the capstan is accidentally hit by a heavy object, it will be bent or otherwise damaged. A defective capstan often causes the tape to ride up and down between the capstan and the pressure roller. Surface damage to a capstan cannot be corrected with conventional equipment, and the capstan must be replaced. Although a bent capstan can be straightened, it is difficult to do a precision job, and replacement is usually necessary. In many designs, a capstan cannot be removed from its sleeve bearing unless it is essentially straight. If a bent capstan is straightened carefully, it may be possible to withdraw it from its bearing with application of moderate force. Otherwise, both the capstan and the sleeve bearing must be replaced.

The most useful tool for straightening a bent capstan is a steel tube that has an inside diameter equal to the outside diameter of the capstan. When the tube is slid over the capstan and pressed in the correct direction, the technician may be able to move the bend sufficiently that the capstan can be withdrawn from its bearing. Unless the capstan can be withdrawn from the bearing easily, the bearing is very likely to be damaged since it is fabricated from a soft metal. Therefore, it is worthwhile to take a little time in the attempt to straighten a bent capstan. If a capstan cannot be straightened, it may be necessary to drive it forcibly through the bearing, because the bearing cannot be removed in many types of machines until after the capstan and flywheel have been removed.

If lubrication has been neglected and the capstan bearing has worn sufficiently to permit the capstan to wobble in azimuth, the bearing must be replaced. A common symptom of this trouble condition is a tendency for the tape to ride up and down between the capstan and pressure roller. A tendency for the tape to ride up and down between the capstan and pressure roller can also be caused by a worn or deteriorated pressure roller. This roller has a rubber tire that eventually requires replacement. Although a new tire can usually be installed on the roller in the case of an elaborate recorder, this may not be practical in an economy-type recorder. In economy recorders it is most expedient to replace the entire roller assembly.

The pressure that the roller applies against the capstan is determined by a spring (Fig. 23). If the pressure-roller spring weakens, wow and flutter symptoms may occur; or, if the spring breaks, the tape will move past the heads at abnormally high speed. In many recorders, no adjustment is provided for the spring tension. If the tension is subnormal the spring must be replaced. However, in the more elaborate recorders the pressure roller spring may be held at one end by a threaded stud and adjustable locknuts. In turn the pressure-roller spring tension is easily adjustable to the optimum value as specified in the service data.

Idler and Pulley Replacement

Recorder pulleys will often outlast the rest of the mechanism, unless lubrication has been neglected. Plastic pulleys, of course, are subject to chipping or cracking if accidentally struck by a heavy object. The majority of pulleys are retained by means of C clips, although machine screws may also be used to secure pulley assemblies. A few pulleys are an integral part of another component. For example, a flywheel pulley is usually cut directly into the flywheel or into its hub. Motor pulleys are often force-fit mounted on the motor shaft, and cannot be removed with ordinary shop tools. A function-roller assembly, includes a pulley which may be riveted on its shaft. In such case, it is expedient to replace the complete assembly.

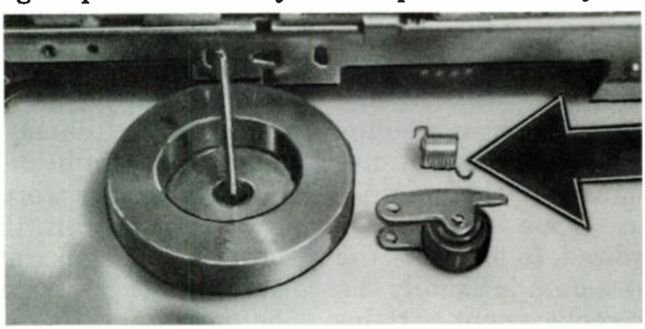


Figure 23 — Arrow points to pressure-roller spring.

A typical idler assembly, shown in Figure 24, provides torque transfer from a rotating source to a load. In this example, the assembly comprises a pair of idler wheels secured to the same shaft. Since the wheels are force-fit mounted on their shaft, the complete assembly must be replaced if a defect occurs. However, each of the rubber tires on the grooved idler wheels can be removed. The tire on a large idler wheel may be cemented in place, which complicates a replacement job. Manufacturers often recommend that a complete idler assembly be replaced if a tire becomes defective. Note that special rubber composition is often used in idler tires to provide the desired torque-transfer characteristic.

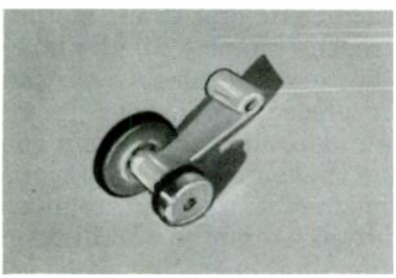


Figure 24 — An idler assembly.

Be careful not to confuse parts that look the same at first glance, but which have an essential difference. For example, a fast-wind idler spring looks almost the same as a take-up shaft spring in some recorders. However, the springs have their ends oriented at different angles. In turn, if the springs are interchanged in the transport mechanism, trouble symptoms are introduced into both the fast-wind and take-up functions. One practical procedure that prevents wasted time due to parts mixup is to keep a compartmented plastic tray handy on the bench. In turn, the parts associated with each assembly can be kept in a separate compartment.

Slide- and Pivot-Plate Replacement

Slides and pivot plates are generally mounted in place by means of machine screws or C clips. Disassembly can be accomplished without difficulty except in the case of some economy-type machines that are assembled with rivets. It is usually impractical to drill out rivets in disassembly procedures, and it is even more difficult to reassemble the mounting with a replacement part. In this situation, it is advisable to discuss the problem with the customer, and to suggest that he either return the recorder to the manufacturer for factory repair, or that he discard the machine.

The technician should be cautioned that slide plates may be provided with slots and ball bearings to minimize friction. The tiny balls will fall out during the disassembly procedure if one is not careful, and considerable time may be wasted in looking for them. Slide plates seldom wear excessively, even if lubrication has been neglected. However, a slide plate can become bent and require straightening. For example, if a recorder is dropped, and the control knob or manual tab is struck forcibly, it will be bent and the force that is transmitted through the assembly can also bend the main portion of the slide. Disassembly should be followed by a thorough cleaning; the slide can then be straightened or replaced. Do not forget to lubricate the assembly before reassembling the recorder.

Position Indicators

Position indicators, such as illustrated in Figure 25, are provided on higher-quality machines. A position indicator is basically a counter that is driven by the feed or take-up reel, and counts the number of revolutions that have elapsed since the tape was started. In turn, the operator can rapidly locate selections within a reel of tape. A position indicator is also called a tape counter, or simply a counter. Instead of indicating by means of odometer-type wheels, it may provide dial indication of the number of elapsed revolutions. A good position indicator will have a repeatability of a few inches of tape. That is, each time that the tape is replayed, a given indication will correspond to the same point on the tape, plus or minus two or three inches.

Some position indicators are actuated by a belt. In case of inaccurate or no indication, we would check the belt first to determine whether it might be stretched or contaminated with lubricant. It is impractical to repair a position indicator with ordinary shop equipment, and a defective unit should be replaced. The indicator mechanism is usually self-lubricated, and requires no attention during normal life.

Motor Replacement

Battery-operated DC motors have come into wide use for small portable transistor tape recorders. These motors have permanent-magnet fields and therefore have the comparatively constant-speed characteristic of a shunt motor. Of course, the motor will slow down if the battery becomes weak and is not replaced. The speed is made more independent of battery condition in the more elaborate recorders by means of a speed regulating circuit, as exemplified in Figure 26. The nominal operating speed is ad-

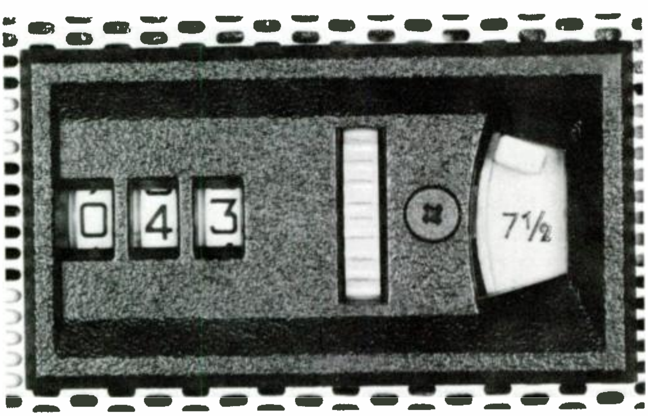


Figure 25 — A typical position indicator.

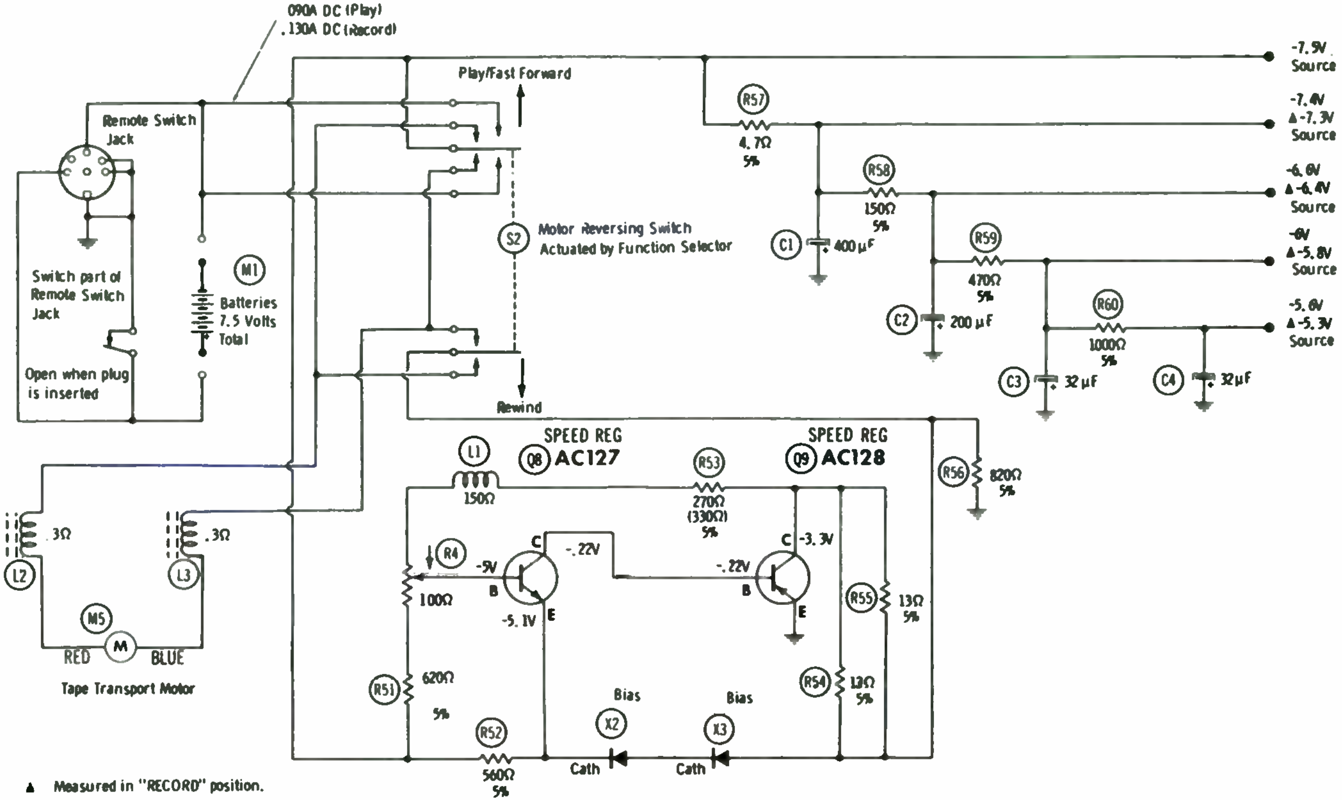


Figure 26 — Motor speed is regulated by R_4.

justed by means of R_4,and transistors Q_8 and Q_9 maintain the motor current practically constant until the battery must be discarded.

The built-in record-level meter in this type of recorder does double duty as a battery-level voltmeter. When the pointer falls below the limit indication on the scale during playback, the battery should be replaced. The technician must be on guard to distinguish between motor trouble and regulator trouble. If a motor fails to operate or develops subnormal torque when energized directly by its rated voltage, replacement is advisable. Repair of small DC motors is a specialized job that usually exceeds the capabilities of a recorder service shop. Commutators and brushes are the most common troublemakers; a commutator cannot be resurfaced unless a small lathe is available.

Larger AC-operated recorders generally use induction motors. Professional machines may have synchronous motors. A synchronous motor provides highly accurate speed. However, this type of motor is comparatively expensive because it must be supplemented by an auxiliary starting motor. The starting motor is ordinarily built into the same housing with the synchronous motor. Some shops do a limited amount of repair work on AC motors, although the general policy is to replace any motor that does not operate normally. Most recorder motors are self-lubricated, although a few require an occasional drop of oil in the bearings.

When slow-speed symptoms are localized to the motor, check the motor bearings. Reduced speed and slow starting can be caused by dry bearings. Gummed bearings can also cause seizure or "freezing" of the motor. To clean and lubricate the bearings, the motor must be disassembled. Remove the necessary nuts and machine screws while laying the parts out in the order that they were removed, as

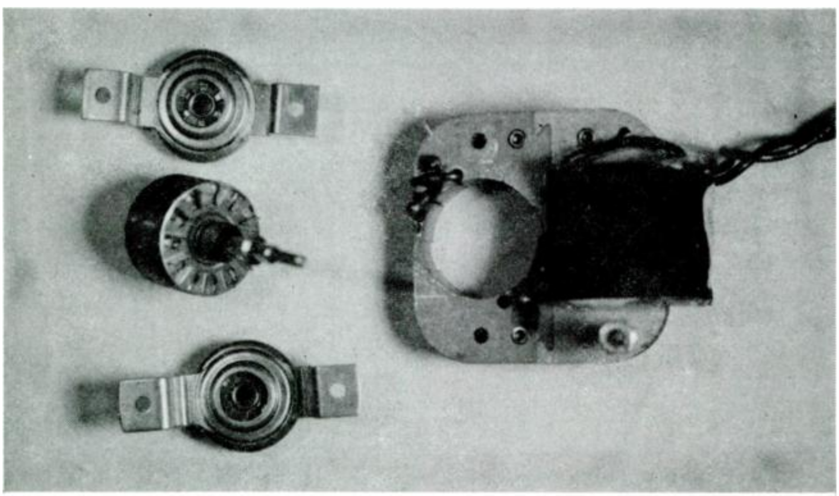


Figure 27 — Disassembled motor parts laid out in order of removal.

illustrated in Figure 27. Note that if the field coil is turned over during reassembly the motor will run backwards. Therefore, it is good practice to mark one end of the coil for identification. Then remove both top and bottom bearing assemblies and withdraw the armature. All parts should now be well cleaned with a suitable fluid such as trichloroethene or its equivalent. (Carbon tet has poisonous fumes and should be avoided.) It is particularly important to remove hardened or scaly deposits in the cleaning process.

With reference to Figure 28, the felt motor-bearing cups should be lubricated with a small amount of light oil, such as sewing-machine oil. If the trouble symptom is noisy or screeching operation, the bearings are probably scarred and excessively worn due to lack of lubrication. Damaged bearings must be replaced. The motor-bearing casing is mounted in the motor end piece.

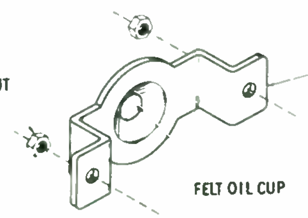


Figure 28 — Motor-bearing cup.

If it loosens, the armature will rub against the field poles, causing a slow-down, or sometimes "freezing" the armature. Loose bearings can be repositioned in most instances, and tapped into place with a small hammer and punch. Finally, check to see that the bearing alignment is correct. The armature should spin freely when twisted between your fingers.

Common Symptoms

1. No Movement of Tape

a. Power failure due to dead battery, defective power cord, defective off-on switch, or similar fault in the electrical circuit.
b. Incorrectly spliced tape is not passed by capstan. Remove tape and splice properly.
c. Pressure roller spring is loose or broken and the capstan does not press against tape. Replace spring.
d. Oil film on drive surfaces. Inspect and clean thoroughly.
e. Worn or otherwise defective belt. Clean pulleys and replace belt.
f. Rubber tire worn or glazed. Replace tire or wheel-and-tire assembly.
g. Defective component in motor regulator circuit.
h. Motor pulley loose on shaft. Tighten setscrew.
i. Defective motor. Remove, inspect, and replace if necessary.
j. Mechanism jammed by power cord. Disengage cord and route it correctly.
k. Idler dirty, worn, or binding. Inspect and replace if defective.

Sometimes the tape will start to move, and then climb up or down as it passes between the capstan and pressure roller before it stops. In most cases, this symptom is caused by foreign matter on the capstan and pressure roller. The trouble can be cured by a careful cleaning procedure. However, if the trouble persists, other possibilities must be checked. In rare cases, the tape fails to move because the supply spindle is jammed due to a brake defect. This trouble should not be confused with reel jamming in a defective cassette. Always check tape travel with a test cassette that is known to be good.

2. Incorrect Tape Speed

a. Drive belt worn, stretched, or greasy. Inspect, and clean or replace as required.
b. Intermediate wheel worn or dirty. Replace or clean.
c. Oil or other contaminant on drive surfaces. Check surface areas and clean if necessary.
d. Brake defect causes brake shoe to drag on supply turntable. Look for loosened, bunched-up felt pad, or other fault in brake assembly.
e. Dry flywheel bearing. Lubricate according to service data.
f. Unusually cold mechanism. Check operation after the recorder has come up to room temperature.
g. Speed selector is not functioning normally. Broken or detached springs in the speed-selector mechanism are frequent culprits.
h. Defective motor, as discussed previously.
i. Contaminated tape or defective cassette; check with a test tape.

3. Defective Braking Action

a. Brake-pad assembly may be misadjusted. Inspect and adjust per service data. Replace pad, if defective.
b. Weak, broken, or missing brake spring. Replace spring.
c. Brake shoe fails to retract. Inspect mechanism for loose screws, misadjustment, or defective parts.
d. Oil or other contaminant on braking surfaces. Inspect and clean thoroughly, if required.
e. Gummy deposits on friction surfaces cause brakes to grab and break the tape. Clean the surfaces and replace the brake pads, if necessary.

4. Incorrect Tape Tension

a. Brake shoe dragging (see symptom 3).
b. Clutch felt gummy or otherwise contaminated. Inspect and clean or replace, as required.
c. Warped reel may be scraping the top plate. Replace defective reel.
d. Gummy or otherwise defective tape; check with a test tape.
e. Dry or otherwise defective idler or drive-wheel bearings. Lubricate according to service data. Replace defective parts.

Although the tape tension is correct, an old tape may occasionally squeak or squeal. Modern tapes are specially lubricated by a treatment designed to prevent squealing. Sticky binder material or excessive surface smoothness can cause the layers to adhere. If a tape is gummy, it will stick to the head intermittently, producing a staccato squeal. This tendency is aggravated by high temperature and humidity. If this source of incorrect tape tension is encountered, the tape heads should be cleaned. The tape can be cleaned with a jockey cloth. In difficult situations, try reducing the force on the pressure pad. Since pads are not used with hyperbolic heads (Fig. 29), this expedient may not be possible. In any case, the pressure of a pad cannot be reduced greatly below its specified value, or sound reproduction will be impaired.

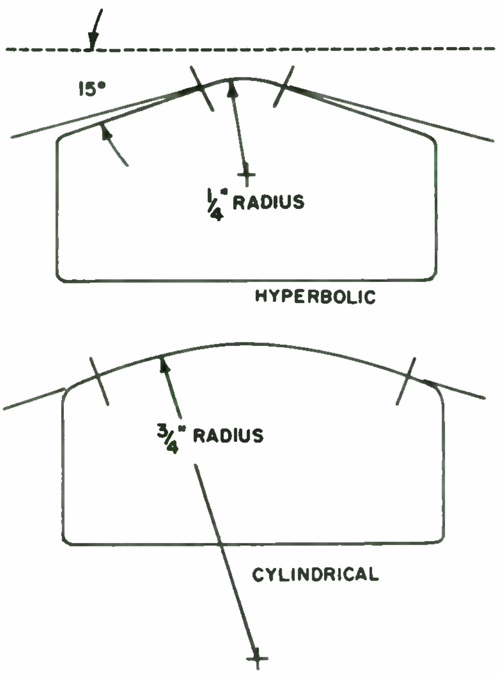


Figure 29 — Cylindrical and hyperbolic types of tape heads.

5. Erratic or No Response to Control Operation

a. Loose setscrew in control knob.
b. Defective cable or plug.
c. Loose or broken spring in pushbutton assembly.
d. When the track-shift mechanism is inoperative in an 8-track machine, make a systematic check as follows:
   1. Inspect the contactors of switch (S_2 Fig. 30) for gummy-deposits or corrosion. Shift mechanism normally operates when the contactors are short-circuited, as by the sensing foil on a tape.
   2. Cam (3) may be binding or worn. Inspect and lubricate or replace, as required.
   3. Pawl (4) may be worn. Replace if necessary.
   4. Arm (6) may be binding. Inspect, clean, and lubricate, as indicated.
   5. Solenoid (M_3) may be open or shorted, or its circuit may be defective. Make voltage and resistance checks.
   6. Occasionally, a defective cartridge will simulate track-shift defects.

6. Take-Up Reel Does Not Revolve in Fast Forward

a. Idler may be dirty, worn, or binding. Inspect and clean or replace, as required.
b. Motorpulley may be contaminated by lubricant or other foreign matter.
c. The reel-spindle boss spring may be missing. Inspect and replace, if necessary.
d. Take-up reel table assembly occasionally binds; mechanism may be contaminated with encrusted foreign substance. Inspect and clean as required.

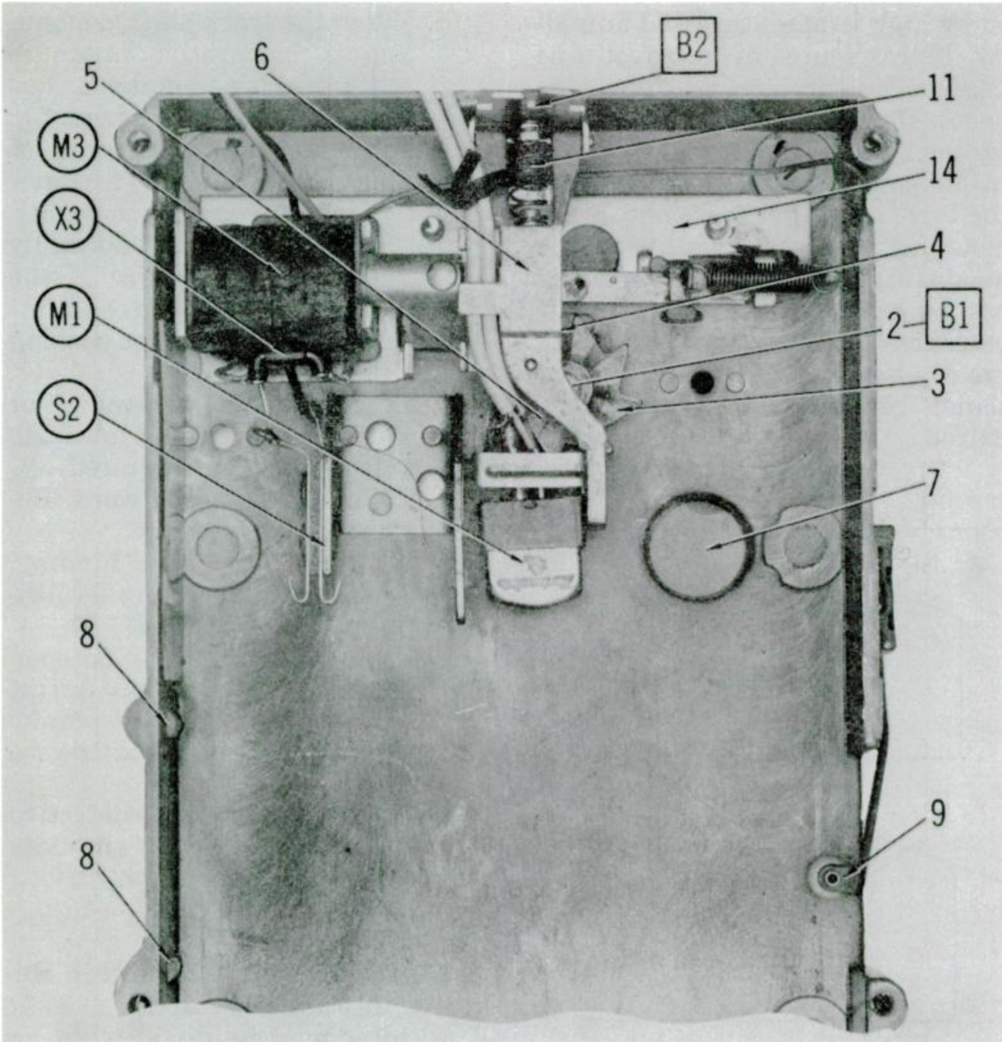


Figure 30 — Shift mechanism for an 8-track machine.

e. Brake defect, as explained previously.

7. Supply Reel Does Not Revolve in Rewind

a. Supply reel table assembly may be binding due to dirt or a mechanical defect. Inspect and clean, as required. Replace defective parts.
b. Reel spindle boss spring missing. Replace spring.
c. Brake defect, as explained previously.
d. Tape jammed due to defective splice. Remove tape and splice correctly.

8. Tape Rides Up and Down Between Capstan and Pressure Roller

a. Oxide deposits or oil on capstan and roller. Clean as required.

b. Pressure roller mounting stud not parallel to capstan. If the stud cannot be bent back into correct position, the assembly must be replaced.
c. Excessive take-up torque. Measure the torque, as explained previously and make necessary adjustments.
d. Scored capstan. Inspect under magnifying glass. Replace if defective.
e. Worn or flattened pressure roller. Replace.
f. Bent capstan. Replace.

RECORDING TROUBLES

Recording troubles can be caused by various technical errors, such as using the wrong type of microphone with a given recorder, use of an excessively long input cable, or omission of an impedance-matching transformer. Other errors are incorrect orientation of a directional microphone, mismatch of recorder and tape player, use of inferior tapes, incorrect monitoring level, improper setting of tone controls, incorrect bias level setting, poor splicing, and incorrect multiple-recording techniques.

Common recording trouble symptoms are:

1. Weak or no recording action.
2. High-frequency attenuation.
3. Low-frequency attenuation.
4. Misplaced pitch.
5. Audio distortion.
6. Noise, hum, or interference in recording.

Microphones

A good recording cannot be made with a poor microphone. Most home recorders are provided with mediocre microphones. Since the sections and components of a recording system must work together to achieve the desired result, it is generally true that a home recorder will perform better with a high-quality microphone than with an inferior microphone. This general rule implies that the high-quality microphone provides an adequate output-signal level for the particular recorder, and that the input impedance of the recorder is such that the frequency characteristic of the microphone is not impaired.

Many high-quality recorders, and most professional types do not include microphones, and the purchaser either uses microphones that he has available, or buys suitable microphones separately. The highest-quality microphones are in the $250 price range, whereas an economy-type crystal microphone may be priced at $5. Microphones supplied with the lower-priced recorders are usually of the omnidirectional type. Although the better units have a reasonably flat frequency response, an omnidirectional microphone can cause recording difficulties by picking up too many echoes. Objectionable reverberation effects can be minimized or eliminated by correct use of a directional type of microphone. Stereo recording requires a pair of identical microphones, as illustrated in Figure 31.

Three types of microphones used with home recorders are dynamic,

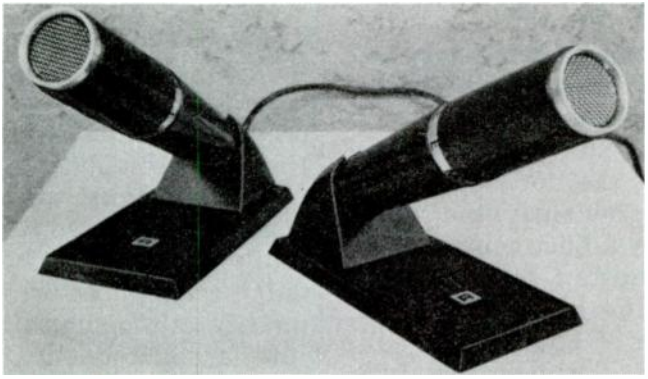


Figure 31 — A pair of identical dynamic microphones for a stereo recorder.

ceramic, and magnetic. A fourth type, the capacitor microphone, is used only with some professional recorders. A dynamic microphone can be compared with a dynamic speaker since it employs a moving coil in a magnetic field. The moving coil may be merely a metal strip, as in a ribbon mike. A dynamic microphone can be designed for any of the common source-impedance values. A dynamic microphone that has a low source impedance can be operated with a suitable matching transformer to provide a high source impedance.

Ceramic microphones are similar to crystal microphones. A conventional crystal microphone employs a bimorph crystal of Rochelle salt. The crystal generates a voltage proportional to the stress or strain produced by an applied sound wave. Although the crystal microphone provides a comparatively high-level output, the susceptibility of the crystal to humidity and elevated temperatures has caused it to become obsolete. Certain ceramic crystals provide a piezoelectric effect and are used in ceramic microphones. Although a ceramic crystal has a lower-level output than a Rochelle crystal, the ruggedness and stability that it provides are very desirable characteristics. The ceramic microphone is basically a high-impedance device, although some designs provide higher impedance than others.

The magnetic type of microphone is also called a variable-reluctance unit. It differs from the dynamic arrangement, in that the coil does not move. Instead, the magnetic flux linking the coil is changed when a sound wave is impressed on the diaphragm. In one basic design, the diaphragm actuates a small permanent magnet. As a rule, magnetic microphones are designed with a high impedance output. Although the fidelity of a magnetic microphone is not one of its outstanding features, it is comparatively economical to manufacture. Many recorders are supplied with magnetic microphones. Although both magnetic and ceramic microphones are generally high-impedance types, their impedance components are significantly different. In turn, the practical characteristics of a magnetic microphone are not the same as those of a ceramic microphone.

Although most modern recorders are transistorized, many tube-type recorders are in use. In recorders that utilize tube-type amplifiers, the use of high-impedance microphones is most logical, with other things being equal. That is, low-impedance and medium-impedance microphones have the disadvantage in this case of requiring a well-shielded input transformer, which is quite expensive. The low-impedance range extends from about 35 to 75 ohms. Medium impedance is from 100 to 400 ohms; high-impedance values extend up to several-thousand ohms.

Recording Level Indication

Some recording troubles result from an incomplete understanding of the use of the level indicator. As previously noted, most recorders have some form of a level indicator such as a meter, eye tube, or neon bulb arrangement. A level indicator may need adjustment, in accordance with instructions provided in the recorder service data. The less elaborate recorders do not provide calibration controls, and any correction of recording-level indication is limited to replacement of defective components. In turn, it is necessary to "get the feel" of the level indicator, so that the volume control can be set to a point that avoids distortion. Note that the optimum level indication will vary according to the grade of magnetic tape that is used.

Tone-Control Difficulties

Most recorders have tone controls, although this feature is usually omitted on economy-type machines. A tone control might be used in only the playback mode for one brand of recorder, whereas the tone control is operative on both recording and playback functions of another make of machine. Still another recorder has a tone control that operates only in the recording mode. A better recorder will usually provide both bass and treble controls. These various arrangements can obviously make for recording trouble if the tone-control function is not clearly understood and utilized accordingly. Therefore, check the schematic diagram for the particular recorder, or make a test run to determine the function or functions on which the control is operative.

Bias-Waveform Distortion

Recording trouble may be encountered even when the bias voltage has a correct value, if the bias waveform is distorted. In normal operation, the waveform is practically sinusoidal. For this reason, it is good practice to check the bias voltage with an oscilloscope instead of a VTVM. If the positive half cycle of the bias waveform has greater or lesser amplitude than the negative half cycle, the tape will become magnetized accordingly, and the recorded tones will have second-harmonic distortion. Therefore, it is extremely important that the bias waveform of any recorder, that is capable of providing good-quality or high-fidelity recordings, be checked in case of a high percentage of distortion.

Although single-ended bias oscillators are used in economy-type recorders, we find push-pull configurations in the high-quality machines, as exemplified in Figure 32. The use of a push-pull oscillator circuit ensures that both the positive and negative half cycles of the output waveform will have equal amplitudes. Of course, component defects can cause waveform distortion. For example, if one of the transistors fails in Figure 32, the output waveform will be weakened and seriously distorted. A defective oscillator transformer can cause the same trouble, although this defect is much less likely to occur. Note that bias-waveform distortion that is normal in a low-priced recorder would be intolerable in a high-fidelity machine.

Common Symptoms

1. Weak or No Recording Action

a. Defective cartridge. Check with a test cartridge.
b. Microphone plug not fully inserted.
c. Defective microphone. Measure microphone output voltage with an audio VTVM, a sensitive oscilloscope, or make a substitution test with a test microphone.
d. Low-level microphone used with recorder designed for a high-level microphone. Check recording action with a high-level microphone of proper impedance.
e. Pressure pad worn or missing. Replace pad.
f. Pressure pad spring weak, broken, or missing. Replace spring.
g. Bias voltage weak or absent. Check value of bias voltage across recording head with a VTVM or scope, and compare with value specified in the service data.
h. Amplifier defect. Check recorder electronics as explained previously.
i. Defective recording head. Refer to previous discussion of heads.
j. Worn or broken function switch. Make continuity checks with ohmmeter.
k. Azimuth adjustment of recording head may be incorrect. Refer to previous explanation of azimuth adjustment.
l. Excessively long input cable used with a ceramic microphone. Use matching transformers to minimize signal loss, or use a microphone preamplifier.

2. High-Frequency Attenuation

a. In a reel-to-reel machine, the tape might be wound on the reel with the wrong side toward the head. Check, and rewind tape correctly, if necessary.
b. Excessive bias voltage. Measure the bias voltage across the recording head with a VTVM or oscilloscope, and compare with the value specified in the service data.
c. Tone control set incorrectly during the recording process.

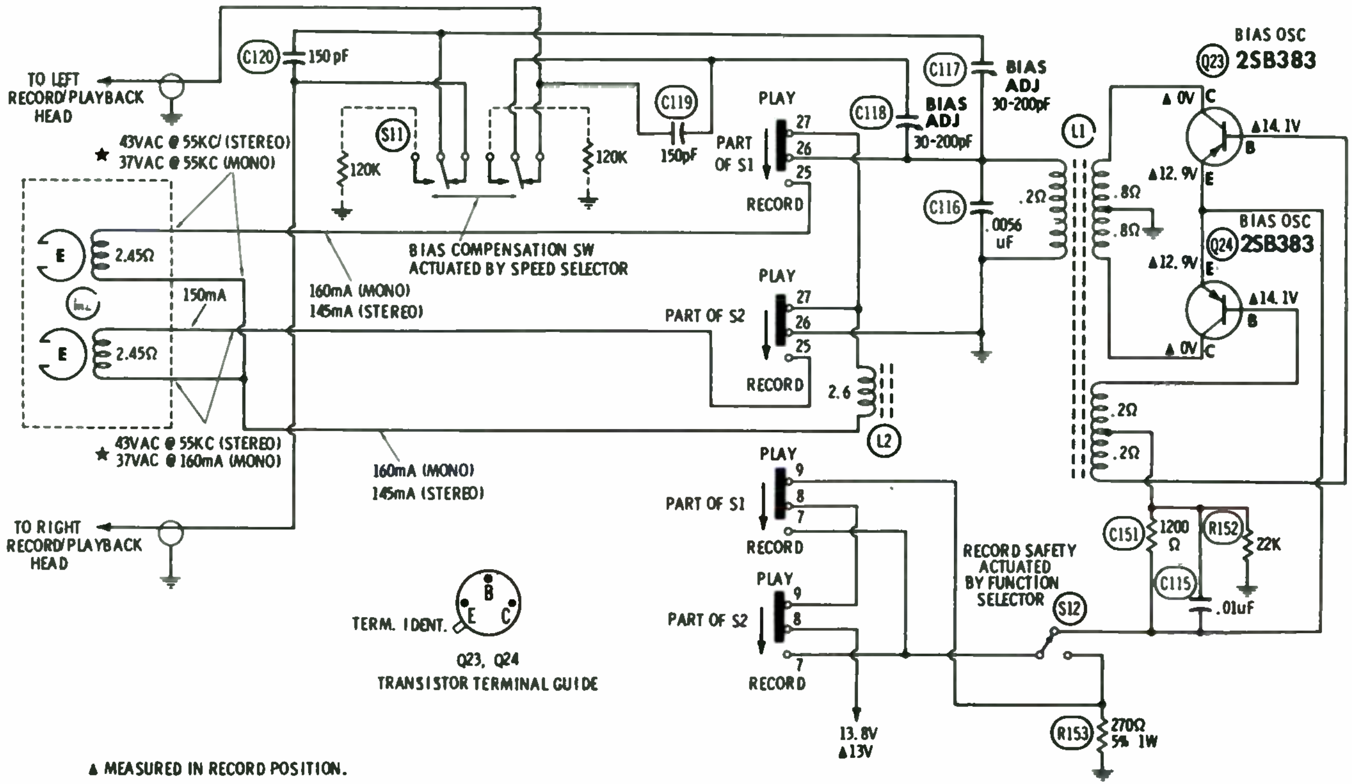


Figure 32 — A push-pull bias-oscillator configuration.

Refer to operating instructions for the recorder.

d. Excessively long input cable used with a high-impedance dynamic or magnetic microphone. Low-capacitance cable may correct the difficulty satisfactorily. Otherwise, use matching transformers to avoid capacitive loading of the microphone.
e. Magnetized recording head or other head defect. Refer to previous explanation of head maintenance and replacement.
f. Defective microphone. Check with a test microphone of the same type.
g. Amplifier defect. Check recorder electronics as explained previously.

Technicians new to tape recorder servicing must be careful to avoid confusion of recording troubles with playback troubles. The usual method is to check the playback action using a commercial prerecorded tape. If the play back is normal, we know that the trouble will be found in the recording function. It bears repeating here that a low tape speed cannot provide as good high-frequency response as a fast tape speed. Therefore, be sure to verify that the slow speed is not being used before concluding that objectionable high-frequency attenuation is occurring in the recording process.

3. Low-Frequency Attenuation

a. Tone control set incorrectly while recording. Refer to operating instructions for the recorder.
b. Incorrect type of microphone for the recorder input circuit. Use recommended type of microphone.
c. Improper or poor quality matching transformer. Use the proper good-quality transformer.
d. Amplifier defect. Check recorder electronics as explained previously.

4. Affected Pitch

a. The recorder may be running too fast or too slow. Check the tape speed, and adjust if necessary, as discussed previously.
b. A tape recorder may have excessive take-up torque. Refer to discussion of take-up torque measurement and adjustment.
c. The pressure-roller spring in the capstan assembly may be weak, with the result that the tape tends to slip. Refer to previous explanation of pressure-roller action and adjustments.
d. Tape may be defective. Check recording action with a known good tape.
e. If the line voltage fluctuates substantially, the slip of an induction motor will vary sufficiently to cause symptoms of misplaced pitch. An automatic line-voltage regulating transformer is a positive cure.

5. Audio Distortion

a. Bias voltage incorrect, or bias waveform non-sinusoidal. Check with calibrated scope.
b. Overdrive, due to incorrect adjustment of recording-level

indicator. Try recording at lower level. Adjust level indicator if necessary.

c. Tape cartridge may be defective.
d. Recording head dirty, misadjusted, or defective. Refer to previous explanation of head maintenance, adjustment, and replacement.
e. Defective microphone. Substitute with known good microphone.
f. Amplifier defect. Check recorder electronics as explained previously.

6. Noise, Hum, or Interference in Recording

a. Tape does not move smoothly past the recording head, or vibration is present at the head. Check transport mechanism as explained previously.
b. Defective tape. Check recording action with a test tape.
c. Dirty or worn switch contacts; check switching circuits with scope for spurious noise pulses.
d. Amplifier or power-supply defect. Check recorder electronics as explained previously.
e. Incorrectly routed cables in a combination unit. Check service data for routing instructions, to avoid stray-field pickup.
f. Defective microphone. Check with a test unit of the same type.
g. Poor-quality matching transformer that picks up stray 60-Hz hum. Use a good-quality transformer.
h. Defect in erase section of recorder. Check recording and erase action with a new tape.
i. Exposure of recorder system to excessively strong fields, as when recording near a radio transmitter. Recorder should be relocated.

REPRODUCTION TROUBLES

Trouble symptoms in the reproduction system can be caused by a wide variety of improper operating procedures, incorrect connecting arrangements, mismatched devices or units, poor installation methods, and so on. Some causes of trouble symptoms, such as weak batteries, are obvious; others, such as audio distortion, may require systematic analysis and tests to locate. It follows from previous discussion that certain types of trouble symptoms, such as poor frequency response, or high percentage of distortion, must be evaluated with respect to system capabilities. In other words, an economy-type system cannot be expected to perform like an expensive professional system. Common trouble symptoms caused by defects in the reproduction system are:

1. No playback.
2. Crosstalk.
3. Weak sound output.
4. Distorted audio reproduction.
5. Noise, hum, or interference.
6. Intermittent reproduction.

SERVICING TECHNIQUES

Trouble symptoms in the reproduction system can be caused either by mechanical or be electrical/electronic defects. Even an experienced technician will not always recognize the exact malfunction or fault without making appropriate tests and measurements. Occasionally a trouble symptom is imaginary, as in the case of a hyper-fidelity buff who fancies that his player is out of rated distortion limits. In such case, the subjective factor must be eliminated by measuring the percentage of harmonic or intermodulation distortion in the output signal. Few hypercritical customers will argue with such an objective measurement.

Speaker Connections

Among the simpler electrical troubles to be contended with are incorrect speaker wiring arrangements. In any audio system, it is important for the speakers to operate "in phase." That is, their cones should be moving in the same direction at any given instant; otherwise, the radiated air waves work against each other. It is evident in Figure 33 that if one cone is "pushing" while the adjacent cone is "pulling," the resulting air waves will be out of phase. This phase error causes a considerable loss of "richness" in either stereophonic or monophonic reproduction. The acoustic deficiency is most prominent at the lower audio frequencies.

An amplifier should not be operated without the speaker or speakers connected, unless a suitable power resistor is substituted for the speaker load. It is quite possible for an amplifier to be seriously damaged if operated without a load. This is especially true of solid-state amplifiers. Load values are measured in ohms and although speaker loads are AC impedances, they can be treated as resistances when using power resistors as substitute loads. In the more elaborate machines a choice of operating impedances is often provided, such as 4, 8, and 16 ohms. We choose an output impedance which most nearly matches the voice-coil impedance of the speaker to be driven.

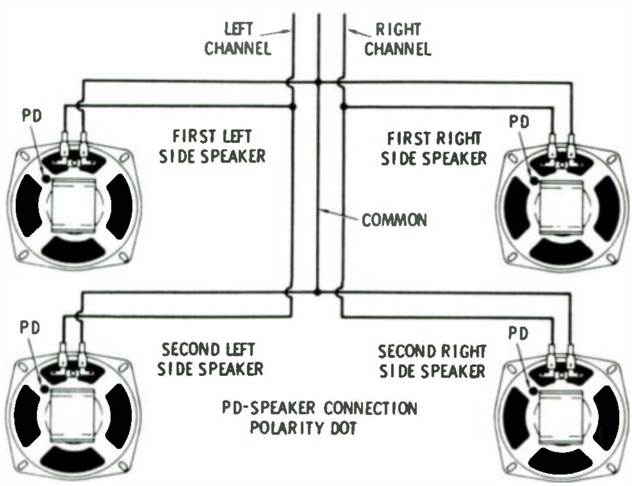


Figure 33 — Typical speaker-wiring diagram.

AUTO UNIT INSTALLATION PROBLEMS

Among typical installation problems, let us consider high noise levels in an auto tape system. Because a tape player employs much higher gain than the audio amplifier in a radio, ignition interference, for example, must be suppressed to a comparatively low level. The basic points of concern are the battery circuit, spark plugs, and ignition coil. Figure 34 shows how a suppressor resistor is installed in the ignition-coil lead near the distributor cap. This resistor lowers the Q of the spark circuit and thereby inhibits oscillatory discharge. Figure 34 also shows the connection of a bypass capacitor from the ignition-switch lead to ground. This capacitor drains the oscillatory discharge from the primary winding of the ignition coil and thereby minimizes radiation from the primary lead. A 0.1-μF bypass capacitor is usually ample. If greater suppression is needed, a coaxial capacitor may be used as shown in Figure 35.

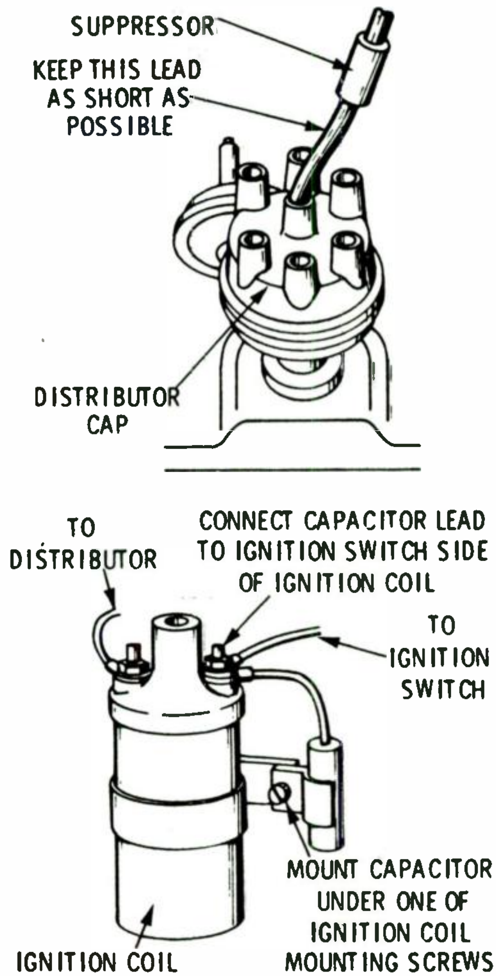


Figure 34 — Ignition noise suppression.

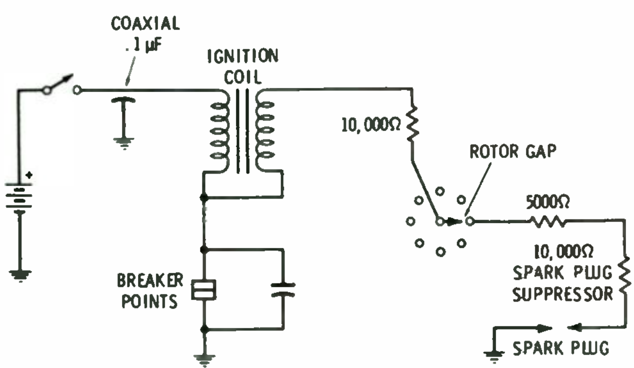


Figure 35 — Suppressor arrangement for an ignition system.

Sometimes the battery circuit remains troublesome, even when a coaxial bypass capacitor is connected across the primary of the ignition coil. In such case, it is advisable to try a pi filter, as shown in Figure 36. The optimum inductance value may be different from the 0.1-mH value indicated, depending upon the particular ignition system. Also, the resistance of the choke must be sufficiently low that it does not overheat. Note in Figure 35 that spark-plug suppressor resistors have a typical value of 10,000 ohms. A suppressor resistor is required for each plug. IF the noise level remains objectionably high, try inserting a 5000-ohm suppressor resistor at each spark-plug tower on the distributor. It is good practice to use commercial suppressors throughout, and to avoid problems encountered with non-standard rigs.

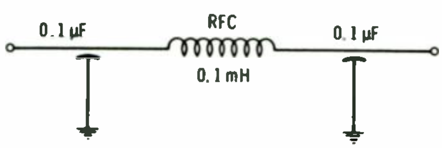


Figure 36 — Pi filter for noise suppression.

When trouble persists, it may be necessary to install shielded ignition wire. A good quality of wire is fabricated with distributed resistance instead of lumped resistance. This design is helpful in reducing any tendency of oscillatory discharge. This shielded wire is available in kit form, and is pre-cut to required lengths. With reference to Figures 37 and 38, generator and alternator bypass capacitors should be connected from the "hot" terminal to ground, and may have a value in the range from 0.1 to 0.25 μF. It is sometimes necessary to bypass the leads that connect to the voltage regulator, as illustrated in Figure 39. A coaxial-type capacitor with a value in the range from. 0.1 to 0.25 μ F is inserted between the battery terminal of the voltage reg-

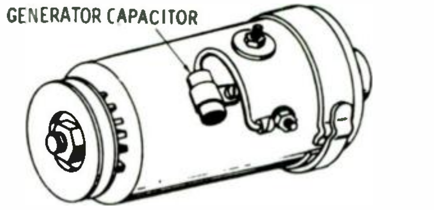


Figure 37 — Generator noise suppression.

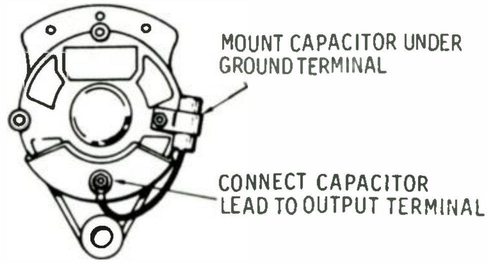


Figure 38 — Alternator noise suppression.

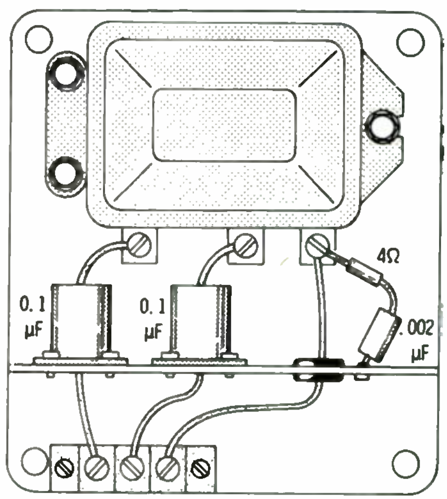


Figure 39 — Bypassing the voltage-regulator leads.

ulator and the battery lead, with a good ground connection. A similar capacitor is inserted between the generator terminal of the voltage regulator and the generator lead. Note that a series resistor-capacitor path is provided from the field terminal of the voltage regulator to ground.

It is often helpful to install a commercial auto-stereo filter in the power lead to the player, as shown in Figure 40. Obscure causes of noise problems occasionally have to be tracked down. For example, a loose machine screw or rivet may permit intermittent contact of metal surfaces with the result that erratic clicking noises become audible from the player. Riveted parts may be mechanically solid, but develop noise due to oxides on the adjacent surfaces. In this situation, copper braid can be used to provide good electrical bonding between the riveted parts.

Remember to check out the obvious trouble possibilities first. For example, a serious noise problem might be caused by a loose connection or by a plug that is not fully inserted into its socket. Sometimes the cause of the trouble is internal, instead of external. That is, a defect in the player can cause a noise problem. Therefore, it is helpful to make a cross-check by listening to the car radio as well as to the player. If the radio is not affected by the noise condition, it is likely that the cause of the trouble is in the player. This is not an invariable clue, however, due to the fact that much higher audio gain is employed in a tape player than in a radio. Remember too, that noise pulses can be traced with a sensitive oscilloscope. If you have a high-gain portable scope, considerable time can often be saved by tracing a noise pulse down to its point of origin.

Common Symptoms

1. **No Playback**
   a. Plug not fully inserted; loose connecting wire.
   b. Tape may be improperly threaded (reel-to-reel machines).
   c. Loose knob on function selector.
   d. Pressure-roller spring weak, broken, or missing (see previous discussion of tape transport).
   e. Defective cassette or car-

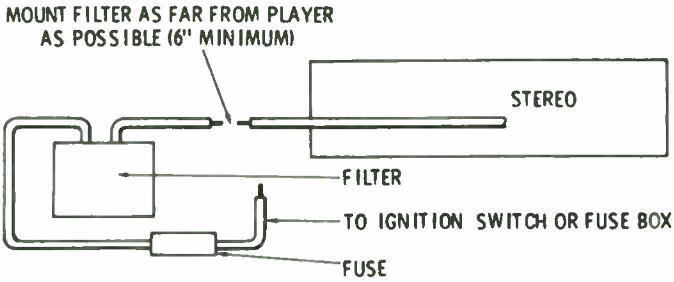


Figure 40 — Interference filter at tape-player power input.

tridge; make a substitution test.

f. Defective playback amplifier (see previous coverage of tape-recorder electronics).

g. Erase-circuit switch jammed or otherwise short-circuited, causing undesired erasure of recorded tape.

h. Speaker switch (if present) may be set incorrectly; check and reset, if necessary.

2. Crosstalk

a. Tape may have been recorded with a defective erase function; check playback action with a test tape.

b. "Fine tuning" control in an 8-track cartridge player may be misadjusted. The control, which adjusts head height, has a normal range up to the edge of adjacent channels, where crosstalk will be heard.

c. Head height may need adjustment (see previous maintenance discussion).

d. Track-shift cam assembly may be worn or otherwise defective (see previous coverage of tape transport).

e. Crosstalk between left and right stereo channels may be caused by certain amplifier defects (see previous discussion of tape-recorder electronics).

3. Weak Sound Output

a. Playback head dirty, defective, or misadjusted (see previous explanation of head maintenance and replacement).

b. Defective cassette. Check with a test cassette.

c. Amplifier defect (see previous discussion of tape-recorder electronics).

d. Excessively long leads from player to speaker; use lower resistance leads to minimize loss.

4. Distorted Audio Reproduction

a. Defective cassette or cartridge; check with a test tape.

b. Playback head excessively worn or otherwise defective (see previous explanation of head maintenance and replacement).

c. Pressure pad matted or otherwise defective (see previous discussion of tape transport).

d. Equalization circuit used in recording does not match equalization circuit used in playback. Use tape with proper equalization for the particular player.

e. Amplifier defect (see previous discussion of tape-recorder electronics).

f. Speaker impedance mismatched; try using another impedance tap, or cross-check with other speakers.

g. Poor room acoustics. Relocation of speakers may be helpful.

5. Noise, Hum, or Interference

a. Loose connection or other defective contact.

b. Defective recording; check with a test tape.

c. Plug not fully inserted.

d. Defective power supply (see previous discussion of tape-recorder electronics).

e. In auto tape units, ignition-spark suppression may be insufficient; use proper suppressor resistors and bypass capacitors. Shield the wiring if necessary.

f. Poor grounds and loose bonding of metal surfaces can also cause noise in auto tape units.

g. Power lead to auto tape unit may require filtering.

h. Interference can be picked up by players operating in strong stray fields. Remove player from field or provide shielding.

6. Intermittent Reproduction

a. Noise may have an intermittent characteristic; see items under symptom 5.

b. Mechanical or thermal intermittent in the amplifier section; use standard radio-servicing techniques to locate.

c. Defective cassette or cartridge; check with a test tape.

d. Erratic operation of tape transport (see previous discussion of transport).

e. Broken conductor inside of an insulated lead; flex the leads to see if the intermittent condition occurs.

SUMMARY

Servicing a tape recorder is similar to servicing any piece of electronic equipment. An important point to remember is the definite dividing line between the tape transport system and the electronic circuitry. Through the use of a systematic checkout of a tape recorder, the problem area may be quickly isolated to a particular section and troubleshooting can proceed from this point.

For example, a customer brings in a tape recorder and complains that the tape is not moving. A logical place to begin would be to check for available power. If power is available, the problem is probably in the drive system. A check to see if the capstan turns when the function selector is placed in the record or rewind position will further isolate the problem. If the capstan does not turn, a check should be made of any automatic stop or shut-off switches. At this point it may be necessary to disassemble the transport system to check the drive motor and drive system. A logical, step-by-step procedure will usually locate the problem.

A systematic check of the recorder should be completed when the malfunction has been repaired. This may uncover other problems that the customer has not discovered.

A quick check of the trouble symptoms listed in this lesson may further simplify troubleshooting of a tape recorder. First, identify the symptoms, find the symptom in the associated trouble section, and check the possible causes listed. This could reduce the service time required for a particular recorder.

TEST

Lesson Number 76

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-076-1.

1. **The playback head in a tape player produces a signal that measures.**
   A. several volts.
   B. 1 or 2 volts.
   C. a few millivolts.
   D. several hundred millivolts.

2. **The available tape loading system(s) in tape players is (are)**
   A. reel-to-reel.
   B. cassette.
   C. cartridge.
   D. all of the above.

3. **A systematic check out and cleaning operation of a recorder brought in for repairs should**
   A. be done only at the customer's request.
   B. be done on nearly all machines.
   C. be done only on newer machines.
   D. not be done because it is a waste of time.

4. **A tape recorder may fail to erase because the**
   A. bias oscillator has failed.
   B. tape is old.
   C. capstan is bent.
   D. motor is fast.

5. A tape recorder may fail to record because the
- A. motor is slow.
- B. tape is old.
- 44h C. capstan is worn.
- D. amplifier is defective.

6. One check for determining misalignment of a combination record/playback head is to
- 12 A. play a tape recorded on a verified test machine.
- B. measure the height of the head.
- C. check output waveform with an oscilloscope.
- D. play back a tape that was recorded on the machine in question.

7. Incorrect braking action can be responsible for
- A. wow and flutter.
- B. poor quality recordings.
- C. poor quality playback.
- D. all of the above.

8. An oscilloscope is generally preferred over an AC VTVM for signal tracing tape recorder electronics because
- A. it can make more accurate voltage checks.
- 21 B. it displays the signal along with noise, hum or other interference that may not be measurable with the VTVM.
- C. an oscilloscope can isolate AC signals from DC levels.
- D. DC levels affect the AC measurements made with an AC VTVM.

9. Variations in tape speed can cause
- A. wow.
- B. flutter.
- C. incorrect pitch. 44
- D. all of the above.

10. Crosstalk in an 8 track cartridge player is often due to
- A. a worn clutch assembly.
- 52 B. worn belts.
- C. a defective or worn track shift cam assembly.
- D. a defective motor.

Notes

Notes

Portions of this lesson from
Tape Recorder Servicing Guide by
Robert G. Middleton
Courtesy of Howard W. Sams, Inc.

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THE ABILITY TO ANALYZE

Your ability to analyze failures in various types of electronic equipment is much more important than your ability to fix or replace the defective parts.

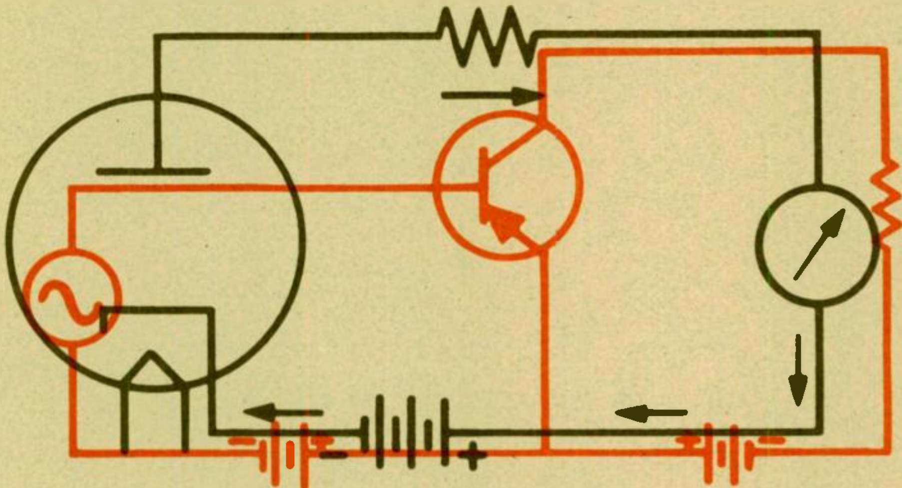
In fact, the man who can quickly and easily analyze such failures and determine the faulty part can do double or even triple the amount of repair work that a serviceman who does not have this ability can perform.

This knowledge will enable you to become a very valuable employee and one whose knowledge and advice are very much in demand.

S. T. Christensen

LESSON NO. 77

REVIEW FILM OF LESSONS 73 THROUGH 76



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-077
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Reprinted October 1974

REVIEW FILM TEST

LESSON NUMBER 77

The ten questions enclosed are review questions of lessons 73, 74, 75, & 76 which you have just studied.

All ten are multiple choice questions, as in your regular lesson material.

Please rerun your Review Records and film before answering these questions.

You will be graded on your answers, as in the written lessons.

REMEMBER: YOU MUST COMPLETE AND MAIL IN ALL TESTS IN THE PROPER SEQUENCE IN ORDER FOR US TO SHIP YOUR KITS.

REVIEW FILM TEST

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-077.

1. A basic phonograph contains a
A. turntable, arm, and cartridge.
B. turntable and motor, tonearm and cartridge.
C. turntable and motor, tonearm and cartridge, amplifier and speaker.
D. none of the above.

2. The theory of operation of a magnetic phono cartridge is
A. a wire in a magnetic field.
B. piezoelectric.
C. thermocouple.
D. static electricity.

3. The theory of operation of a ceramic cartridge is
A. a wire in a magnetic field.
B. piezoelectric.
C. magnetism.
D. static electricity.

4. Phonograph motors are usually
A. AC types.
B. DC types.
C. dynamotor types.
D. syncronous types.

5. Shading coils are
   A. used to keep motors cool.
   B. found in DC motors.
   C. used to start AC motors.
   D. kept in the shade.

6. The RIAA curve is the graph
   A. of the runout groove used to trip an automatic record player.
   B. found in record player schematics.
   C. adopted by the phonograph manufacturers.
   D. adopted by the Record Industry Association of America.

7. The most critical section of a tape recording playback head is:
   A. the coil.
   B. the gap.
   C. the laminations.
   D. none of the above.

8. High frequency audio response is impaired by
   A. tape oxide deposits on the playback gap.
   B. low bias oscillator power.
   C. slipping belt drives.
   D. low AC power line voltage.

9. Erasure of magnetic signals on a magnetic tape is due to
   A. hysteresis loops.
   B. a decaying DC field.
   C. atomic reorganization.
   D. de-polarization.

10. In the fast forward mode of a tape recorder
   A. the supply reel has high torque and takeup reel has low torque.
   B. the supply reel has high torque and the takeup reel has high torque.
   C. the supply reel has low torque and the takeup reel has low torque.
   D. the supply reel has low torque and the takeup reel has high torque.

Notes

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DOERS AND DREAMERS

You have completed more than three fourths of your ASI Radio and TV Service and Repair training program. By now, you are undoubtedly using much of the knowledge you have learned.

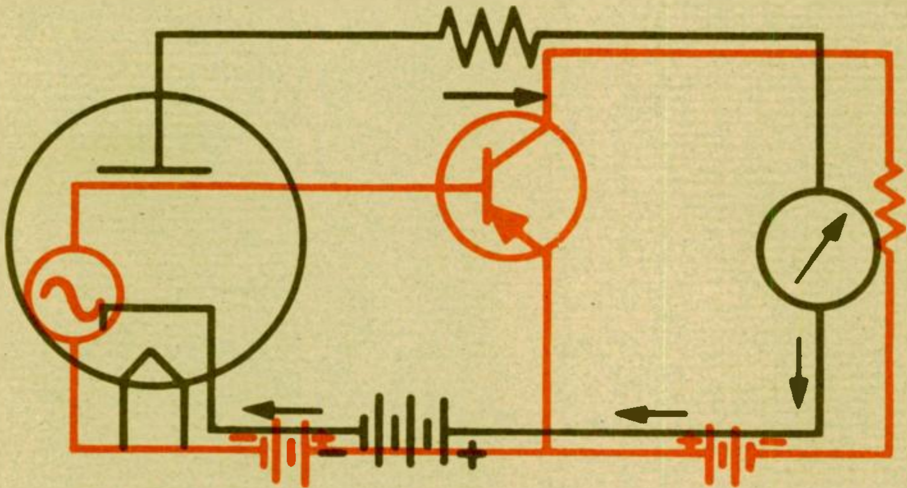
You are actually doing what many men just dream of doing. That is the difference between a dreamer and a doer. The very fact that you are a doer, that you have worked out a plan and are putting it into action, indicates that you have that certain "something" that all successful men have.

ASI has worked out a program of training that provides you with the knowledge and know-how necessary in the Radio and TV Service and Repair field. If YOU are a doer, you are already using your training to increase your earnings.

S. T. Christensen

LESSON NO. 78

STEREO HI-FI



RADIO and TELEVISION SERVICE and REPAIR

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LESSON CODE
NO. 52-078
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Reprinted October 1974

Contents

STEREO HI-FI

INTRODUCTION

As Hi-Fi stereo servicing is a major source of income for shops that are properly equipped and staffed, a reputation for reliability and competence in this field places the technician in a privileged position. Audio enthusiasts are well aware of the fact that true tonality is the chief vehicle of musical meaning; this segment of the home-entertainment market is much more demanding than the TV viewer or the casual radio listener. The dominant characteristics of a Hi-Fi stereo system are uniform frequency response over the entire audio-frequency range, a low percentage of harmonic and intermodulation distortion, and ample stereo separation. The acoustic properties of a Hi-Fi installation are also of basic concern. In turn, a working knowledge of Hi-Fi circuitry and troubleshooting procedures should be augmented by an understanding of audio test and measurement procedures.

Hi-Fi technicians often tend to specialize, because the field is so extensive. One who aspires to general practice in the hi-fi stereo field must acquire competence in troubleshooting of FM and AM tuners and multiplex, and should understand the repair of tape recorders, and record players. He must be fully familiar with the operation of audio oscillators, signal generators, sweep generators, stereo-multiplex generators, oscilloscopes, etc. This lesson covers all components of the Hi-Fi stereo system except record players and tape recorders, which are the subject of another lesson.

STEREO MULTIPLEXING

Basically, an FM stereo signal consists of two different audio-frequency signals that occupy the same FM channel. These separate audio signals provide stereophonic sound reproduction. The individual audio signals are identified as "left" (L) and "right" (R). In conventional programming, this pair of audio signals originates from a pair of microphones at a sound studio, as shown in Figure 1. The audio signal from the L microphone differs from that of the R microphone. Therefore, the stereo signal consists of two audio waveforms that vary independently in frequency and amplitude. At the receiver, the L and R signals are fed to separate speakers. These speakers are spaced a suitable distance apart to simulate the placement of the transmitting

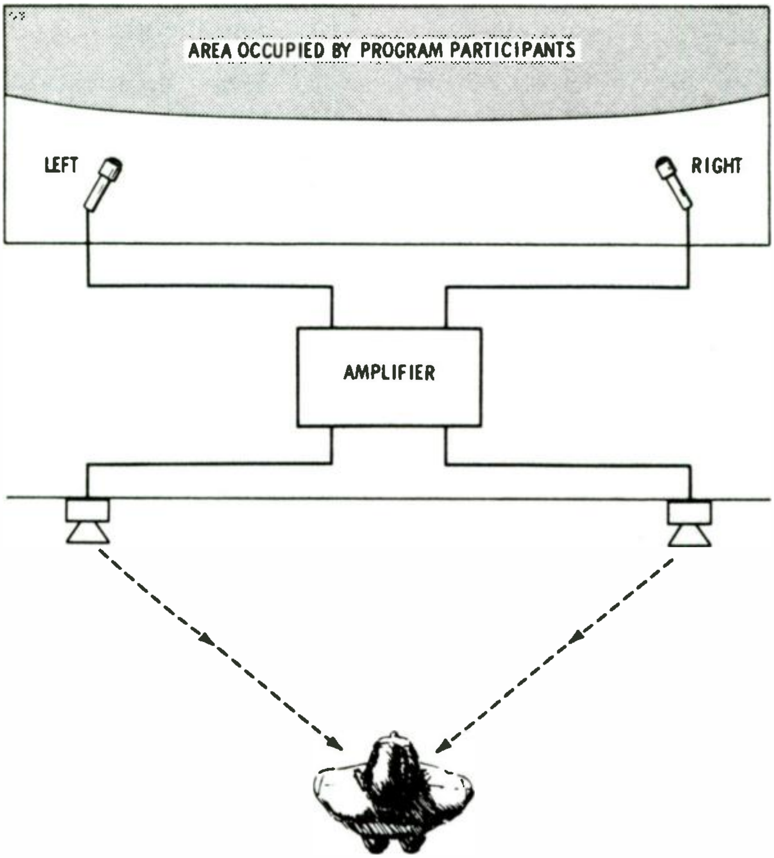


Figure 1 — Basic principle of stereophonic sound reproduction.

microphones. Figure 2 shows a block diagram of a typical AM/FM stereo chassis. The multiplex section in this example comprises the bandpass amplifier, 19-kHz pilot amplifier, 38-kHz oscillator, stereo indicator, detector, and matrix sections.

Common trouble symptoms caused by defects in the multiplex sections are:

1. No output.
2. One channel dead.
3. Weak output.
4. Poor separation.
5. Distorted output.
6. Separation-control setting drifts.
7. Stereo indicator failure.

Signal Generation

We know that in monophonic FM transmission, a swing of ±75 kHz represents full modulation and produces sidebands that occupy the entire channel. For this reason, the question arises how one channel can be used to transmit two signals without mutual interference. If high fidelity were not required, an FM channel could be divided into

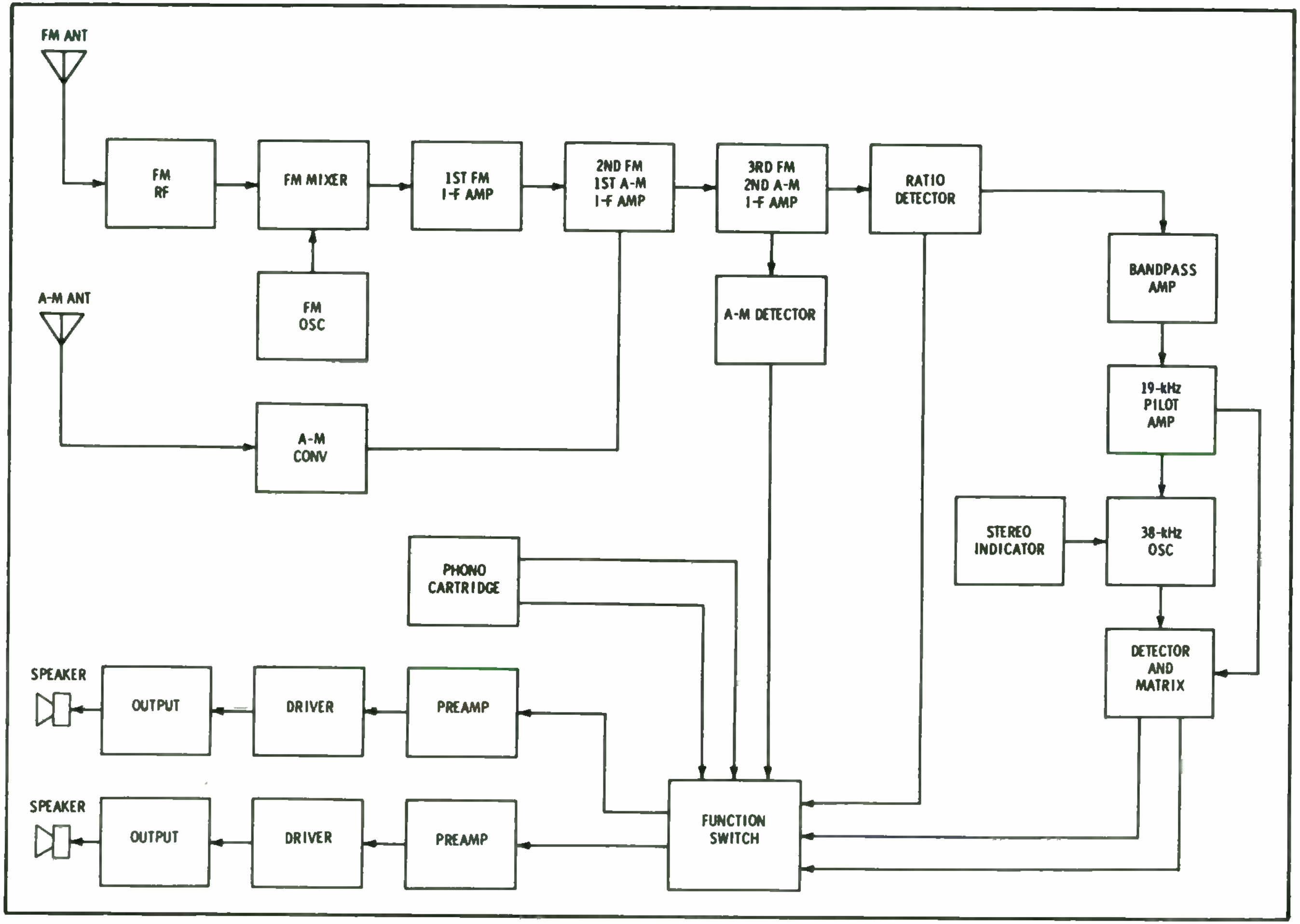


Figure 2 — Block diagram of a typical AM/FM stereo chassis.

two equal parts for transmission of the L and R signals on individual carriers. However, since Hi-Fi transmission is a basic requirement, a modulation method must be employed that permits each signal to occupy the entire channel bandwidth.

To transmit both the L and R signals with high fidelity in a single channel requires multiplex transmission. This is a technique that permits satisfactory separation of the L and R signals at the receiver. Standard multiplex transmissions are also compatible, which means that to a conventional mono receiver, the FM multiplex signal "looks like" a mono transmission. But to a stereo-multiplex receiver, the FM multiplex signal "looks like" separate L and R signals. A stereo-multiplex system starts with the conventional mono audio signal, which is produced as the sum of L and R signals. That is, two microphones are employed as the equivalent of a single microphone. When the L and R signals are mixed, as shown in Figure 3, the mono (L + R) signal is produced.

The L + R signal is frequency modulated on the RF carrier, and the result is the same as if a single microphone were used. Furthermore, to an ordinary FM receiver, only a mono signal is being transmitted—actually, as explained next, additional information to which an ordinary FM receiver is *unresponsive* is also being transmitted. To explain this additional transmitted information, let us consider the effect of adding a 38-kHz carrier as shown in Figure 4. Both the L + R signal and the 38-kHz carrier are frequency-modulated on the RF carrier. However, only the L + R signal can be reproduced at the FM receiver. That is, the 38-kHz carrier is out of the range of *audibility.* This is the fundamental multiplex transmitting principle.

Next, if amplitude modulation is impressed on the 38-kHz carrier, this modulated signal will be inaudible on an ordinary FM receiver. With reference to Figure 5, the L + R signal is frequency-modulated on the RF carrier, as before. In addition, an audio signal,

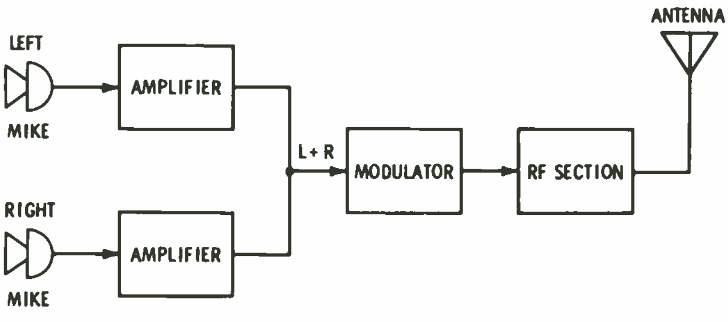
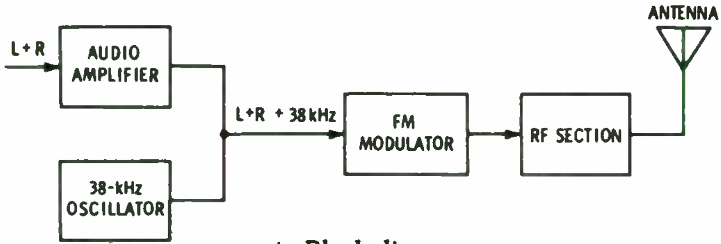
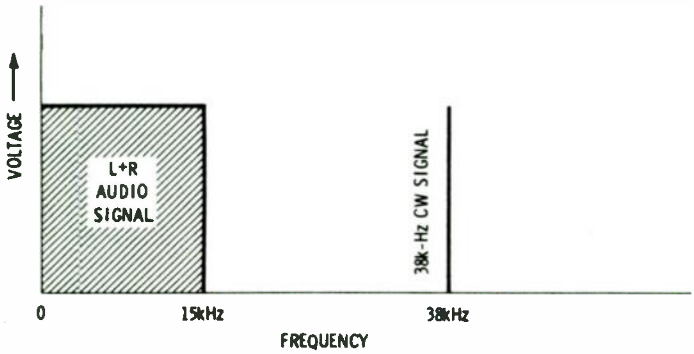


Figure 3 — Mixing of L and R signals produces a conventional monaural signal.



A Block diagram.



B Transmitted frequency spectrum.

Figure 4 — L+R and 38-kHz signals modulated on an RF carrier.

A2, is amplitude-modulated on the 38-kHz carrier; this amplitude modulation produces sidebands, and the RF carrier is modulated by these sidebands along with the L + R signal. Figure 5B shows the frequency spectrum of the modulating waveforms. The L + R signal has frequencies up to 15 kHz. On the other hand, the amplitude-modulated 38-kHz carrier has frequencies in the range from 23 kHz to 53 kHz. This represents an audio-frequency range up to 15 kHz.

Note that after the foregoing frequency spectrum is frequency-modulated on the RF carrier and then processed through the ratio detector of an ordinary FM receiver, the frequency spectrum is recovered in its original form, as shown in Figure 5B. Of course, only the L + R signal is reproduced by an ordinary FM receiver. In other words, the frequencies from 23 kHz to 53 kHz will be rejected by the audio system in an ordinary FM receiver; even if an extended-range audio amplifier were used, the reproduced tones would be inaudible to the ear. In multiplex terminology the frequencies from 23 kHz to 53 kHz are said to be "encoded" in the radiated FM signal.

Encoded Signal

Now, let us see how the encoded signal is recovered. Figure 6A

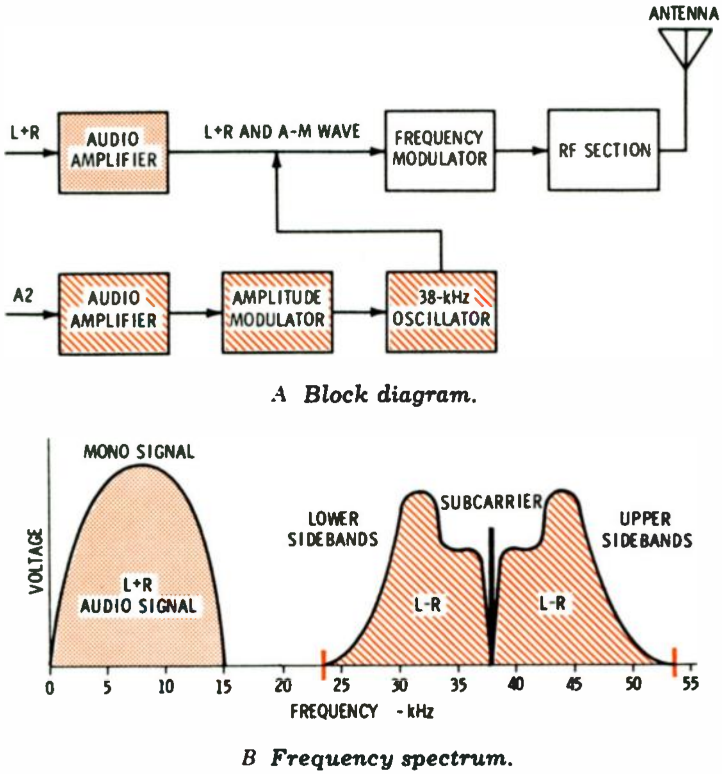
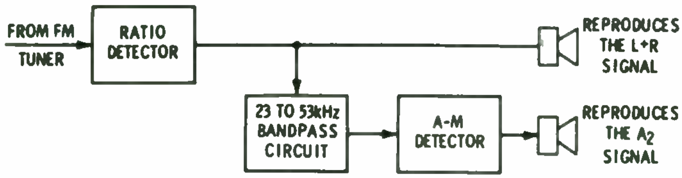


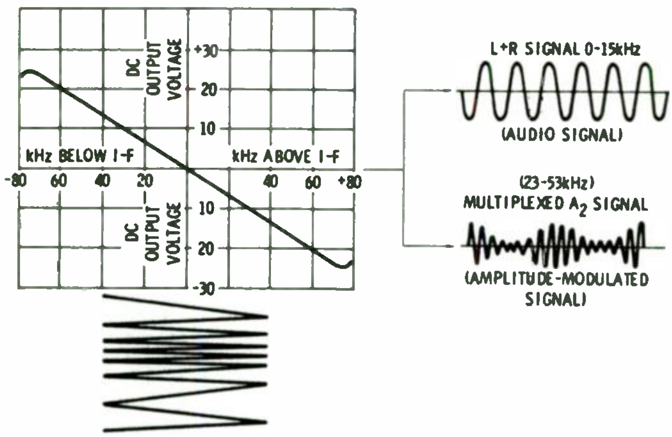
Figure 5 — Amplitude-modulated 38-kHz subcarrier combined with L and R signals.

shows a bandpass filter with response from 23 kHz to 53 kHz, driven by the ratio detector, and followed by an AM detector and a speaker. The bandpass filter picks out the AM signal, which is then demodulated by the AM detector. In turn, the demodulated (audio-frequency) wave envelope is fed to a speaker. This is the A2 signal shown in Figure 5. Note that the output from the ratio detector in Figure 6B is a mixture of the L + R and the A2 AM signal. Thus, the bandpass filter provides separation of the signals in this example. These basic functions are elaborated somewhat in actual practice so that the L signal will be reproduced by one speaker, and the R signal reproduced by another speaker. Basically, an L − R signal is generated by means of a phase inverter at the transmitter, as shown in Figure 7.

Observe that by inverting the polarity of the R signal and then adding it to the L signal, we obtain an L − R signal. Now, both L + R and L − R signals are available for processing (Fig. 8). If we add L + R to L − R, we will obtain 2L (the L signal with the R signal cancelled or separated). Again, if we subtract L − R from L + R, we will obtain



A Basic decoding system.



B Ratio-detector action.

Figure 6 — Method for reproducing the multiplexed signal

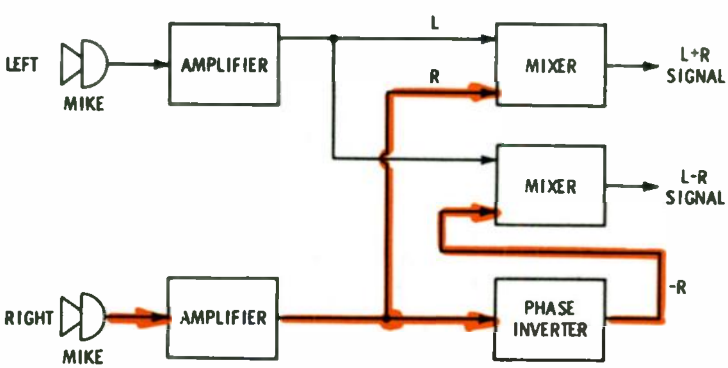


Figure 7 — Developing the L+R and L−R signals

Adding the (L+R) to the (L−R) Signals

$$\begin{array}{r} (L+R) \\ \underline{+\ (L-R)} \\ 2L+0 = 2L \end{array}$$

Subtracting the (L−R) signal from the (L+R) signal

$$\begin{array}{r} L+R \\ \underline{-\ (L-R)} \end{array}$$

is equivalent to

$$\begin{array}{r} L+R \\ \underline{-\ L+R} \\ 0+2R = 2R \end{array}$$

Figure 8 — Illustrating algebraic addition and subtraction of the L and R signals.

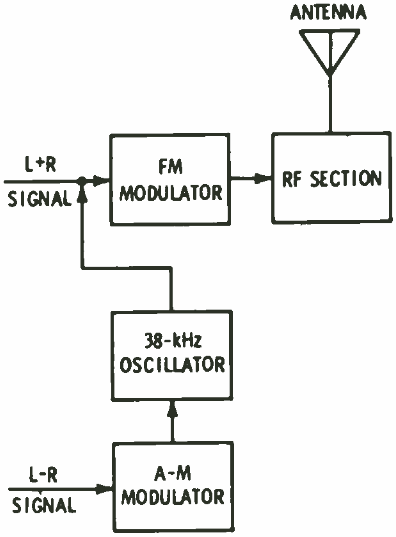


Figure 9 — Generation of the composite stereo signal at the transmitter.

2R (the R signal with the L signal cancelled or separated). Signal addition or subtraction is accomplished in mixers, with associated inverters. After the L and R signals have been separated from the L + R and L − R signals, we can feed the R signal to one speaker, and feed the L signal to the other speaker, thus obtaining stereo reproduction.

At the transmitter, the L + R and L − R signals are employed to frequency-modulate the RF carrier, as shown in Figure 9. The L − R signal is amplitude-modulated on a 38-kHz carrier, and the resulting signal is mixed with the L + R signal. In turn, the mixed signals frequency-modulate the RF carrier. Figure 5B shows the frequency spectrum of the modulating signal, wherein the upper and lower sidebands flanking the 38-kHz carrier are produced by the L − R signal. At the receiver, this same frequency spectrum appears at the output of the ratio detector.

To obtain stereo reproduction, the L − R signal is separated by means of a 23- to 53-kHz bandpass filter, amplitude-demodulated, and further processed in a phase inverter and a pair of mixers, as shown in Figure 10. The addition of L + R and L − R produces a 2L signal (Fig. 8). Subtraction of L − R from L + R (the same as adding L + R and −L + R) produces a 2R signal. Thereby, stereo reproduction is obtained from the speakers. Hi-Fi reproduction results if this processing is normal.

38-kHz Subcarrier

In theory, the 38-kHz carrier (technically termed the subcarrier)

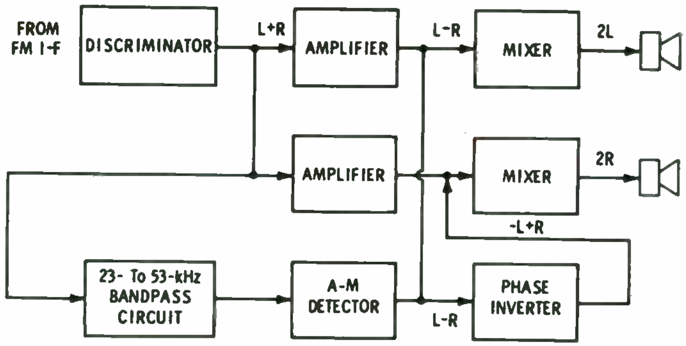


Figure 10 — Block diagram of a multiplex adapter for stereo reproduction.

could be transmitted. However, the subcarrier is suppressed in practice, thereby permitting the L − R sidebands to be transmitted at a higher level, which improves the signal-to-noise ratio. In turn, the 38-kHz subcarrier must be reinserted at the receiver. This is accomplished by mixing a locally generated subcarrier with the L − R sidebands. This mixing process must be done at exactly the correct frequency and exactly the correct phase, in order to provide Hi-Fi reproduction. To permit precise reinsertion of the missing subcarrier at the receiver, a 19-kHz pilot subcarrier is transmitted. Figure 11 shows how the 19-kHz pilot subcarrier is transmitted in an empty portion of the spectrum between the L + R signal and the lower sideband of the L − R signal.

The pilot subcarrier is transmitted at relatively low power, and because it is separated from the L + R and L − R signals, it can be easily trapped at the receiver free from interference. Thus, both a 38-kHz and the related 19-kHz subcarrier are generated at the transmitter, but the 38-kHz subcarrier is trapped out prior to transmission, so that the L − R signal is radiated as a suppressed-carrier signal. At the receiver, a tuned trap picks out the pilot subcarrier (at 19-kHz) and

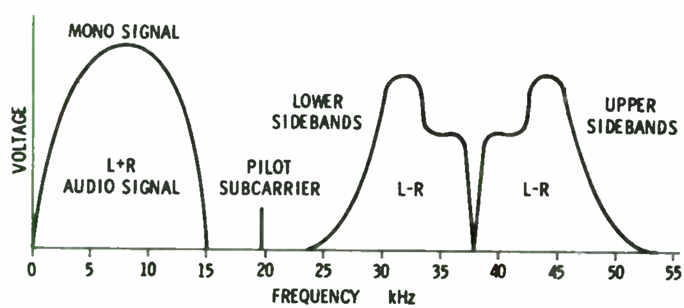


Figure 11 — Composite stereo signal showing 19-kHz pilot subcarrier in empty portion of spectrum.

feeds it to a doubler, thereby developing the missing 38-kHz subcarrier. This 38-kHz subcarrier is then mixed with the L − R sidebands, and the end result is the same as if the complete L − R signal had been transmitted.

STEREO-MULTIPLEX GENERATORS

Stereo-multiplex troubleshooting requires the use of a suitable generator. A basic generator supplies an L + R signal, an L − R signal, and a 19-kHz pilot subcarrier. The L + R and L − R signals have a 1-kHz audio frequency in the basic generator; the more elaborate generators may also provide 400-Hz and 5-kHz tones. Most generators include a 100-MHz RF oscillator, which may be frequency-modulated by the composite audio signal (Fig. 12). The composite audio signal is fed directly into a multiplex adapter (or combo section) for tests. On the other hand, an FM RF signal is required when the tests or measurements are made through the RF tuner. We will find that an L + R signal or an L − R signal seems to have the same waveform; this is because the only difference between them is their phase with respect to the pilot subcarrier. Let us see how these waveforms are produced by the generator.

A *Test setup.*

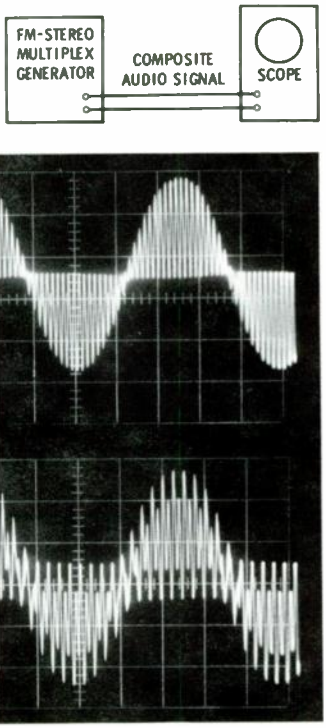


Figure 12 — Checking the output from a multiplex generator.

Generating Waveforms

With reference to Figure 13, we observe:

1. The waveshape of the subcarrier and both sidebands is the same as that of an ordinary amplitude-modulated signal.
2. When the subcarrier is suppressed, the sidebands without the subcarrier form an envelope that has twice the frequency of the original envelope.
3. In the generator, an L + R (or L − R) signal is produced by modulating a 38-kHz sine wave by a 1-kHz sine wave, and then suppressing (removing) the 38-kHz frequency.
4. Next, to develop an R signal, we may consider the result of energizing the R microphone only in Figure 7. In turn, with reference to Figure 13, we see that the R sine-wave signal is mixed with the −R signal

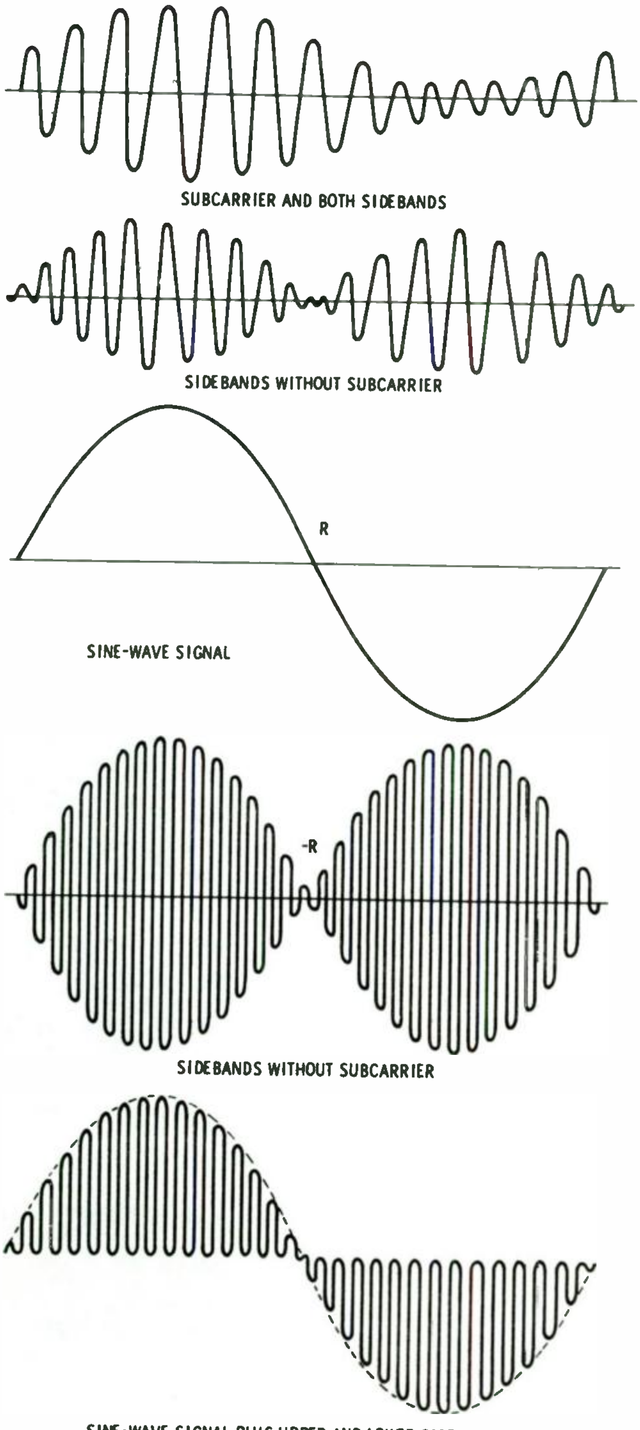


Figure 13 — Development of the composite audio signal.

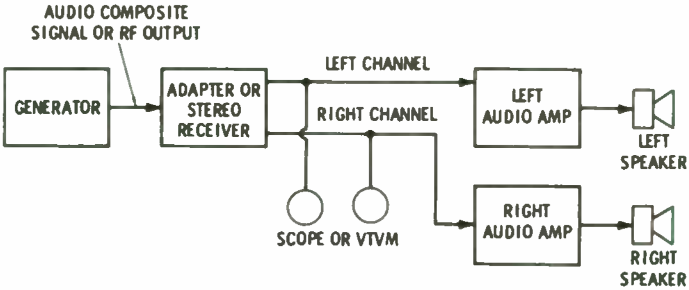
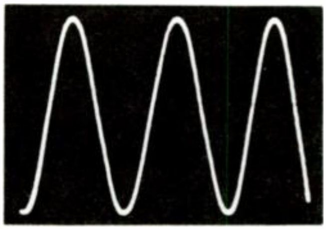


Figure 14 — Setup for testing separation in a stereo system.

which consists of sidebands without subcarrier. This mixture produces the sine-wave signal plus upper and lower sidebands.

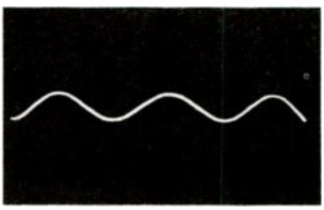
5. If an L signal is to be developed, the end result is the same, except for a phase difference, since the output from the L microphone in Figure 7 does not pass through a phase inverter.

In a stereo-multiplex generator, of course, the L and R signals are produced by audio oscillators instead of microphones. The most basic test of a multiplex adapter is its ability to separate L + R and L − R signals. Figure 14 shows a typical test setup. If a multiplex adapter is being checked without the FM tuner, we apply the composite audio signal to the adapter input terminals. Either a scope or an AC VTVM can be used as an indicator. In theory, when we apply an R-channel signal to the adapter, we would observe full output from the R section and zero output from the L section, as shown in Figure 15A and B. In practice, however, separation cannot be perfect, and the L channel output (undesired output) might appear as seen in Figure 15C. Similarly, when an L-channel signal is applied to the adapter, it is impractical to reduce the undesired output from the R channel to zero.



A R-channel output.

B Ideal L-channel output.



C Normal L-channel output.

Figure 15 — Waveforms observed during separation test.

A stereo-multiplex generator provides a test signal that has virtually complete separation, unless a defect occurs in the generator. In turn, we are concerned with how many decibels of separation should be normally provided by a multiplex adapter. A high-quality multiplex adapter (or multiplex section in a combo) will provide approximately 30db of separation. It is generally considered that a separation of 10 db is barely tolerable. Note that 30 db corresponds to a voltage ratio of more than 30 between the L and R channels. On the other hand, 10 db corresponds to a voltage ratio of approximately 3 between the L and R channels. In the example of Figure 15, we have a voltage ratio of 7 to 1 between (A) and (C); this is equal to about 17 db, and represents average multiplex-adapter performance. A VTVM with a db scale is illustrated in Figure 16; this provides convenience in making separation tests. Note that a multiplex adapter or section is basically a signal processor and provides practically no gain from input to output.

Figure 16 — VTVM with a db scale.

Defects That Cause Poor Separation

Although poor separation is usually caused by a component defect, drift in tuned-circuit adjustments can also impair separation. Four-tuned circuits are utilized in a typical multiplex circuit, as shown in the circuit in Figure 17. The composite stereo signal is amplified by V1A and then fed to the grid of phase-inverter V2A. V2B operates as a mixer for the two outputs from V2A after sampling by the ring demodulator consisting of X3 through X6. Always check tubes first. If V2 is not defective, check the other tubes also. Next to tubes, capacitors are prime suspects. A systematic approach in this sample entails checking C_8, C_{11}, C_9, C_{10}, and C_{15}.

In the event that no capacitor defects are found, the next step is to check (or replace) the diodes in the ring demodulator. Diodes X3, X4, X5, and X6 must have good front-to-back ratios, and must also be reasonably well matched to obtain optimum separation. Another possibility of poor separation is a faulty frequency-doubling diode, such as X1 or X2; these diodes

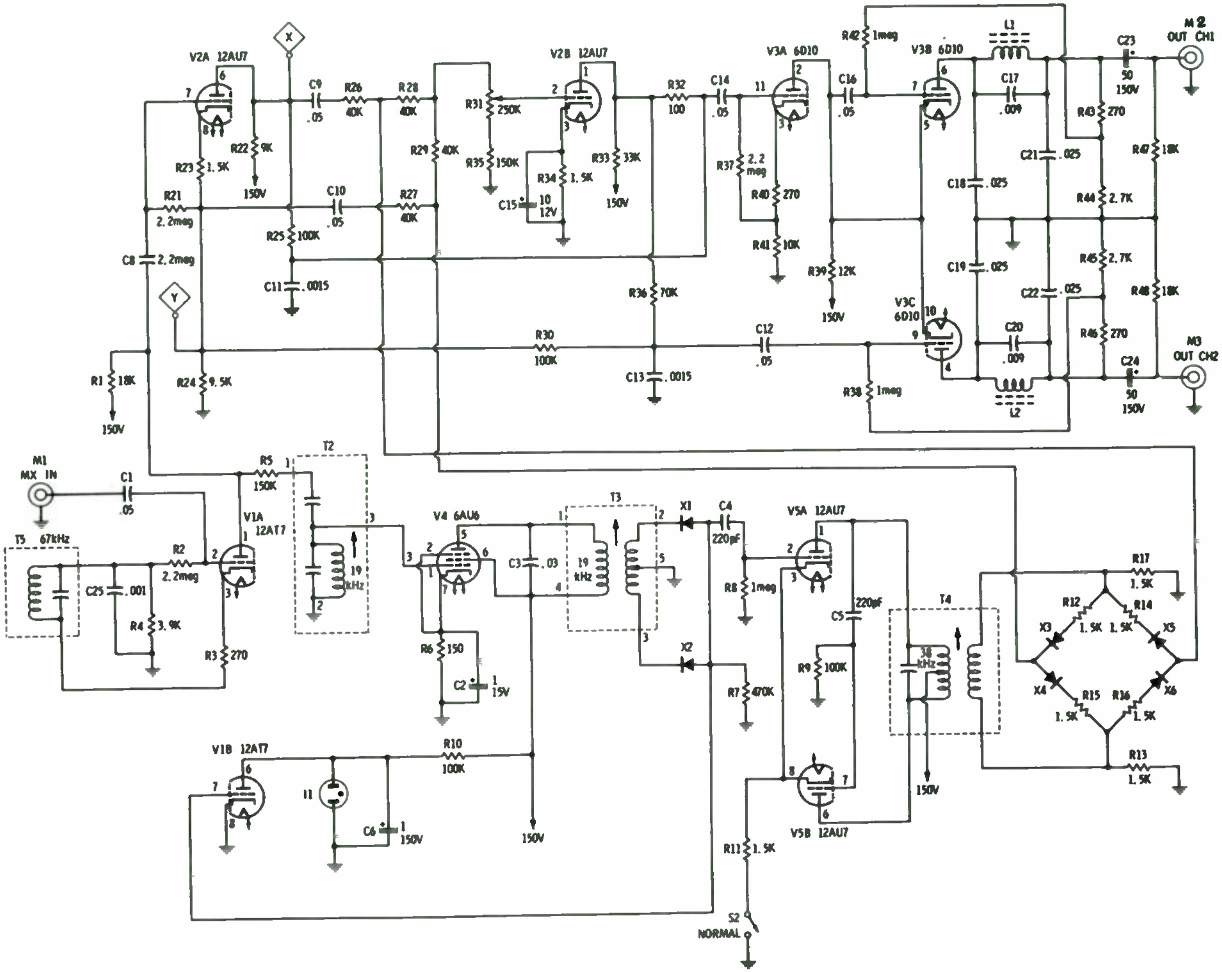


Figure 17 — Schematic of a typical tube-type stereo adapter.

change the 19-kHz pilot subcarrier into a 38-kHz subcarrier. Resistors are less common troublemakers, but become ready suspects in case a shorted tube has been replaced. For example, R_{33} and R_{34} can be 3 damaged by overloads. If R_{34} is increased in value, V2B becomes incorrectly biased and does not operate as a linear mixer; in turn, separation is impaired. The setting of R_{31} determines the amount of L - R signal that is applied to mixer V2B, and thereby affects separation. In case R_{31} checks out satisfactorily, we would check R_{35} as a possible troublemaker.

Alignment of a multiplex adapter or section in the receiver is checked last, because this is statistically the least likely cause of poor separation (unless a do-it-yourselfer has been tampering with the alignment adjustments). Alignment of the adapter in Figure 17 is 4 comparatively simple; T_2 and T_4 are the most critical circuits, and are peaked at 19 kHz and 38 kHz, respectively. To align T_2, we inject an unmodulated 19-kHz signal at the grid of V1A, and connect an AC VTVM at the plate of V4. The slug in T_2 is then adjusted for maximum output. To align T_3, inject a 19-kHz signal at the grid of V4 and connect an AC VTVM at the plate of V5A. The slug in T_3 is then adjusted for maximum output. To align T_4, we inject a 38-kHz signal at the grid of V5A, and connect an AC VTVM at the junction of X5 and X6. Then, the slug in T_4 is adjusted for maximum output. Sometimes a slight compromise adjustment of T_4 will give optimum separation.

Note that T_5 in Figure 17 is a 67-kHz trap. It is tuned by a slug (not shown in the diagram). This circuit does not affect separation; instead, its purpose is to suppress "birdies" in case an SCA signal is being transmitted. With reference to Figure 18, an SCA signal employs a 67-kHz subcarrier. A subsidiary-carrier-assignment (SCA or storecasting) signal cannot be heard on a conventional stereo multiplex receiver, unless a special SCA adapter is used. However, an SCA signal can sometimes cause "birdies" in conventional FM stereo reception unless the SCA signal is trapped out. To check the alignment of T_5 in Figure 17, we feed a 67-kHz signal into the adapter, and connect an AC VTVM at the plate of V1A. Then, the slug in T_5 is adjusted for minimum output.

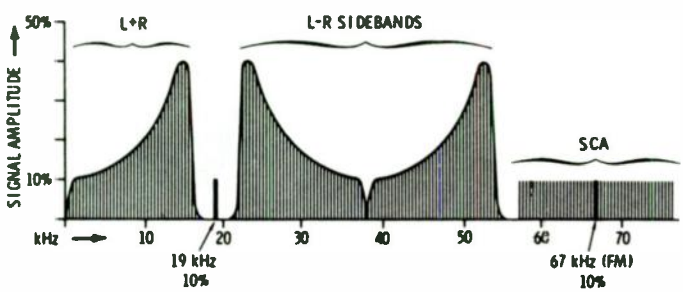
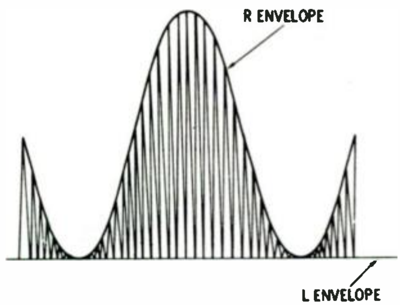
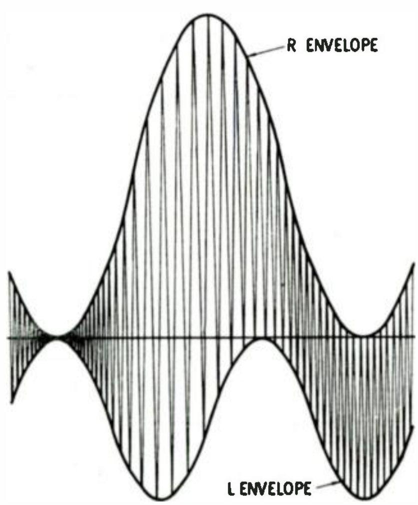


Figure 18 — Frequency spectrum of signals applied to modulator in FM transmitter.

Although the end result is the same, the configuration in Figure 17 processes the multiplex waveform in a different manner from the arrangement in Figure 10. That is, the multiplex signal is *sampled* in Figure 17. It is important that this process be understood. The waveforms shown in Figure 19 show how the envelopes above and below the zero axis provide the L and R signals after the 38-kHz subcarrier is inserted. Thus, the positive and negative excursions of the subcarrier serve to develop the individual L and R signals in the bridge circuit of Figure 17. We will find another processing method called the envelope-detector configuration; this method employs a pair of oppositely polarized amplitude detectors. It is evident that when a multiplex waveform passes through a positively polarized detector, the output waveform will be the R signal. Similarly, the output from a negatively polarized detector will be the L signal.

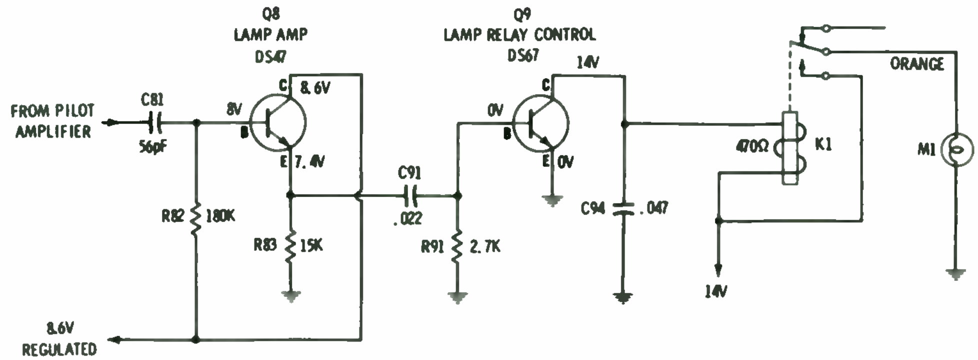


Right microphone energized; composite signal at receiver with subcarrier inserted.

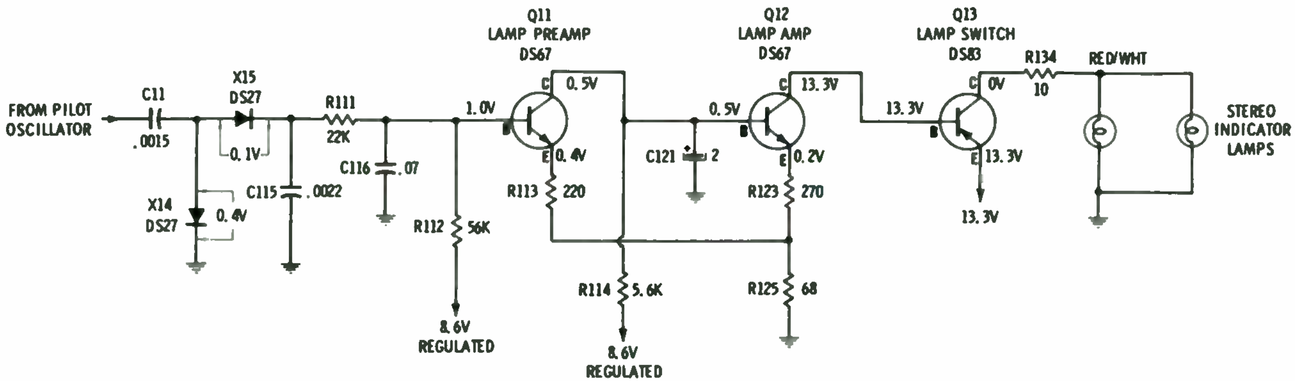


Both microphones energized; composite signal at receiver with subcarrier inserted.

Figure 19 — Representative multiplex waveforms.



A Actuated by pilot-amplifier signals.



B Actuated by pilot oscillator.

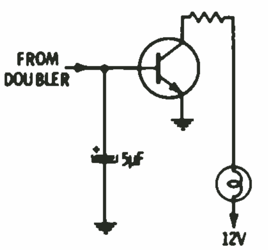
Figure 20 — Stereo-indicator light circuits.

STEREO INDICATOR CIRCUITS

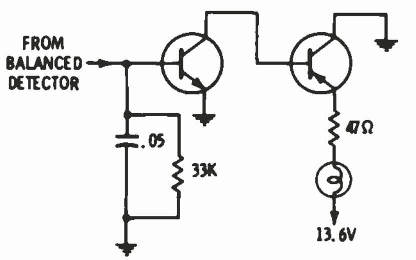
Most receivers have lamps that indicate when a stereo broadcast signal is being received. Typical arrangements are shown in Figures 20 and 21. The first section, in Figure 20A, is actuated by the pilot-amplifier signal. The input circuit couples a 19-kHz energy to the lamp-amplifier stage, whenever a pilot carrier is present. This amplifier is a conventional emitter follower. The output load of the control transistor is a relay coil, which is returned to the collector-supply voltage. When a drive signal is applied, the bias on the control transistor changes, and the collector current increases. In turn, the relay closes and a potential of 14 volts is applied to the indicator lamp.

Next, with reference to Figure 20B, the three stages operate as DC amplifiers. Actuating energy is obtained from the pilot oscillator. In turn, the 38-kHz signal is rectified by twin diodes X14 and X15, which operate in the sensing stage. The negative-going change in DC voltage at the base of Q11 produces an opposite change at its collector. Thus, the base of Q12, connected directly to the Q11 collector, is driven positive. In turn, the voltages at the collector of Q12 and the base of Q13 go negative. This voltage change causes Q13 to conduct heavily. Since there is collector current through the stereo-indicator lamps, their filaments glow as long as the base of Q13 remains negative. Note that the input circuit for Q11 is a filter that smooths the pulsating outputs from the input diodes. Additional filtering is provided by C121.

The stereo-indicator arrangements in Figure 21 are comparatively simple. Both of them operate by means of applied DC voltages at the bases of the transistors. In Figure 21A the pulsating DC output from the pilot-subcarrier doubler circuit is filtered by means of a 5-μF capacitor, and drives the base positive, thereby turning the transistor on. The arrangement in Figure 21B is basically similar, except that two stages are provided. Note also that the input is actuated by the output from a balanced stereo detector; therefore, less filtering is required at the base of the input transistor.



A Single-stage design from a Tenna multiplex adapter.



B Two-stage design by Motorola.

Figure 21 — Two simple stereo-light systems.

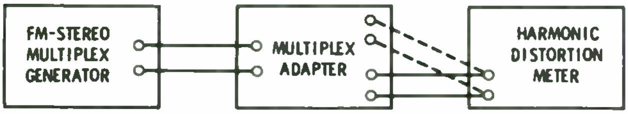


Figure 22 — Harmonic-distortion test setup for a multiplex adapter.

TROUBLESHOOTING PROCEDURE

Bench work on an operating complaint starts with localization of the defective section. With reference to Figure 2, trouble in the bandpass or matrix section could be confused with trouble in the ratio-detector circuit, or with a defect in one of the audio channels. Therefore, it is advisable to drive the multiplex section directly with the audio composite signal from a multiplex generator. For example, the signal would be applied at M1 in Figure 17. A scope can be connected at M2 for preliminary analysis of the Ch-1 output; next, the scope can be connected at M3 for analysis of the Ch-2 output. This approach will identify prominent malfunctions, such as lack of output on one or both channels, poor separation, high hum level, or serious waveform distortion.

On the other hand, less prominent malfunctions such as moderate distortion or poor frequency response require additional tests for definite identification. A harmonic-distortion meter must be connected in place of the scope at the output of the multiplex adapter to measure percentage of distortion. Figure 22 shows the test setup that is used. If it is suspected that the adapter or receiver has poor frequency response, the multiplex generator is externally modulated by means of an audio oscillator, and the output from the adapter is indicated by an AC VTVM as shown in Figure 23. The adapter should provide a reasonably flat frequency response from 20 Hz to 15 kHz, prior to the de-emphasis network.

In the case of a "dead" adapter, or lack of output on one channel, conventional signal-tracing procedures with a scope are useful to localize the defective stage or circuit section. Then, DC voltage and/or resistance measurements will usually serve to close in on the defective component. Most operating troubles in multiplex systems are caused by leaky or open capacitors. However, a worn and erratic separation control occasionally causes trouble, and may be overlooked by the technician apprentice. Some adapters are designed to

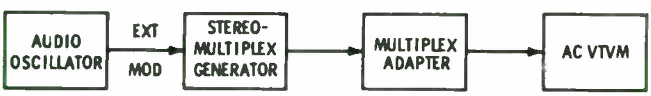


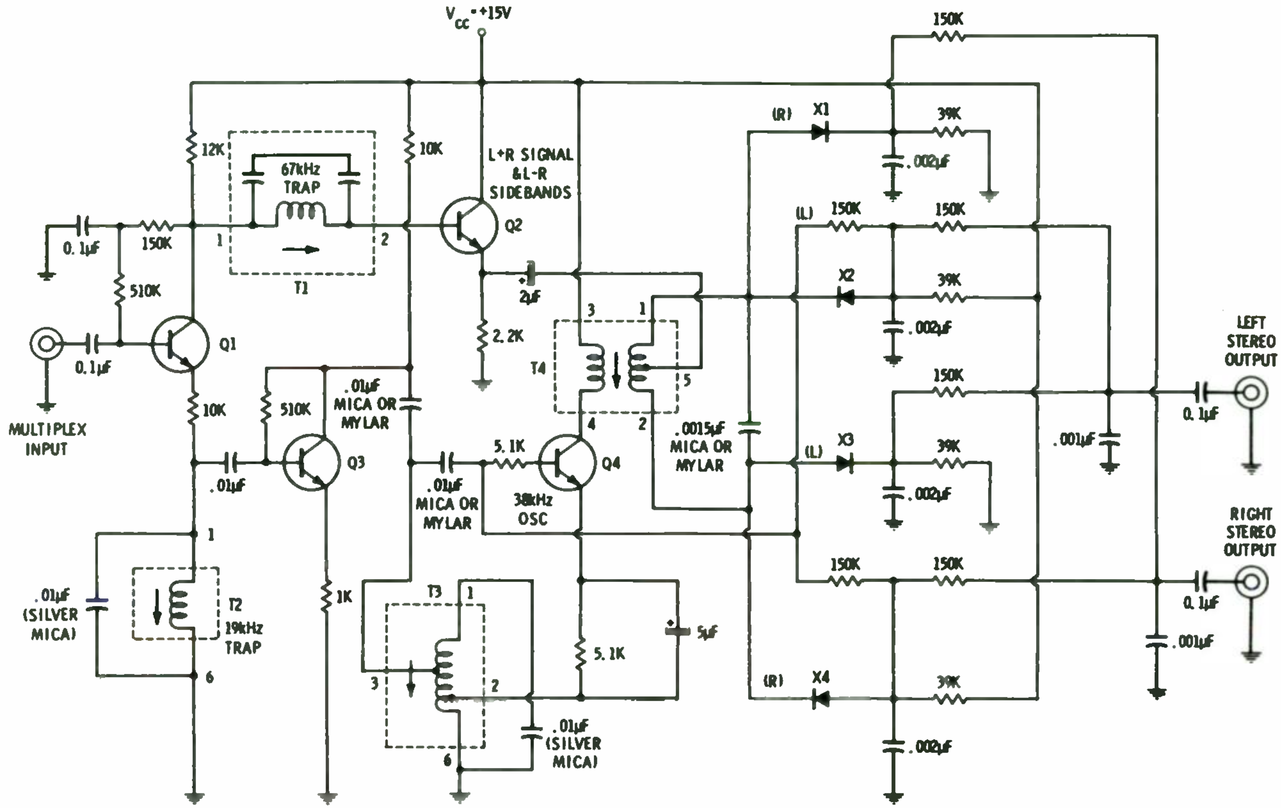
Figure 23 — Frequency-response check of a multiplex adapter.

operate with a certain value of input-cable capacitance; if a cable with excessive capacitance is substituted, trouble symptoms may be introduced. Note also in Figure 17 that C_{25} operates in combination with T_5 to produce optimum SCA rejection. However, when using some types of FM tuners, C_{25} may affect the range of the separation control; that is, the separation control might require setting near one end or the other, or might be out of range. In such a case, we vary the value of C_{25} from 2700 pf to zero, choosing the value that provides midrange setting of the separation control. Finally, T_5 should be realigned for optimum 67-kHz rejection.

The troubleshooting procedure for a transistor multiplex unit is much the same as for a tube-type unit, since designs are based on a transistor-for-tube basis, as seen in Figure 24. A typical adapter is illustrated in Figure 25. With reference to Figure 24, Q1 is a high-impedance input transistor, with a 19-kHz resonant trap in its emitter circuit. Thus, the 19-kHz pilot subcarrier is dropped across the trap, and does not appear in the collector circuit. SCA signals are rejected by T_1. Q2 operates as an emitter-follower buffer stage for the multiplex signal. Q3 amplifies the 19-kHz pilot subcarrier, and Q4 operates as a 38-kHz locked oscillator, synchronized by the output from Q3. In turn, the complete multiplex signal appears at the secondary of T_4. Diodes X_1 through X_4 operate in a switching bridge; X_1 and X_4 provide the R signal output, while X_2 and X_3 provide the L signal output. Note that the de-emphasis networks comprise series 150k resistors with 0.001-μF shunt capacitors.

In normal operation, we will find a separation of approximately 25 db between the L and R channels. An input signal level of at least 0.5 volt RMS is required to maintain tight locking of the 38-kHz subcarrier oscillator. At lower values of input signal, the oscillator locks erratically, causing serious distortion and noise in the output. This is a comparatively simple design, which does not employ a stereo-indicator light. We will find that there is a small amount of 19-kHz and 38-kHz signal in the L and R outputs; the normal 19-kHz rejection is greater than 20 db, and the 38-kHz rejection is greater than 30 db below 1 volt. To obtain an accurate harmonic-distortion test, the 19- and 38-kHz residual signals can be effectively suppressed by passing the adapter output through a 15-kHz audio amplifier.

By way of comparison, we will observe in Figure 17 that all residual signals above 15 kHz are greatly attenuated by means of pi filters inserted in the L and R output circuits. One of these pi filters comprises L_1, C_{18}, C_{21}, and C_{17}; the other filter comprises L_2, C_{19}, C_{22}, and C_{20}. Basically, filtering is not provided for convenience of testing, but to avoid interference in tape-recording procedures. That is, tape recorders employ ultrasonic AC bias, which can form audible beats with ultrasonic residual signals that are produced in the multiplex decoding process. By pro-



NOTES:

T1	- MILLER 1352 (67kHz)	Q1	- FAIRCHILD S-3330
T2, T3	- MILLER 1354 (19kHz)	Q2, Q3, Q4	- FAIRCHILD S-3320
T4	- MILLER 1355 (38kHz)	X1, X2, X3, X4	- FD100 OR EQUIVALENT

Figure 24 — A transistor multiplex adapter.

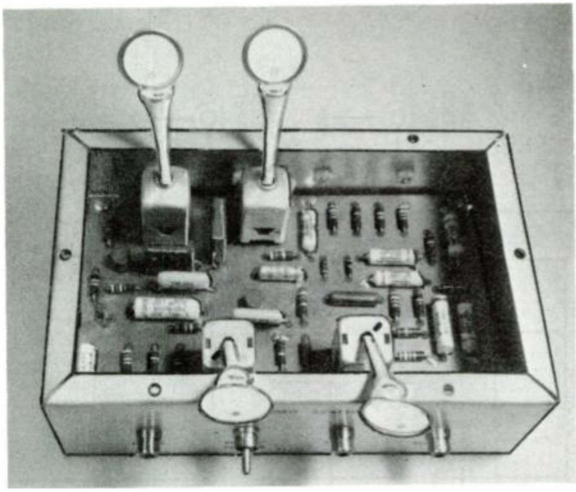


Figure 25 — Markers show tuned-circuit locations in a transistor multiplex adapter.

viding filter action, the residual signals are reduced to an imperceptible level.

ANALYSIS OF COMMON SYMPTOMS

An analysis of the common trouble symptoms listed earlier is presented in this part of the lesson.

No Output

When there is no output from either the L or the R channel, we know that the defect is common to both channels. For example, there might be an interruption of supply voltage to the multiplex section of the circuit. Again, the input plug might not be fully inserted. In case the trouble is not readily apparent, it is helpful to analyze the circuit diagram of the unit, to determine the signal-flow paths. If we avoid a "shot-gun" approach, we will usually save considerable time in the long run. After identifying the signal test points in the circuit, a scope can be used to trace up to the defective component or branch.

Possible causes of signal stoppage in a multiplex configuration are:

a. Open coupling capacitor to base of transistor, such as Q1 in Figure 24.
b. Leaky or shorted capacitor, causing cutoff or saturation of the transistor.
c. Transistor failure.
d. Cracked PC board, or damaged printed wiring.
e. Unsoldered or cold-soldered connection.

One Channel Dead

If only one channel is dead in a multiplex unit, the trouble symptom provides preliminary localization. The signal-flow paths can be determined by analysis of the circuit diagram, and signal-tracing with a scope will lead to the defective branch circuit or component. For example, with reference to Figure 24, a block diagram that denotes signal-flow paths can be drawn as illustrated in Figure 26.

Possible defects causing one channel to fail are as follows:

a. Open capacitor, such as a series capacitor in the output lead of a channel.
b. Shorted capacitor, such as a de-emphasis capacitor in the output lead of a channel.
c. Cracked PC board, or damaged printed wiring.
d. Poor connection or otherwise open secondary winding in 38-kHz transformer (such as terminal 1 of T_4 in Figure 24).
e. Output connector not fully inserted.

Weak Output

A defect that causes weak output may affect one or both channels. In case both channels have subnormal output, we know that the defect is in a circuit that is common to both the L and R channels. Normal waveform amplitudes are seldom specified in the service data. Therefore, it is helpful to compare the observed amplitudes with those in another receiver of the same type. When the defective circuit has been localized, DC voltage and resistance measurements will usually serve to pinpoint the defective component.

Possible defects that cause weak output on one or both channels are:

a. Leaky coupling capacitor.
b. Open bypass capacitor.
c. Transistor with collector leakage.
d. Off-value bias resistor (less likely, but possible).
e. Low V_{cc} supply voltage.
f. Replacement transistor incorrectly wired into circuit.

Poor Separation

Poor separation can be caused either by component defects or by misalignment of a multiplex section. Alignment is particularly critical in a matrix-type decoder; the bandpass of Figure 10 has an optimum frequency response shown in Figure 27. Although not shown, the bandpass circuit has a phase

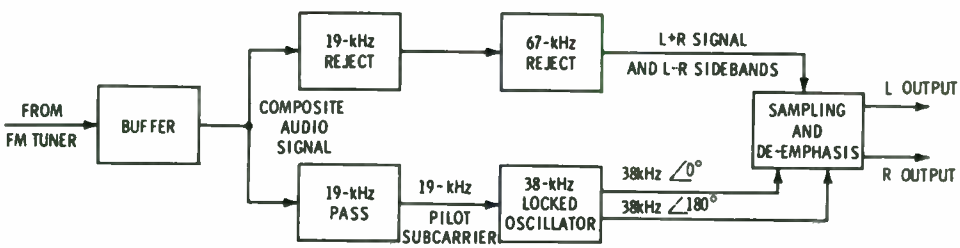


Figure 26 — Block diagram for circuit of Fig. 24.

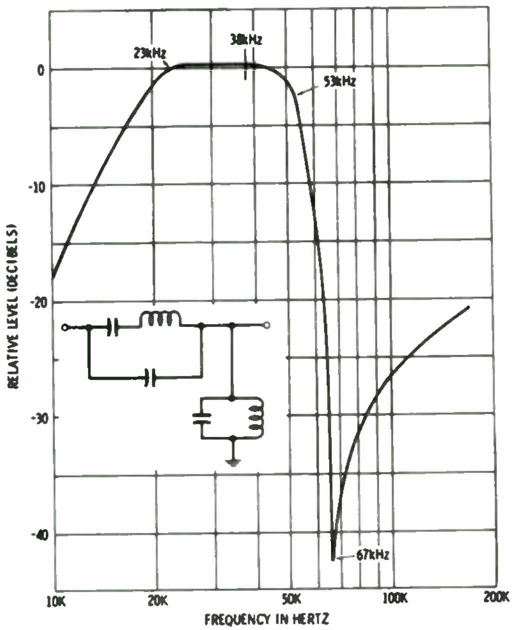


Figure 27 — Response of the bandpass filter.

characteristic that affects the relative timing of the upper and lower sidebands in the L − R signal. In theory, the phase characteristic should be linear; however, in practice, linearity can only be approximated. A bandpass circuit has best linearity when the frequency characteristic has the shape shown in Figure 27.

Possible defects that can cause poor separation are as follows:

a. Poor front-to-back ratios, or unmatched diodes in the sampling bridge.
b. Leaky capacitor in sampling-bridge circuit.
c. Weak output from 38-kHz oscillator (check for transistor collector leakage).
d. Misalignment of bandpass circuit.
e. Off-value resistor in matrix or bridge circuit (less likely, but possible).

Distorted Output

Two basic types of distortion can occur in multiplex sections; these are nonlinear distortion and frequency distortion, as explained previously. Distortion can also be caused by interference, such as SCA squeals or birdies due to trap misalignment or defects. Erratic locking of the 38-kHz subcarrier oscillator can also cause distortion. For example, subnormal supply voltage can result in audio distortion.

Possible defects that can cause distorted output are as follows:

a. Leaky capacitor in the sampling bridge.

b. Defective diode in the sampling bridge.
c. Transistor with collector leakage.
d. Marginal electrolytic capacitor in subcarrier-oscillator section.
e. Defective or mistuned SCA trap.
f. Off-value resistor (less likely than preceding defects).

Drift of the Separation-Control Setting

When the separation-control setting drifts, there is an unstable component present that affects the separation process. Separation controls are provided only in matrix-type multiplex units; for example, a separation control (R_{31}) is included in the configuration of Figure 17, whereas no separation control is present in Figure 24. An elusive troublemaker consists of a worn and erratic separation control, because the possibility of resistance drift in this component is often overlooked. Therefore, we should always check the control first.

Possible defects that can cause the separation control setting to drift are as follows:

a. Deteriorating bypass capacitor.
b. Coupling capacitor with unstable leakage condition.
c. Marginal diode or transistor.
d. Poor connection with fluctuating contact resistance.
e. Inconstant supply voltage to adapter section.
f. Burned or otherwise defective resistor.

Stereo-Indicator Failure

In most cases, stereo-indicator failure is obvious, and requires only the replacement of a burned-out lamp. However, if the lamp is not burned out, broken, or otherwise defective, we turn our attention to the indicator circuit and its components. A stereo FM indicator bulb will light only if a stereo-multiplex signal is applied to the adapter section. If the 19-kHz or 38-kHz tuned circuits are badly out of alignment for any reason, the stereo-indicator circuit cannot be energized. However, we check alignment last, unless there is reason to believe that the adjustments have been tampered with.

Possible defects that can cause stereo-indicator failure are as follows:

a. Defective switch contact, or poor connection. (See Figure 28.)
b. Stereo-indicator light plug not fully inserted.
c. Open coupling capacitor, such as C_{91} in Figure 20A.
d. Shorted capacitor, such as C_{121} in Figure 20B.
e. Defective transistor in indicator section.
f. Diode with poor front-to-back ratio, such as X15 in Figure 20B.

Audio Problems

The audio sections of stereo amplifiers operate just as all other audio amplifiers do. There might be dual controls in some cases, such as dual volume controls, and dual treble and bass controls. A balance

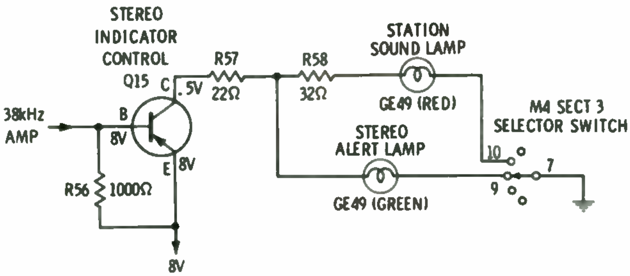


Figure 28 — Poor connection to pin 9 on M4 caused failure of stereo indicator.

control is always included to permit an equal volume of sound to come from the left and the right speakers.

STEREO DISC RECORDING

It was not until practical methods of stereo disc recording were developed that standardized stereo could reach our homes. Although other good methods have been considered, the Westrex method of stereo recording is the one adopted by the recording industry.

Requirements

Let's review briefly the general requirements of a stereo disc recording method. They are as follows:

1. Two completely independent left and right signals must be recorded separately in such a way that there is a minimum of interference or mixing between them, and so that, in playback, they can be separately recovered in the same form as that in which they were recorded.
2. The system must be compatible with monophonic recording and playback systems. A stereo playback system should play monophonic records without loss of fidelity; likewise, a monophonic system should play stereo records and produce as good a monophonic output as when it is playing monophonic records.

When Edison first developed phonograph recording, he used vertical motions of the recording stylus to record the sound vibrations. This came to be known as the "hill-and-dale" method of recording. However, in such a system, the "hills" in the record groove had to lift the playback arm and cartridge. Since early arms and cartridges were relatively heavy this motion caused excessive wear. Because of this, the record industry adopted the lateral recording method, in which the needle goes from side to side in accordance with the sound vibrations. All commercial monphonic records for home use are laterally recorded, and monophonic pickups are designed accordingly.

The Westrex System

In the Westrex stereo recording system, both stereo and mono, lateral and vertical motions are employed. Modern pickup and arm design is such that vertical motions are usable under the proper conditions. The basic principle of the Westrex system is illustrated in Figure 29. The sound signal for each stereo channel is recorded along a direction at 45 degrees to the horizontal. In other words, each channel is recorded on one side of the record groove in such a way that its undulations will move a playback stylus back and forth along one of the 45-degree directions. The two directions are at right angles (90 degrees) to each other, and motions along either one alone do not affect motion along the other. Thus, the motions of one channel do not interfere with the motions of the other, and two separate output signals, each corresponding to the motions for its respective channel, are obtained from the stereo cartridge.

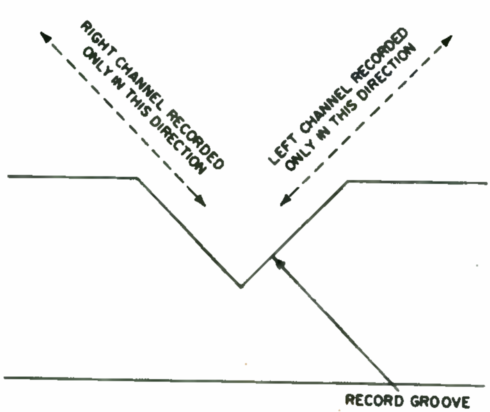


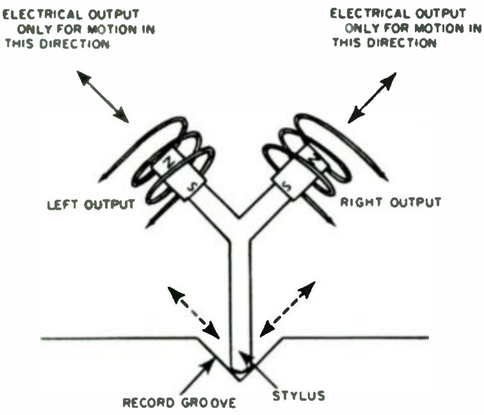
Figure 29 — How sound vibrations are cut at 90° to each other and 45° from the horizontal in the Westrex system.

A symbolic representation of how the axial motions in the two 45-degree directions can generate two separate signals is given in Figure 30. Imagine the assembly of the stylus and the two bar magnets free to move in any direction but not to rotate. Then, if the stylus is pushed to the left, it goes into a position like that of Figure 30B. The magnet at the left moves directly into the coil, thus generating a current in it. The magnet at the right merely moves across the diameter of the coil perpendicular to its axis. There is no axial motion in or out of the coil, so no current is generated in the right coil.

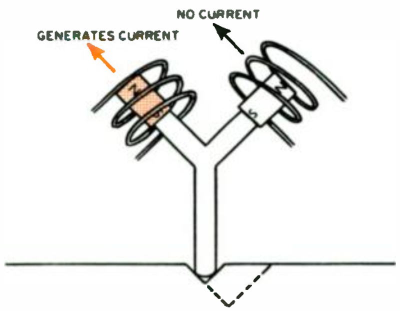
Now suppose that the stylus-magnet assembly is pushed to the right, as shown in Figure 30C. Conditions are now the reverse of those in Figure 30B. A current is generated in the right coil but none is generated in the left coil.

Thus, vibrations recorded in the groove so that they push the stylus at 45 degrees toward the left produce pickup output current only in the left coil. Likewise, vibrations recorded in the groove so that they push the stylus at 45 degrees toward the right produce pickup output current only in the right coil.

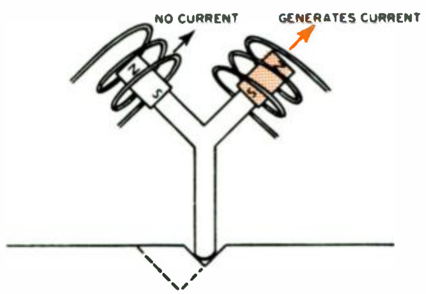
It is difficult to imagine any case in which both left (L) and right (R) signals would not be present. Because of this, you may wonder how the playback needle moves in both 45-degree directions at once. Naturally, it cannot do this. Instead it moves in a direction and with amplitude dictated by the *vector resultant* of the two forces along the 45-degree paths. This means the needle can move as a whole in any resultant direction,



A Rest position.



B Movement to left.

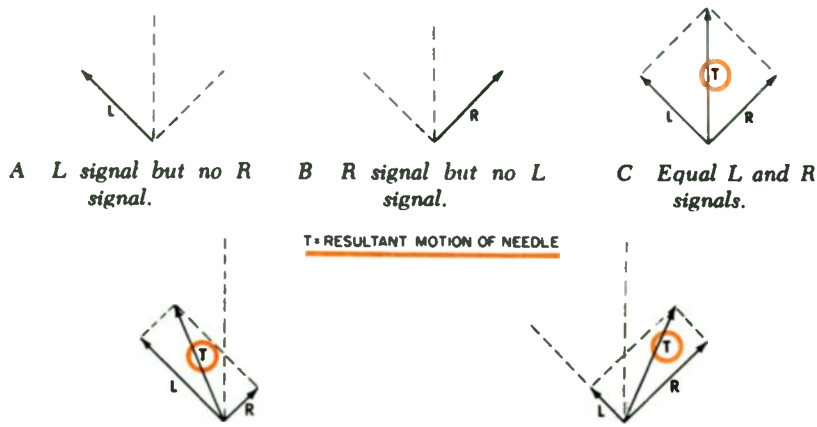


C Movement to right.

Figure 30 — How stylus motion in either of the 45° directions causes pickup in one coil but not in the other.

including side to side and straight up and down. Five combinations of relative L and R signals are analyzed in Figure 31. Only one signal is present in Figures 31A and B. Accordingly, in each of these cases the needle moves along the direction of the single channel present. Thus if the needle's motion is along one of the 45-degree sides of the groove, it "senses" that it is receiving signal from only one channel. Figure 31C illustrates the special case of equal signals from L and R. In this case, the resultant motion is always vertical, and the record "looks" to the needle like a "hill-and-dale" recording. The vertical motion indicates that both signals are equal in amplitude and the mount of motion indicates their amplitude. Figure 31D indicates the motions when the L signal is much stronger than the R signal. The larger the L signal with respect to the R signal, the further the resultant is to the left of vertical. The angle of resultant motion "tells" the pickup the ratio between the two amplitudes, and the amplitude of the resultant indicates their amplitudes. The situation depicted in Figure 31E is the same except that the R signal is stronger than the L signal. The examples in Figure 31 show that for any combination of resultant needle angle and amplitude of motion, there is a distinct amplitude for both the L signal and the R signal.

Since the amplitude of the L and R signals are usually approximately equal at any instant, the conclusion to be drawn from Figure 31 and the preceding discussion is that the groove modulation in stereo

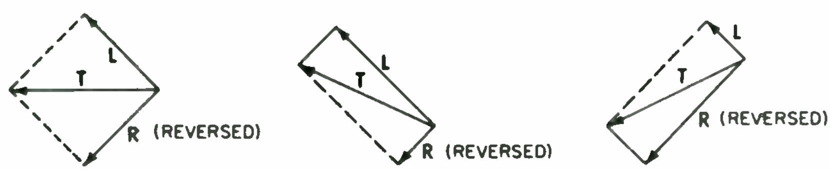


A L signal but no R signal. *B R signal but no L signal.* *C Equal L and R signals.*

D Strong L signal, weak R signal. *E Strong R signal, weak L signal.*

Figure 31 — How motions along the two 45° directions in a stereo record groove add up to a single resultant motion.

records is predominantly vertical. However, vertical groove modulation tends to be more distorted and produce more record wear than lateral modulation. To change the Westrex recording system to one in which groove modulation is predominantly lateral, the phase of one of the signals driving the stereo record cutter is reversed. This changes the resultant needle force from a predominantly vertical motion to one which is predominantly lateral. This method is illustrated in Figure 32. Note that Figures 32A, B, and C are the same as Figures 31C, D, and E, respectively, except that the R vector is reversed. The Record Industry Association of America (RIAA), which accepted the Westrex system, has stipulated that "equal-in-phase signals in the two channels shall result in lateral modulation of the groove." This requirement is satisfied by the phase reversal of one of the signals to the cutter as shown in Figure 32; but a compensating reversal must take place at the pickup or later in the system for playback. However, this is a simple matter, because it involves only reversing the connections of one of the pairs of leads from the pickup.



A Equal L and R signals. *B Strong L signal, weak R signal.* *C Strong R signal, weak L signal.*

Figure 32 — Vector addition of motions of needle in stereo record groove after electrical inversion of one channel.

Special Factors in Stereo Disc Systems

Although the phase reversal of one of the signals to the recording head makes the modulation of a stereo record predominantly lateral, the fact still remains that vertical motions play a vital part in recording and playback. This fact brings with it some special problems in stereo pickup design.

The stereo pickup must have high vertical *compliance;* that is, it must allow for easy motion of the needle in the vertical direction. If it does not, the needle exerts undue pressure on the record, causing rapid wear. A good stereo pickup is designed to have this necessary vertical compliance, but monophonic pickups are not. Even though the monophonic pickup will have what appears to be compatible motion, the continued use of a monophonic pickup on a stereo record will destroy it after relatively few playings. Therefore, never play stereo records with a monophonic pickup.

Another important factor is the *pinch effect* illustrated in Figure 33. It arises from the fact that, in its lateral motions, the cutting stylus' flat front edge is not at right angles to the direction of motion of the record it is cutting. For example, at A in Figure 33, there is no signal and the stylus is laterally motionless; therefore, the flat front of the stylus is at right angles to the direction of the groove, which at this point has its greatest width, W. However, at B, modulation has been applied; the stylus still has the motion it had at A, but now it

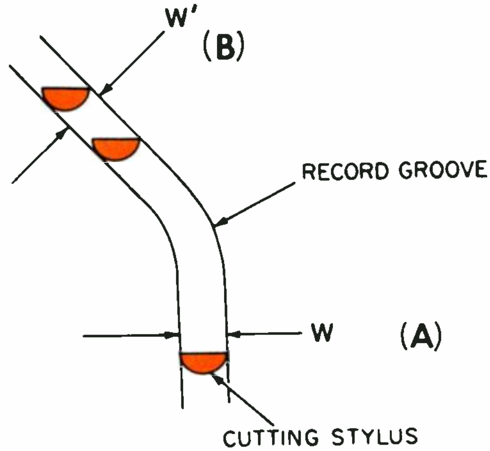


Figure 33 — The cause of the pinch effect.

also has the lateral motion imparted by the signal applied to the pickup cartridge. The flat front of the stylus, with its cutting edges, now plows sideways through the record materials, so the width of the groove here is W', which is considerably less than W, the width at A. Unless the tip of the playback needle is extremely fine, the narrowing at B tends to lift it out of the V-shaped groove. This lifting motion is the same as might be experienced with vertical groove modulation. It does not affect a monophonic pickup (except to make the record wear faster), but with the vertical-sensitive stereo pickup it introduces an unwanted signal and distortion.

To attempt to overcome the effects of pinching, the tip radius of stereo pickup needles has been reduced from the over 1-mil (0.001 inch) monophonic microgroove value to 0.5–0.7 mil. However, this reduction in tip diameter introduces another disadvantage—the tip pressure on the record is increased. Pressure is force per unit area, so even if the force of the needle on the record has not increased, a decrease in its area causes a corresponding increase of pressure. Pressure is a main factor in wear on records, so the smaller needle tip results in greater wear, if the other factors remain equal. To keep wear down, stereo pickups are operated at very low needle force. Four grams is usually considered a reasonable maximum.

The same types of pickup devices are used for stereo as for monophonic reproduction. They include moving-coil and moving-magnet magnetic, piezoelectric, and ceramic cartridges. The suspensions used for the needle and its associated mechanical vibrating assembly are very critical and many clever arrangements have been worked out by the engineers.

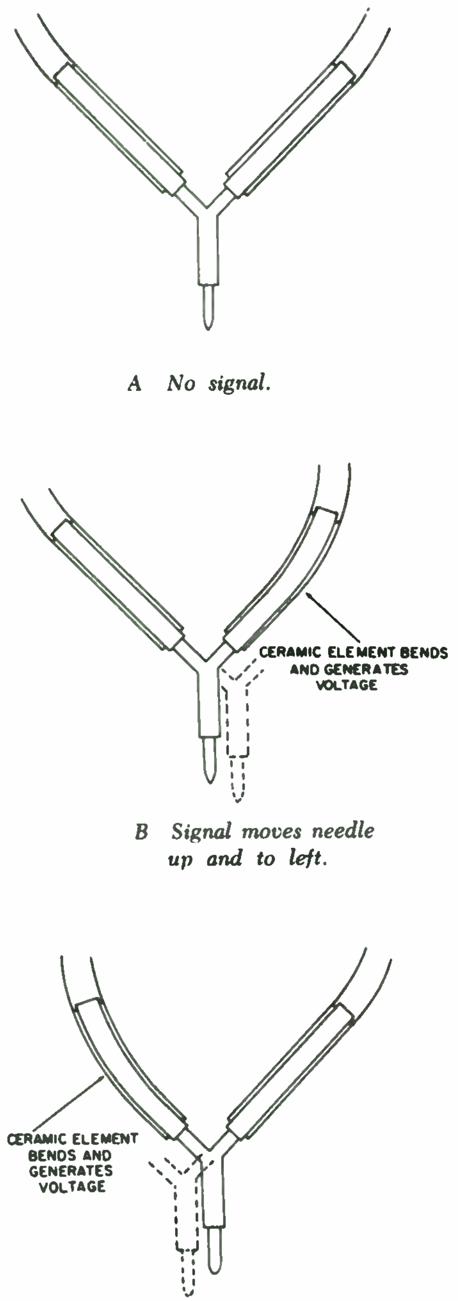
The principle of how moving magnets are used to generate the two stereo outputs was illustrated in Figure 30. Although that diagram does not correspond to any manufactured cartridge, the manufactured ones do have a small magnet (or two) moving near a core having a pair of coils. The motion of the magnet(s) generates voltages in the fixed coils. The pole pieces and moving magnets are oriented so that motion of the needle in one 45-degree direction cuts magnetic lines of force for one coil but moves the lines of force parallel to the other coil so that no voltage is generated in it. For movement in the other 45-degree direction, the situation is reversed and voltage is generated in the other coil.

As implied by the name, in the moving-coil magnetic-type (dynamic) pickup, the coils move and the magnet stands still. A special linkage mechanism with jeweled bearings imparts rotational motion to either or both of the coils as the needle is moved by the record undulations. Each coil responds to needle motion in one of the 45-degree directions. The coils operate in a magnetic field, so an audio voltage is generated in them when they turn.

Ceramic elements can also be used in a stereo pickup, as illustrated in Figure 34. As the ceramic crystals are bent, a voltage is generated. As the needle moves to the left, one ceramic element is bent (Fig. 34B); similarly, movement to the right bends the other element (Fig. 34C). Thus, two isolated stereo outputs are provided.

Record Player Needles

Reproducing needles are made of a number of materials. Plain, hardened steel and osmium needles are good for only a limited number of plays and therefore are seldom used in Hi-Fi playback. Those made of sapphire are the most common. Sapphire needles have a longer life than steel needles. A properly used sapphire needle will give hundreds of plays. Diamonds are also used in reproducing needles and are considered to be the best. Diamond needles will give satisfactory performance for thousands of playings, and when properly shaped and polished they are superior to all other types. Their only disadvantage is that they are very



A No signal.

B Signal moves needle up and to left.

C Signal moves needle up and to right.

Figure 34 — Stereo playback using ceramic elements.

expensive and delicate and may be fractured by a slight impact. A chipped diamond or sapphire needle will quickly ruin any type of recording. The comparative life of diamond needles against other materials varies according to the manufacturer and the user. A life expectancy for a diamond needle many times longer than that of competitive materials is not unusual. Wearing qualities of different needles are shown in Figure 35. Prices on diamond needles are dropping to reasonable levels, making them best buys for top Hi-Fi playback.

The needle-tip size for monophonic (single-channel) records may be over 0.001 inch (1 mil), while needle tips for stereo records are either 0.5 or 0.7 mil.

PICKUP CARTRIDGES

The construction and the electrical characteristics of the various available pickups vary greatly. They can be classified into five distinct groups. These are: crystal, ceramic, magnetic, dynamic, and capacitance.

Units of varying quality can be obtained in each group. The tastes and desires of the user and the use to which the pickup is to be put may govern its choice. With systems designed to reproduce the voice for reference purposes only, an inexpensive pickup with a comparatively narrow frequency range is suitable. Where the highest quality of reproduction is required, a special high damped pickup having a frequency characteristic flat to beyond 15,000 Hz is necessary.

Figure 35 — Needle wearing qualities.

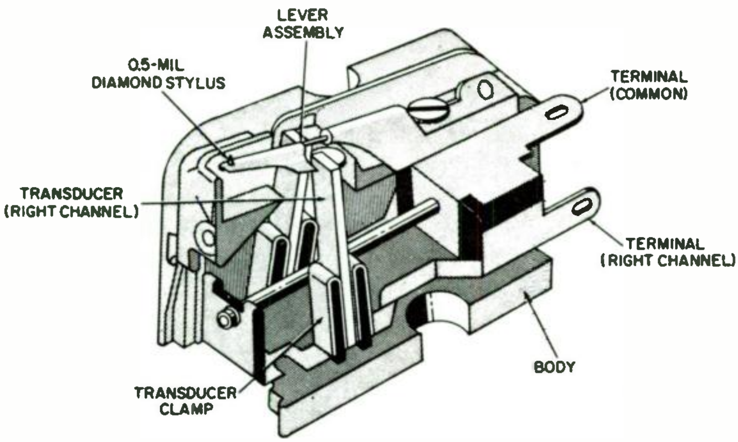
Crystal and Ceramic Pickups. Crystal and ceramic pickups are the lowest-cost units mentioned in the foregoing. They are simple in design and construction, have fair frequency response characteristics, and Hi-Fi types have low distortion content (Fig. 36).

Some crystalline substances possess the ability to produce a charge under certain conditions. When they are stressed mechanically, a charge is produced on their surfaces. If a voltage is applied to the surfaces of a crystal with piezoelectric properties, a mechanical deformation of the crystal will take place.

The *piezoelectric crystal* acts as a generator and converts mechanical motion into an electrical charge. Crystal microphones and phonograph pickups can be thought of as piezoelectric generators. A crystal is also similar to a motor. When a potential is applied to a crystal, it moves. It converts electrical energy into mechanical motion. Crystal headphones and record cutters are piezoelectric motors.

Magnetic Pickups. The magnetic pickup is a current-operated device. The construction of magnetic pickups varies greatly. Essentially they consist of a coil and magnet and another magnet to which the needle is attached. The movable magnet to which the needle is affixed is damped. This is accomplished in a number of ways, depending on the construction of the particular cartridge.

The coil is connected directly to the input of the preamplifier. Current through it varies with the



Courtesy CBS Electronics, Div. of CBS, Inc.

Figure 36 — Construction of the Columbia *Professional* 55 ceramic stereo cartridge.

change in the density of the flux about the fixed magnet. This variation in flux is produced by variation in the force exerted on the movable magnet, for each change in position. Since the reproducing needle is connected to this magnet, it produces output in proportion to the movement.

The frequency range of a magnetic pickup is greater than that of the crystal type. The finest magnetic pickups have a frequency range of 50 to over 15,000 Hz. The distortion content of a fine magnetic pickup may be as low as 0.1 percent at 400 Hz, and 1 percent to 4 percent at high frequencies. A typical Hi-Fi reluctance-type magnetic cartridge is shown in Figure 37.

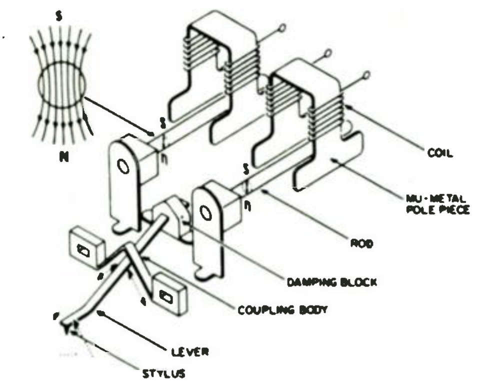


Figure 37 — A moving-magnet type of stereo pickup.

Dynamic Cartridges. The dynamic cartridge, as the name implies, is of the moving-coil type. The unit consists of a movable coil, to which the needle is mounted, and a permanent magnet. The coil is connected to a low-impedance input of a preamplifier. When the needle moves the coil, causing a magnetic field to be set up around it, this field interacts with the field of the permanent magnet; and as a result, an output voltage is produced. The results obtained with a dynamic pickup are as good or better than that obtained with magnetic pickups. A dynamic cartridge is illustrated in Figure 38. The response of this cartridge extends beyond 20,000 Hz, and it gives almost as much output as a good reluctance pickup.

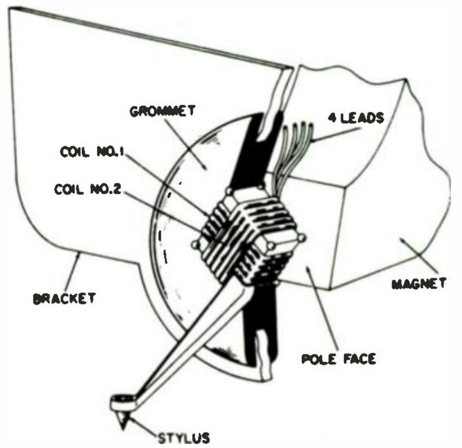


Figure 38 — The Grado moving-coil type (dynamic) of stereo pickup.

Stereo Cartridges. In stereophonic application, one of the most critical components is the pickup cartridge. The weight of a cartridge and pickup arm assembly is transmitted to the record as needle force. The maximum allowable needle force without excessive record wear is related to the size of the needle tip. This is because wear is dependent on pressure, which is force per unit area; thus the smaller the needle tip, the less the needle force must be to prevent wear. If needle-tip size were made too small, the necessary reduction in needle force would result in loss of tracking; that is, the needle would skate over the record instead of staying in the groove. Thus the minimum needle-tip size is kept to 0.5 mil, and the range of needle force is roughly from 1/2 to 6 grams.

As is the case with all high-fidelity system elements, we are interested in the frequency response of a cartridge. Response is usually stated in terms of frequency range and the deviation, in db, of the response over that range. We are naturally interested in the widest possible frequency range, but it is doubtful if response below 20 Hz makes much difference. However, the high limit of the range should extend to near 20,000 Hz or beyond to take full advantage of the better recordings.

The output voltage of a cartridge is important, not only because it is used to calculate how much amplification is needed, but also because the higher the output, the more chance there is of having a good signal-to-noise ratio. However, sometimes it is desirable to sacrifice some signal strength to ensure minimum distortion, best frequency response, and minimum record wear. Output voltage does not establish criteria unless the level at which the needle is driven is also specified. Standard records are used to provide the drive for output voltage tests. Some cartridge manufacturers state output for a 5-cm/sec needle velocity, and others for a 10-cm/sec needle velocity. Naturally, the output should be higher for the greater velocity. For total outputs below 10 millivolts, a separate preamplifier may be necessary, depending on the gain of the system used.

Channel separation is the indication of how well the left signal is kept out of the right channel, and the right signal out of the left channel. Good separation is necessary for good stereo effect, since the difference between the two signals is what produces the spatial effect. If a cartridge were not carefully designed with separations in mind, one channel would affect the other and the outputs of the two channels would tend to become the same. Tests have shown that a minimum of 15-db separation should be maintained.

To operate properly, a cartridge must be connected to the proper amplifier input impedance. Generally speaking, ceramic and crystal pickups must work into a relatively high resistance (15 kilohms to several megohms) compared with magnetic cartridges (5 to 100 kilohms). Each cartridge manufacturer specifies the proper load characteristics for his models.

PLAYBACK PROBLEMS

Tracking Problems

Trackability distortion is produced when a phono stylus/cartridge transducer does not track or "trace" the grooves of a record in the same manner as originally cut by the cutting stylus. This action causes all kinds of distortions to be produced and parts of the original sound are not reproduced. As techniques of record and tape making improve, wider frequency ranges and greater transients are accurately recorded in the program material mediums. These improvements in program material mediums create a requirement all the way through the Hi-Fi system for improved pickup, amplification, and reproducing techniques, and for the equipment to keep pace. However, the essence of a quality system is the ability of its pickup device to provide precise dynamic coupling to the medium and accurately transduce the program material as it was recorded.

A number of factors must be just right to ensure proper *tracking,* that is, to ensure that the needle stays in the groove and does not cause excessive wear. Good tracking is achieved when the needle follows both sides of the groove with equal pressure on each side at all times. Tracking is much more important in stereo playback than in monophonic playback because the needle will wear one side of the groove more than the other if it is forced against the side of the groove. In stereo, wear on one side of the groove reduces the amplitude of one stereo channel with respect to the other stereo channel; therefore, if the wear is appreciable, a stereo record would become useless much sooner than a monophonic record under the same conditions.

This wear on the sides of the grooves is another reason why the needle force of a stereo pickup must be less than that of a monophonic pickup. But, reduction of needle force means more difficulty in maintaining tracking because the needle will sometimes have a tendency to "skate" across the record. Fortunately, the reduction of the needle-tip radius to 0.5 to 0.7 mil to overcome pinch effect as explained before also improves tracking.

It can be seen from the preceding discussion that the pickup arm for stereo cannot be too carefully adjusted. It must have an absolute minimum of resistance to lateral motion so that it tracks smoothly when balanced for the recommended needle force.

Pickup arm and needle adjustment is easier with a "single-play" turntable than with a record changer because of the elimination of complex changer mechanism. With a changer, the needle must rest heavily enough in the grooves to allow the pickup arm to trigger the change mechanism. This takes a lot more force than necessary to move the arm across the record. In addition, because the records are stacked on the turntable during operation of a changer, the needle has a different angle for each record. Thus distortion is introduced in the reproduction and record wear is much greater than with single-play mechanisms. This does not mean that changers cannot give top-quality reproduction, but, everything else being equal, the single-play setup is simpler to adjust and operate.

Turntables

At first thought it would seem that the requirements for turntables and turntable drives would be the same for stereo as for monophonic systems. However, this is not so. Stereo turntable and drive requirements are more exacting because of the greater inherent sensitivity of stereo pickups to vertical vibration and the susceptibility (in the case of magnetic pickups) to hum pickup from the motor.

Rumble

Rumble is the effect produced in the sound output by low-frequency signals generated by vibrations in the motor and drive systems. These signal components usually have frequencies of from 30 to 60 Hz. Therefore, if the system as a whole does not have extended low-frequency response, rumble is not such a great problem. Thus, if your speaker system cuts off at about 100 Hz, you can stop worrying about the fine points of rumble production. However, any high-fidelity system worthy of the name reproduces signal components down to 50 Hz or below, and turntable rumble is an important factor.

A stereo pickup is more sensitive to rumble than a monophonic pickup because it is sensitive to vertical vibrations, and the vertical vibrations are usually two or three times as strong as the horizontal vibrations in a turntable drive assembly. Therefore, special measures must be taken for stereo-system turntables to minimize vibration and its effects. Otherwise, severe rumble is present in the output signal of the pickup. Although there is no standard, rumble is usually measured with respect to a fairly strong 1000-Hz signal obtained from a standard test record. Low-level passages of music may be as much as 40 db below the test record output, so rumble should be at least 45 db down. At −60 db it is usually completely inaudible, so this is a desirable objective.

In record players designed for stereo, rumble should be minimized by damping in the drive system and by the use of motors which deliver power as smoothly as possible.

Hum Pickup

The reason for the greater susceptibility of some stereo pickups to hum is the fact that there are two channels instead of one. The hum currents in the two coils of a magnetic-type stereo pickup combine in the output during operation. When a monophonic record is being played, the hum currents can be made to cancel by connecting the coils in parallel.

The source of most hum pickup is the turntable drive motor. Induction and synchronous motors have coils carrying alternating current from the power line, and thus they radiate hum. In general, the higher the motor power, the more hum is radiated. It would seem that the motor power should be made as low as possible. However, the lower the motor power, the more difficult it is to get good speed regulation and the more likelihood of *wow* being introduced. It is general practice to make the turntable relatively heavy to provide the inertia for good speed regulation. But more motor power is required to drive the heavier turntable; hence more hum is produced. Record changers require more drive power than single-play systems, so changers tend to be more subject to hum pickup.

TAPE RECORDING

Stereo recording and playback from tape may soon be as common as stereo records, because of technical improvements, price reduction, and greater convenience in use. Many audiophiles believe that tape offers the greatest opportunity for the ultimate in high-fidelity stereo reproduction.

Although stereo tapes were available long before stereo records came into general use, certain basic problems have slowed them from enjoying a wide distribution. The first of these problems is price. At present, stereo tapes cost more than comparable discs and they must be played on a machine of relatively high quality, which also costs more than record players providing comparable reproduction. The second basic problem, now overcome, was the inconvenience of handling. A disc can easily be slipped onto a turntable, the pickup placed on it, and music obtained with little delay. When a tape is to be played, ordinary rolls must be carefully keyed into position, and the tape threaded through the guides and past the heads of the machine to the pickup reel. Magazine-type tapes are now available which eliminate such time-consuming operations, but they are still expensive.

In spite of the price disadvantage, tape does have many advantages. It is practically immune to wear and deterioration of quality with playing. A tape can be played thousands of times without noticeable degradation, providing reasonable care is used in its storage. The transfer from storage on the tape to an electrical signal in the amplifier is accomplished without the necessity of mechanical parts vibrating at sound frequencies as they do in phonograph pickups. Thus wear and resonance effects are minimized.

The difference between a stereo tape system and a monophonic tape system is that the stereo system simultaneously uses two tracks, recorded on the tape as shown in Figure 39. The recording and playback heads each have two units, one for each track. The tracks and the gaps in the head are separated

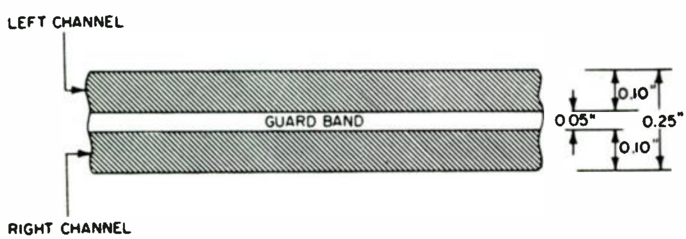


Figure 39 — Dimensions of tracks and guard band for two-track stereo tape.

Figure 40 — Dimensions of tracks and guard bands for four-track stereo tape.

by a guard band so that there is no interaction between the two signals.

The arrangement in Figure 39 allows two tracks to be simultaneously recorded or played back. Four-track permits additional playing time for the same length of tape. Using four-track tape, the tape can be played in one direction first and then turned over and played in the other direction the same as monophonic tape. The four tracks are recorded on the tape as illustrated in Figure 40. The guard bands do not need to be as large as for the two-track tape in Figure 39 because in Figure 40 only alternate tracks are used during tape travel in a given direction.

All stereo tape machines now use "in-line" heads, where the gaps for the two channels are exactly centered along the same vertical line. However, there were some machines made for staggered heads; in these the tape passed over first one head, then the other. Tape recorded for this arrangement is obviously not playable on the in-line-head machine. It was at first thought that staggering was necessary to prevent crosstalk between the channels, but the desired isolation is now obtained by proper spacing between the in-line gaps.

One of the advantages of tape as a stereo medium is the fact that isolation between channels is inherently much better than for phonograph pickups. Even with the small spacing between the tracks of a two-track system 40 db of separation is normally obtained. The separation is obtained much easier in the four-track system because head gaps have more physical separation.

SPEAKERS

The speaker system constitutes several links in the overall high-fidelity equipment chain. These links are illustrated in the block diagram of Figure 41. Each link must be considered not as a separate entity but in its relationship to the links which precede and follow it.

The amplifier output stage may be considered the energy source which supplies the driving power to the speaker system. Because most speaker electrical input circuits have a low impedance (2 to 20 ohms), most systems must employ an output transformer to match

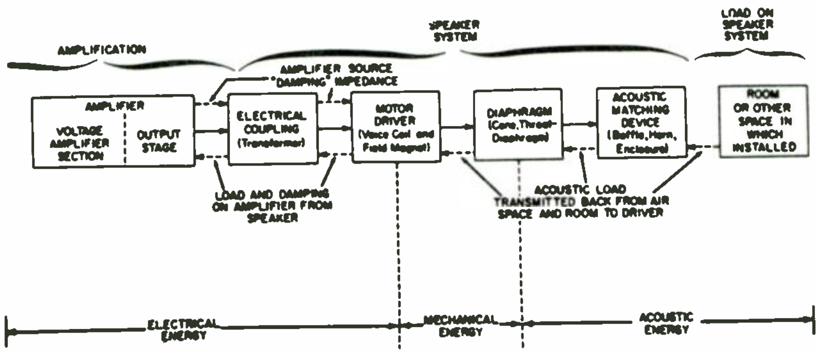


Figure 41 — Block diagram showing detailed sections and functions of the output of a high-fidelity system.

this low impedance to that of the output amplifier, which is ordinarily about 1500 to 6000 ohms. As will be explained, the transformer works both ways. The load on the speaker system is reflected back to the amplifier stage and influences its operation, and the amplifier impedance is reflected forward to contribute to the load on the speaker driver and radiator.

The speaker system itself can be divided into three functional parts:

1. The electromagnetic part, consisting of the voice coil and field magnet. Audio-frequency electric current in the coil causes mechanical motion of the cone or diaphragm on which it is mounted. This part is often referred to as the *driver* or *motor* of the system.
2. The mechanical part, on which the driving coil is usually mounted and which is set into mechanical motion by the audio-frequency electric current in the driving coil.
3. The acoustic part, which transmits the sound energy developed by the mechanical part to the room or other area served by the system, in the most efficient and faithful manner possible. This takes the form of a baffle or enclosure, with a horn being a form of enclosure.

A complete understanding of the operation of speaker systems requires a sufficient view of the whole flow of sound energy from the output amplifier stage to the listener, as depicted in Figure 41.

Speaker Drivers

The speaker driver is that portion which converts electrical energy from the output transformer to mechanical energy in the diaphragm or cone radiator. The driver is also sometimes called the *motor* because, like electric motors, its input is electrical and its output mechanical.

A number of different types of speaker drivers have been tried during the history of sound-system development. Those sufficiently successful to be commerically available include the following:

1. Moving-coil dynamic driver
2. Crystal drivers
3. Capacitor drivers

Of these, by far the most popular and useful in fidelity applications is the dynamic moving-coil type.

It should be mentioned here that the performance of direct-radiator speakers is very importantly influenced by the type of baffle or enclosure used. Baffles and enclosures will be discussed later.

Moving-Coil Dynamic Drivers

The principle of the dynamic speaker driver is based on the interaction of two magnetic fields. One field is relatively strong and steady; the other, developed by the passage of an audio-frequency signal current through the voice coil, varies with the instantaneous amplitude of the sound to be reproduced. The voice coil, which is wound on a cylinder of fiber or aluminum, fits into the annular air gap in the core and frame structure (Fig. 42). The AF electrical signal output from the output transformer is applied across the voice coil. The AF current resulting in the voice coil generates a varying magnetic field which works against the strong field of the permanent magnet, and the resultant motor force produces mechanical motion of the voice coil. The voice coil is mounted to the cone-type radiator; hence the coil also moves with it and radiates the sound. The use of the dynamic driver is by no means limited to cone radiators; it is also frequently employed with horn-type radiators, as illustrated in Figure 43.

For minimum distortion and maximum frequency range, it is important that the voice coil and radiator or diaphragm have a minimum mechanical mass. Excessive mass in this structure would result in inertial effects becoming worse at high frequencies, and the cone or diaphragm would have a tendency to distort physically in an attempt to follow the rapid variations of high-frequency sound components. For this reason, the voice coil is made as small and light as possible.

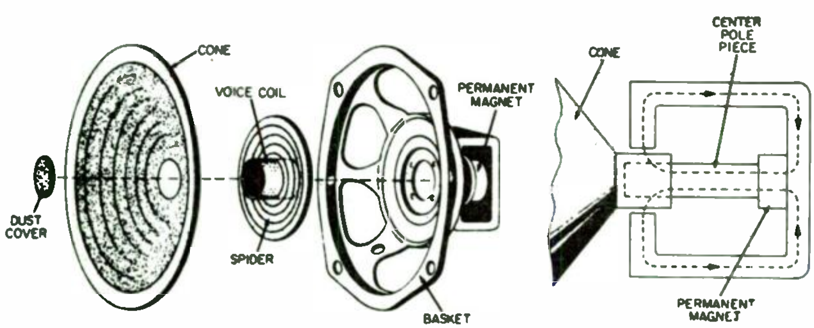


Figure 42 — Permanent-magnet speaker construction

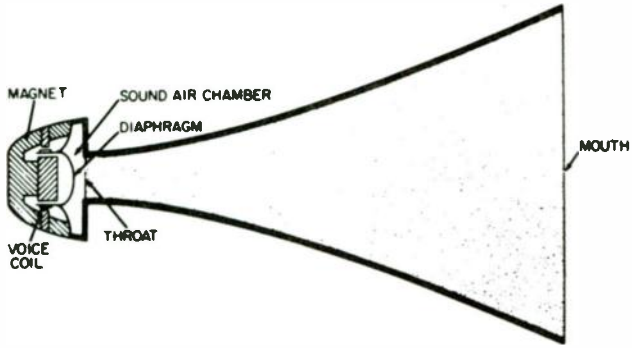


Figure 43 — Cross sectional view of a horn-type reproducer

It usually consists of a single layer of fine enameled wire about 1/2 to 2 inches long wound along the outside surface of the voice-coil form. Because the voice coil must be so compact and light, its impedance is necessarily low; this is why output transformers must be used to couple efficiently between the relatively high impedance output amplifier tubes and the dynamic speaker.

Leads from the voice coil are usually cemented to the middle portion of the cone surface, then brought out to terminals mounted on the basket of the speaker structure.

The impedance rating of the voice coil, in commercially available units, may be any value from 2 to 16 ohms. This impedance is not that of the voice coil alone but includes the effect of acoustic loading on the cone or diaphragm and mechanical effects in the structure. These factors tend to resist motion of the voice coil and thus raise the impedance "looking into" the voice-coil terminals. These latter effects are the largest part of the rated impedance, and the effects of the self-inductance and resistance of the voice coil are relatively small. The impedance rating is also specified for some standard frequency, usually either 400 or 1000 Hz. For the foregoing reasons, a simple resistance test of the voice coil will show a relatively low resistance, compared with the impedance rating of the speaker as a whole.

Practical permanent-magnet dynamic speakers were made possible by the development of high-grade magnetic materials, particularly Alnico. Very powerful magnets, which hold their magnetic properties indefinitely with little loss, can be made from this material. A round piece of this magnetized material is mounted between the core and the frame of the magnet structure in the dynamic-driver unit, as shown in Figure 42. It is thus effectively in series with the other iron in the magnetic circuit, producing flux in the same way as the many turns in the field coil of an older style electrodynamic type. Also, because the permanent magnet is lighter than a field coil providing the same amount of field, the overall weight of the speaker is reduced below that of an equivalent electrodynamic unit.

Since the permanent magnet supplies the fixed field for operation of the driver, the output power of the speaker is limited by the available flux and the size of the permanent magnet. In addition to power-handling capability, the size of the magnet also affects frequency response because the lower-frequency components contain most of the power in the audio signal; and they are attenuated in driver units with small magnets. Permanent-magnet speakers in general contain magnets weighing from 2 to more than 20 ounces. Types desirable from a high-fidelity standpoint are those with 6-ounce or heavier magnets, depending on the power requirements for the speaker.

Cone-Type Radiators

Of the functional blocks of the speaker system illustrated in Figure 41, we have discussed the driver only. The next step is the diaphragm which converts energy of mechanical motion into energy of air motion, called *acoustic energy*. There are two commonly used forms of diaphragms: (1) the cone type and (2) the horn type. The cone type acts as both diaphragm and radiator because it not only converts the mechanical energy of the driver into acoustic energy but also at the same time couples this energy into the room or area where the listeners are located. On the other hand, the horn-type diaphragm provides only mechanical-to-acoustic conversion; its acoustic energy output must be fed to the throat of a horn which couples it to the listening area. First, we will consider the cone-type diaphragm and radiator, which is more common than the horn-type diaphragm.

It is the purpose of the cone or any diaphragm-radiator combination to convert mechanical energy from the driver into acoustic energy in the listening area. The conversion must be such as to provide the greatest amount of acoustic power output for a given electrical power input, with a minimum of distortion of the output sound waveform. Although the speaker cone is a power transducer, output quality is more important than output power. Although efficiency (ratio of output acoustic power to mechanical power input) should be as high as possible, the modifications necessary to keep distortion to desirable low levels make the majority of speakers inherently low-efficiency devices. Most speakers have overall efficiencies ranging from 5 to 15 percent; some very elaborate systems approach 40 percent.

For higher efficiency in transfer of the mechanical energy to the air, it is desirable that the greatest possible area of contact be made between the radiator and the air. Since it is desired that the air mass be alternately moved forward and backward (and not up and down or sideways), it is natural to envision a large flat sheet driven by the speaker driver, as shown in Figure

A *Flat-sheet radiator.* B *Cone-type radiator.*

Figure 44 — Schematic representation of two types of radiators.

44A. The greater the area of contact, the better the air mass loads the driver unit. Unfortunately such a flat structure is not mechanically practical, because when it is constructed light enough for good high-frequency response it does not retain rigidity over its entire surface. To retain better overall mechanical rigidity with comparable large-area air contact, the cone type of radiator has been used; this type is shown in Figure 44B. It has been found that, with such a shape, a relatively large area of air may be activated with a relatively high ratio of strength to weight.

Treated paper is universally used in cone construction. The more rigid the paper, the greater is the sound output obtained, but the poorer is the frequency response. Soft, blotterlike cone materials improve uniformity of response in the low- and medium-frequency ranges but give poor response at high frequencies. Soft cones are also better for transient-response rejection. High-fidelity speakers often use a two-piece cone of different materials, as will be explained later.

The size of the cone is important because it influences both the low-frequency response and the power-handling capacity. The larger the cone diameter is, the greater is the power capacity for all frequency components combined, and the better is the low-frequency response. However, such improvements are not necessarily derived from larger cones unless the voice coil is appropriate. The acoustic impedance offered to the cone rises as the cone is made larger; the voice-coil impedance must then also be made larger for proper energy transfer and efficiency. The larger the cone is, the lower is the lowest useful frequency of operation. But frequency range is not the only factor improved by increase of cone size. Because the major portion of the ordinary AF signal power is in the low-frequency components, the overall power-handling capacity is also improved, as mentioned previously. The increase in the frequency range at the low end of the spectrum by an increase of cone size is illustrated in Figure 45. Note that these curves show a response peak just before the response falls off at the low-frequency end of the range. This peak occurs at the resonant frequency of the speaker, which will be explained later.

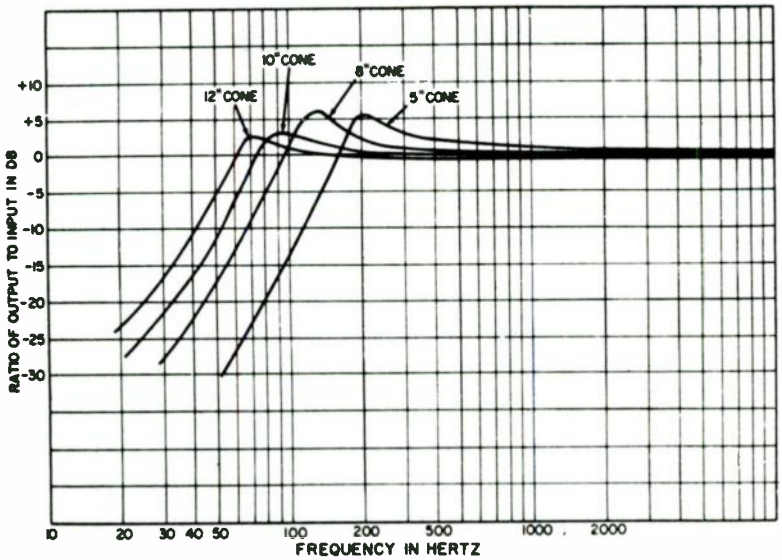


Figure 45 — Effect of cone size and resonance on low-frequency response.

The size of the cone is also important in the choice of an enclosure in which the speaker is to be mounted. Enclosures are designed to operate with speakers of specified characteristics which depend mostly on size; that is why a given enclosure is stated to be used only with a speaker (or speakers) of a given size. Of course, it is assumed that the overall design of the speaker is consistent with high-fidelity performance with the nominal cone size. A large cone with a small voice coil is not considered adequate for high-fidelity output.

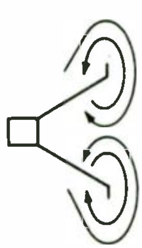
SPEAKER BAFFLES AND ENCLOSURES

Baffles

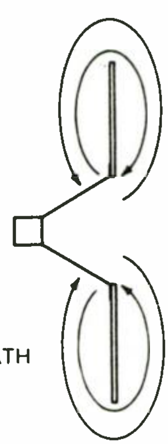
Sound energy is released from both sides of a speaker cone. This is natural because there is air on both sides of the cone and the cone moves as a unit; however, when the cone moves forward, the air in front of it is compressed and the air in back of it is rarefied. The sound released from the rear of the cone is of opposite phase to that released from the front of the cone. If the sound from the rear is allowed to flow so that it meets the sound from the front, cancellation takes place and the response of the speaker drops off sharply. Such cancellation is substantial only when the paths to the meeting place are short compared to a wavelength and maximum when the total path length from the front of the cone to the back is exactly equal to zero or one wavelength. Sound waves from the rear change 360 degrees in phase in one wavelength and therefore oppose front waves. The wavelength of sound becomes longer as the frequency decreases; consequently, front-to-back interference is worst at the lowest frequencies and ordinarily marks the cutoff frequency of the speaker mounting. Such interference is not appreciable at higher frequencies at which the wavelength is small compared to the path length between the front and back of the cone. At these frequencies, the compressions and rarefactions are so closely spaced that there is no definite general cancellation action as at the low frequencies.

The longer the path length between front and rear, the lower is the frequency at which interference can take place. By extending the edges of the cone with some rigid flat material, we make it necessary for sound waves from the rear to travel out to the edges of the material before they can meet the sound waves from the front and interfere with them. The added material is called a *baffle,* and its principle is illustrated in Figure 46. With the speaker alone (Figure 46A), the front and rear waves must travel only along one side of the cone to meet at the edge. This path is so short that a speaker alone without baffle will usually not reproduce much below about 350 Hz. In Figure 46B is shown the situation when a baffle is added. The length of the interference path is increased by the width of baffle material on each side. The reader can clearly demonstrate this effect by operating a speaker connected to a radio receiver or record player. First, listen to the speaker alone; then place it against a temporary, improvised baffle. The latter can be a large piece of cardboard or corrugated carton with a hole cut in it. The increase of low-frequency response will be very clearly noticeable.

Baffles should be made of good sound-insulating material and should be soft enough to prevent rattle. Soft woods are satisfactory, but material like *Celotex* is more appropriate. The speaker must be securely fastened to the baffle, and

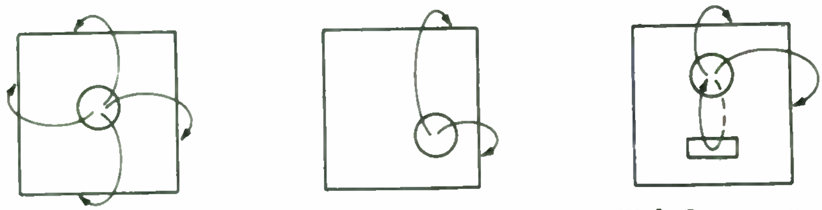


A Speaker alone.



B Speaker and baffle.

Figure 46 — Increasing the front-to-back interference path length by adding a baffle.



A Symmetrical mounting. *B Offset mounting on baffle.* *C With Compensating port.*

Figure 47 — Mounting a speaker on a flat baffle.

the baffle must be rigidly mounted to prevent rattle.

If a baffle is to be of limited size, the speaker should not be mounted in the center. The center is a bad position because the path lengths to all four edges are the same, and the frequency components at which the path length (one side) is one wavelength are severely attenuated. The center position is illustrated in Figure 47A. If the speaker is moved toward one corner, as in Figure 47B, the uniformity of response is much better because the path length to each edge is different and the interference attenuation is distributed. The interference does not have to take place around the edge of the baffle but sometimes is purposely made to take place through a port, as illustrated in Figure 47C. The design principle of such an arrangement is to equalize the response peak due to speaker resonance by the sharp attenuation around that frequency by spacing the port so that the sound travels a half wavelength. Some audiophiles adjust the size and shape of the port until it balances out the resonant peak of the speaker.

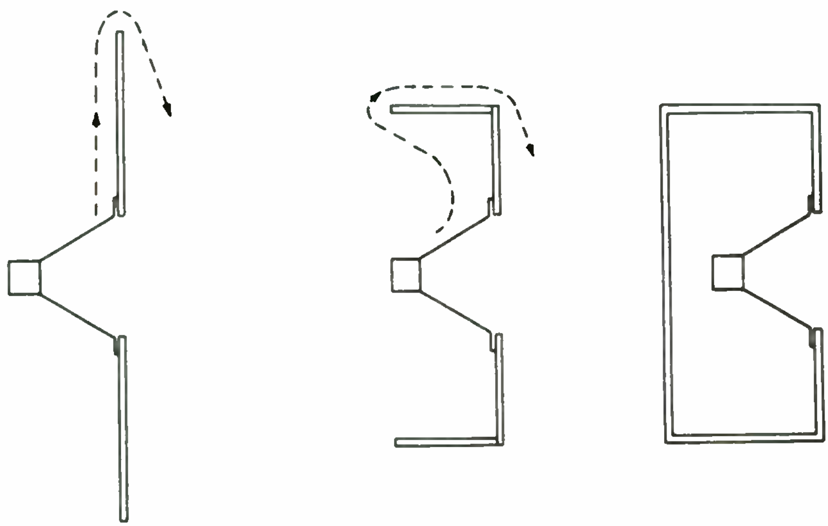
For a theoretically perfect speaker, the ideal baffle is one which has infinitely long lateral dimensions. The interference path lengths are then infinite, and no matter how low the frequencies of the sound components, cancellation or reinforcement due to baffle limitations cannot take place. Obviously, an infinite baffle in the fullest sense cannot be realized. However, if the baffle dimensions are sufficiently large, the baffle is referred to as *infinite*. For example, a speaker mounted in a hole in the wall of a house and placed at least 6 feet from the nearest opening, with its back opening on one room and its front on the adjacent room or outside is, for all practical purposes, an infinite baffle. For use as an infinite baffle, one or two identical wide-range speakers with essentially flat response over the desired frequency range are recommended to be placed at ear level or directed toward ear level. Speakers for this application should have very low resonance characteristics because there will be no provision for eliminating such defects. In the previous discussion of speakers, it was stated that each direct-radiator speaker was assumed to be mounted in an infinite baffle because this removes the effect of front-to-rear interference and allows us to consider the inherent effects of the speaker.

Simple Enclosures

An infinite baffle, or an approximation of it, is one of the best speaker mountings. However, its size is a disadvantage in an ordinary home. For example, to reduce the frequency of interference to 50 Hz, the baffle must be at least 12 feet square! Because of this size problem, various arrangements have been developed in an attempt to get the same effect without the use of so much space. This had led to the design of speaker enclosures.

The evolution from a flat baffle to a simple enclosure is illustrated in Figure 48. The simple flat baffle is symbolized in Figure 48A. To reduce the maximum dimension of the baffle, the outer portions can be bent back at the four edges to form an open box, as indicated in Figure 48B. The path length is as great as for the flat version, but the lateral dimensions are smaller. In Figure 48C the process is carried one step further, and the back of the enclosure is closed; the back prevents any sound from the rear from getting to the front.

The open-back cabinet arrangement of Figure 48B is the one commonly employed for radio and television receivers. A glance at the size of midget radio cabinets and a quick estimate of their path lengths will quickly show why low-frequency response is lacking in this type of receiver. The small speaker used is also a low-frequency limiting factor, but the cabinet is usually the important limitation. Large console models employ larger speakers and larger cabinets, but the path length is seldom sufficient to allow reproduction as low as 150 Hz, unless some



A Speaker with simple flat baffle. *B Open-back enclosure.* *C Closed-back enclosure.*

Figure 48 — Evolution from a flat baffle to a simple enclosure.

special cabinet design other than the simple open-back box is used.

Another disadvantage of the open-back box is the fact that it acts as a resonant tube at some frequency well within the operating range, unless it is very large. Sounds of frequency near resonance are reproduced with annoyingly excessive volume relative to other sound components. Any sudden sound peaks of any frequency or sounds of low frequency can shock-excite the box into oscillation at the resonant frequency. Low-frequency sounds which are not attenuated by the interference path all seem to sound the same, because of shock excitation at the resonant frequency. This accounts for the fact that many console radio receivers and some of the earlier juke boxes emitted a constant booming during reproduction of music.

It would seem, then, that simply closing the box as in Figure 48C would be the answer; and the box could be as small as desired as long as it holds the speaker because the sides and back would block the rear-to-front interference path. Unfortunately, this is not so. As soon as the box is closed up tight, as in Figure 48C, the air in it is no longer free to move in the open as in the open-back cabinet. Instead, the action of the cone causes pressure changes in the cabinet rather than a combination of pressure and velocity. This means that the springiness or compliance of the air is an important factor. Compliance is acoustic capacitance and combines with the compliance of the cone suspension in such a way as to raise the resonant frequency of the system to a value higher than that of the speaker alone. The reason for this effect can be noted from the equivalent circuit for the closed box, given in Figure 49. The mass (inductive effect) of the cone, the compliance (capacitive effect) of the cone suspension, and the compliance (capacitive effect) of the air in the box are all effectively in series with each other. The smaller the box, the smaller is the acoustic capacitance it simulates. Use of a small box lowers the capacitance connected in series with the series-resonant circuit of the speaker and thus raises the overall resonant frequency.

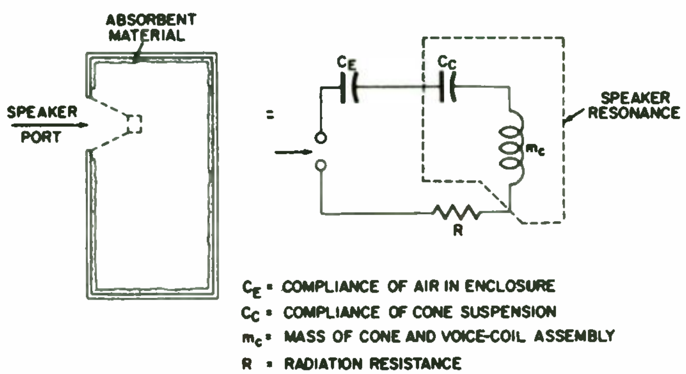


Figure 49 — Equivalent circuits of closed-box enclosure.

An important feature of the closed box is the fact that, because there is no motion of air in and out of it, there is no inertance or inductive effect. There is only compliance, or capacitive effect. Accordingly, the box itself does not resonate as do some other types. All it does is enter the resonant circuit of the speaker unit and raise the resonant frequency of the system above that of the speaker.

Compliance and thus the capacitive effect of a closed box increases with size if the box can be made large enough so that the equivalent air compliance capacitance is large compared with equivalent speaker-suspension compliance capacitance. Then the box will raise the resonant frequency only a negligible amount above the resonant frequency of the speaker. On the other hand, because the only effect of the box is to raise the resonant frequency, a speaker with a very low self-resonance could be put into a relatively small box. Then the system resonance would still be low enough for good results, even though it is raised above the resonant frequency of the speaker alone. Generally, a closed box of a given volume will raise the resonant frequency of the system a given percentage above the resonant frequency of the speaker.

Because the closed box keeps back radiation from getting around to the front and interfering, it is frequently referred to as the *infinite-baffle enclosure* and sometimes even as *infinite baffle.* As should be clear from the preceding discussion, this closed-box enclosure is not at all equivalent to a true infinite baffle unless it is so large that its effect on the resonant frequency is negligible.

Acoustic Labyrinth

Another method of acoustic phase inversion is exemplified by the acoustic labyrinth, depicted in Figure 50. The cabinet is divided into parts by a series of baffles in such a way that the spaces between the baffles will form a lengthened passage, or duct, of approximately constant cross section between the back of the speaker and the front of the cabinet. The labyrinth thus feeds the back radiation around to the front.

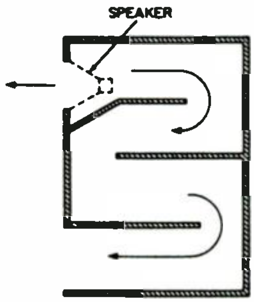


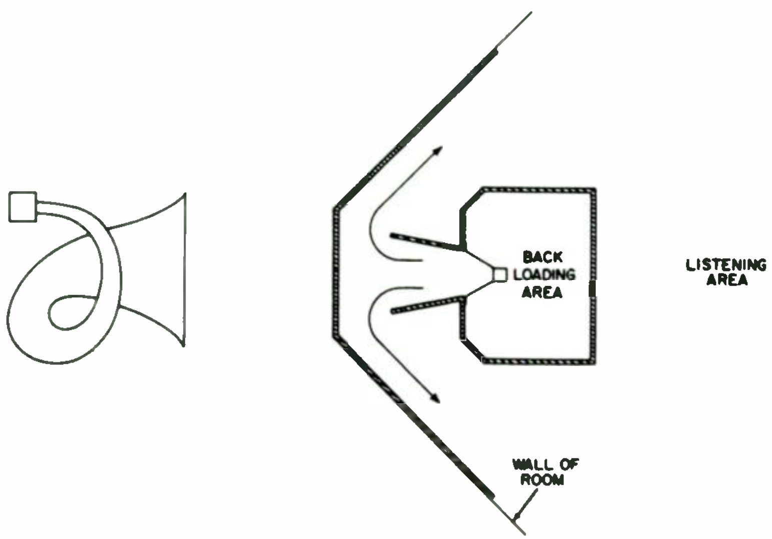
Figure 50 — An acoustic-labyrinth cabinet arrangement.

Besides the acoustic inversion effect, the labyrinth has another very important design consideration. The pipe or tube simulated by the space between the baffles acts as a tuned line when it is exactly a quarter-wave-length long at the resonant frequency of the speaker. It simulates a parallel-resonant circuit which equalizes the series resonance of the speaker unit in the same manner as in the bass-reflex cabinet. The labyrinth has two main beneficial actions: (1) It equalizes the resonant bump in the speaker response and spreads out low-frequency response, and (2) it provides reinforcement of the sound in the range near the frequency at which the duct length is a half-wavelength (twice the resonant frequency of the speaker).

HORN-TYPE ENCLOSURES

Audio engineers have always been attracted to horns because of their high efficiency and good frequency response above cutoff frequency; but, a conventional horn structure for a low enough cutoff frequency for high fidelity (say 50 Hz or lower) is so large at the mouth as to be prohibitive for ordinary use. To overcome this problem, a number of designs have been developed to simulate the performance of a large horn without the large dimensions necessary in the conventional type. In home installations, the use of horn-type enclosures is confined to the low-frequency range, and they are ordinarily employed in conjunction with a separate tweeter (which may itself have a separate horn), or they are driven by a coaxial or extended-range, single-cone driver. In the home, cone-type drivers are almost universally used to drive the horns at low frequencies.

One of the first measures taken to reduce size is the folding of the horn. Folded or rolled exponential horns have been used for centuries in musical instruments, and these look like that shown in Figure 51A. Of course, this type has a small throat and in electrical sound systems would be used with a diaphragm-type driver. In high-fidelity systems, horns are driven by cone-type speakers (for low frequencies) and must therefore have large throat diameters.



A Musical instrument type. *B Low-frequency horn.*

Figure 51 — Folded horns.

ELECTRICAL DIVIDER (CROSSOVER) NETWORKS

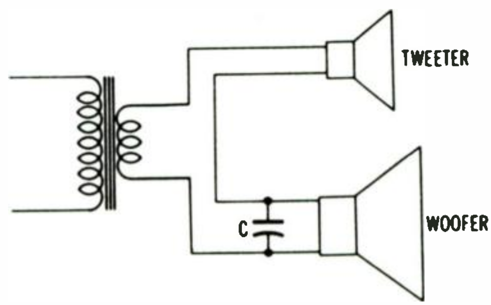
In dual or multiple speaker systems, the audio-frequency energy from the amplifier must be divided so that only the appropriate frequency components are fed to each unit of the system. In most cases, the individual parts of the system, although designed for optimum operation in their specified respective portions of the frequency spectrum, are subject to distortion and sometimes even overheating if they are driven to full power rating at frequencies outside their normal range. This is an important factor adding to the more obvious one: overall efficiency is substantially reduced by feeding too much low-frequency energy to a high-frequency unit and high-frequency energy to a low-frequency unit.

In dual systems employing a common voice coil, the mechanical compliance between the high- and low-frequency radiator sections of the cone divides the energy after it has been converted to mechanical motion of the voice-coil form. The compliance acts as a low-pass filter, eliminating most of the high-frequency components from the woofer or larger section of the cone. Low-frequency energy is fed to the high-frequency portion of the radiator, but not to it alone, because at low frequencies it acts only as part of the total mass composed of both low- and high-frequency portions.

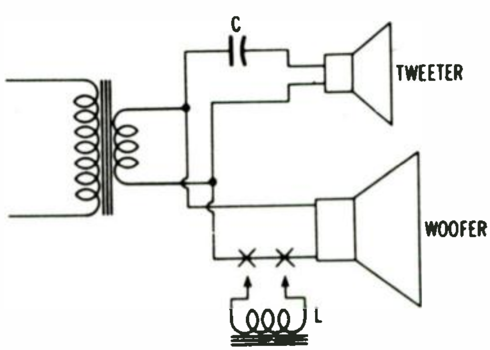
When each of the units in a multiple system has its own voice coil or at least two have separate voice coils, the division of low- and high-frequency energy must be done electrically by divider networks.

Simple Network

The simplest type of divider network consists merely of a single capacitor, as illustrated in Figure 52. The fact that the reactance of a capacitor is inversely proportional to frequency is employed to distribute the audio signal. In the arrangement of Figure 52A, the tweeter and woofer voice coils are connected in series and a capacitor is connected across the woofer. The value of capacitance is made such that at frequencies above the desired range of the woofer the reactance of C becomes so low that it



A Series connected.



B Parallel connected.

Figure 52 — Simple divider circuits employing single reactances.

shunts the woofer, which acts as a bypass capacitor. Low-frequency components can be kept out of the tweeter if a parallel connection of voice coils is used with capacitor in series with the tweeter circuit, as illustrated in Figure 52B.

Inductances can be used with capacitances to make the divider network more complete. For example, in Figure 52B the inductance (L) can be connected in series with the woofer leads as shown. The inductance, the reactance of which increases with frequency, chokes the high-frequency components out of the woofer, and the capacitor (C) blocks low-frequency components out of the tweeter. The values of C and L must be such that the reactance in each case is about equal to or a little lower than the voice-coil impedance in the frequency range to be attenuated.

A capacitor or inductor provides gradual attenuation with frequency, as the range of undesired frequency components is approached. Although the crossover range should not be too narrow, simple reactance circuits as in Figure 52 are ordinarily too broad in the changeover region. Instead, a combination low-pass (for the woofer) and high-pass (for the tweeter) filter circuit is usually employed. With this type of circuit, much more rapid attenuation can be made near the crossover frequency than is possible with simple capacitor and inductor arrangements as illustrated in Figure 52. Attenuation of about 12 db per octave is considered proper in most applications. Gradual crossover arrangements attenuate at about 6 db per octave. Filters with sharper cutoff than this can be constructed by use of additional components, but power losses in the filter become excessive, and the additional sharpness is not necessary anyway. A typical divider-network response graph is shown in Figure 53. The curve of woofer output crosses the curve of tweeter output response at the crossover frequency. This intersection is also at the -3 db or half-power level; at the crossover frequency, half the output power is being fed to each unit. From this, it can be seen why the respective individual response characteristics of the woofer and tweeter units must overlap substantially. If the crossover level were lower, there would be a lessening of total output in the crossover region; and this would result in frequency distortion of the system. The dashed-line curve of Figure 53 represents a gradual crossover attenuation of 6 db per octave, compared to the more commonly encountered solid-curve value of 12 db per octave.

Network Design

The construction of divider networks is not as simple as the schematic diagrams may indicate. Some of the reasons are:

1. The capacitors ordinarily require fairly accurate odd values that are hard to obtain without several components being connected together.
2. There is no polarizing voltage, applied voltages are purely AC voltages at audio frequency, and electrolytic ca-

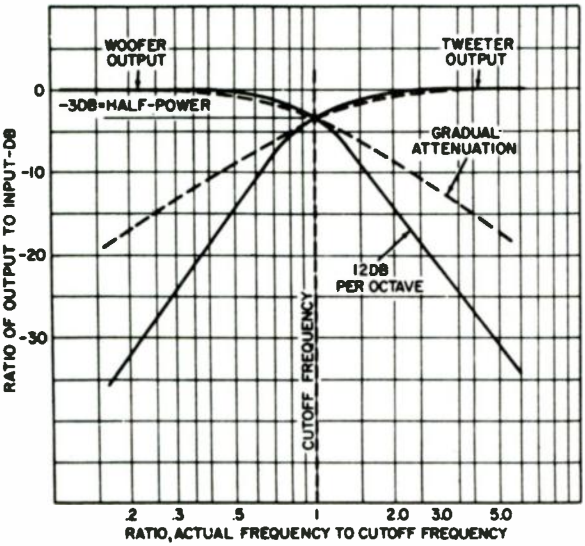


Figure 53 — Divider-network response curves.

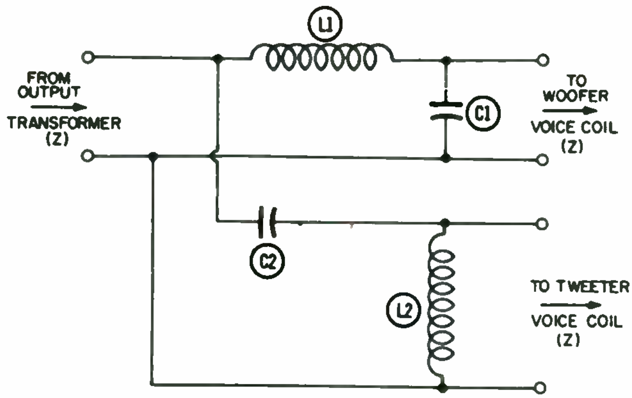
pacitors cannot be used. At the values necessary, other types of capacitors are relatively bulky and expensive.

3. Current at low impedance is appreciable; therefore, fine wire cannot be used for the coils, which have hundreds of turns for the values required. Again, the values are odd, so standard units are not applicable.

To illustrate the problem, the schematic diagram of one of the more popular types of divider networks is shown in Figure 54, with formulas for calculating the values required for any crossover frequency f_c and speaker impedance Z and an example of its use in a practical application. The values obtained in the solution of this example illustrate the previous statements about the odd values and sizes of the capacitances involved. The circuit shown in Figure 54 can be expected to give an attenuation of about 12 db per octave.

Although the difficulties mentioned must be taken into consideration, they are not insurmountable, and some audiophiles prefer to construct their own divider networks. If the reader wishes to do so, it is suggested that he consult some handbook for data as to diameter, number of turns, etc., for his calculated inductance values. Although the number of turns and overall size of the coils can be reduced by use of iron cores, this is not recommended, because the latter introduce nonlinearity. The capacitors can be of the oil-filled variety and can be made up from standard sizes connected in series or parallel.

For those who prefer to buy their crossover networks ready-made, the latter are available from a



$$L1 = \frac{0.255Z}{f_c} \text{ henrys} \qquad C1 = \frac{0.15}{f_c Z} \text{ farads}$$

$$L2 = \frac{0.15Z}{f_c} \text{ henrys} \qquad C2 = \frac{0.10}{f_c Z} \text{ farads}$$

Example: Find component values for $f_c = 500$ Hz $Z = 8$ ohms

$$L1 = \frac{0.255 \times 8}{500} = 4.08 \times 10^{-3} = 4.08 \text{ millihenrys}$$

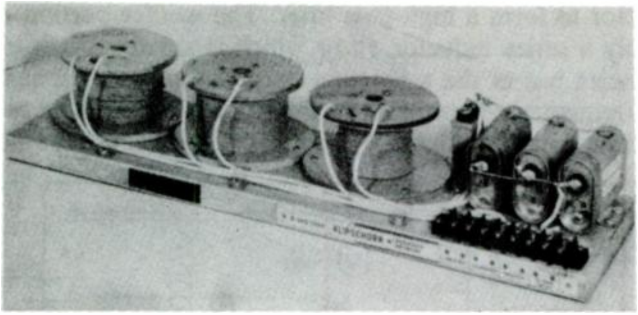
$$L2 = \frac{0.15 \times 8}{500} = 2.4 \times 10^{-3} = 2.4 \text{ millihenrys}$$

$$C1 = \frac{0.15}{500 \times 8} = 37.5 \times 10^{-6} = 37.5 \text{ mfd}$$

$$C2 = \frac{0.10}{500 \times 8} = 25.0 \times 10^{-6} = 25.0 \text{ mfd}$$

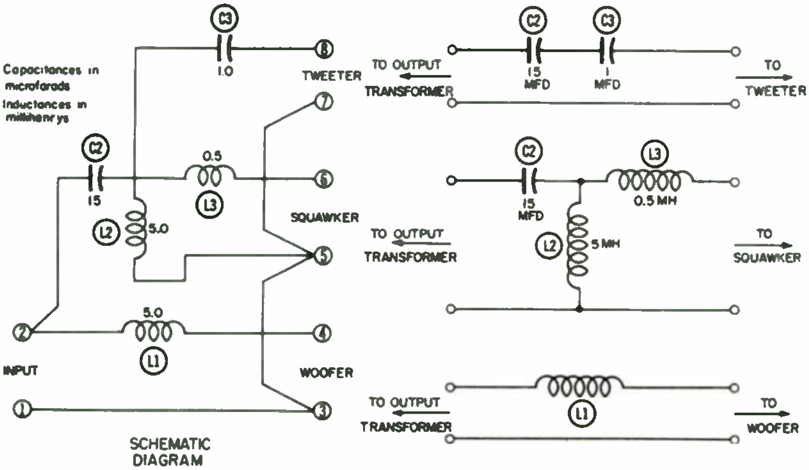
Figure 54 — A filter-type divider circuit, formulas, and sample calculation.

number of manufacturers of audio-frequency equipment. The schematic diagram, response curve, and physical construction of a commercial three-way network are shown in Figures 55A and B. Note from the response curve that the crossover between the woofer and squawker is 500 Hz and that the crossover between the squawker and the tweeter is 5000 Hz. This model employs gradual attenuation of 6 db per octave except at the low end of the squawker response, where it is 12 db per octave. The input and speaker impedances are 16 ohms. The schematic diagram is analyzed in Figure 55C. The tweeter portion includes simply the two series capacitors, C_2 and C_3, for a total capacitance of slightly less than 1 mfd. The squawker circuit employs a series capacitor, a shunt inductor, and a series inductor to form a high-pass filter. The woofer portion of the circuit is simply a series inductor (L_1) which is small enough to pass the low frequencies but at the same time large enough to attenuate all but the lowest frequency components in the woofer circuit. The tweeter and woofer circuits are of the single-reactance type and cause the slow rate of attenuation (6 db per octave). The squawker circuit has more rapid attenuation because it is of the composite filter type.

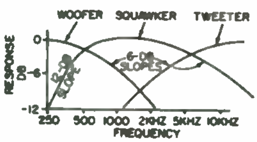


Courtesy Klipsch & Assocs., Inc.

A Construction.



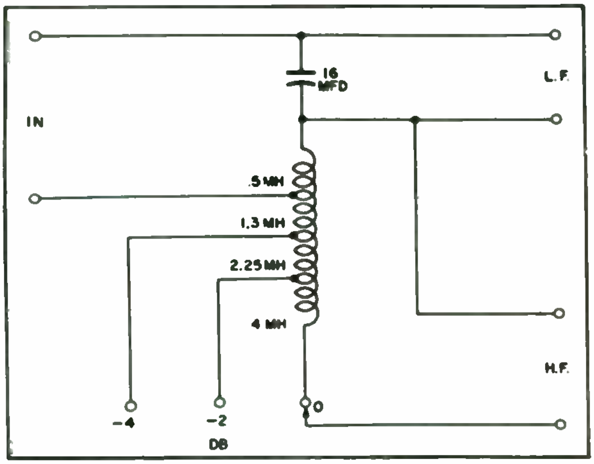
B Circuit.



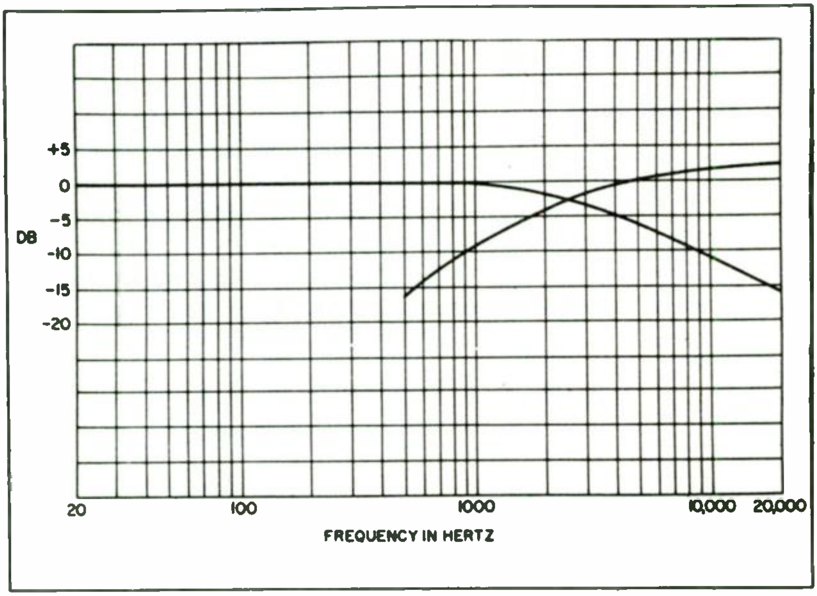
C Response.

Figure 55 — Design features of a commercial three-way divider network.

When a horn-type tweeter is used with a cone-type woofer, there is a tendency toward energy unbalance between the high and low frequencies because of the high efficiency of the horn. Some divider networks are designed to provide adjustment of the output of either section, relative to the other, to compensate for the difference in reproducer efficiencies. A typical commercial crossover network of this type is illustrated in Figure 56A. The response characteristic of



A Circuit.



B Response characteristics.

Figure 56 — A commercial divider network which provides adjustment of the tweeter output to compensate for tweeter-horn efficiency.

the network is shown in Figure 56B. The response shown applies for the 0-db position. Note that the tweeter response can be reduced either 2 db or 4 db with respect to the woofer response by moving the tap.

When divider-network response is considered, it should be remembered that the actual acoustic attenuation at the crossover frequencies may be much greater than that indicated by the electrical circuit. This is because, even when separate voice coils are employed, there may be, between units, mechanical compliance which acts as an attenuator.

The divider networks described thus far are connected between the output transformer and the speaker units. Because the power level is high and the impedance low, the inductors must be capable of handling fairly high current and are therefore bulky. Because of the low impedance, the capacitors must also be large, as has been explained. For these reasons, some systems provide frequency division in the amplifier ahead of the power output stage. At that point, the power level is so low and the impedance so high that simple resistance-capacitance-type filters can separate the high-frequency components from the low-frequency components. From this dividing point to the speakers, two separate channels are provided. There are several output amplifiers and separate output transformers, one for each channel, as illustrated in Figure 57. This is not as expensive an arrangement as might at first seem because, since each channel need have only a limited frequency response, the output transformers can be much less expensive.

Center Speaker For Stereo

Individual speaker requirements for stereo reproduction are substantially the same as for monophonic reproduction. The same low-distortion and wide-frequency-range requirements must be met in each unit of the stereo system.

One special feature developed especially for stereo is the dual voice coil. A typical speaker of this type is illustrated in Figure 58. Two voice coils are wound on the same form on the cone structure of the speaker. This arrangement forms a convenient method of mixing the left and right stereo signals for the center speaker. Since the center

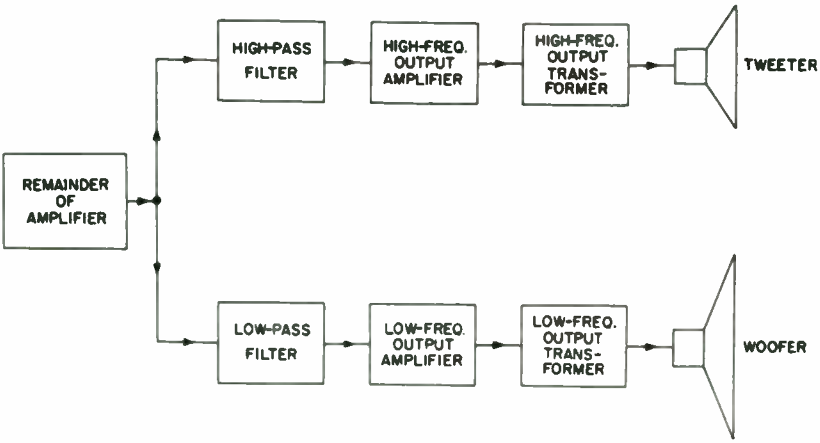
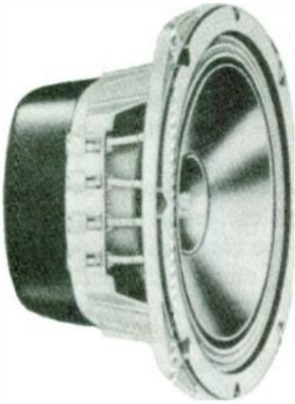


Figure 57 — A dual-speaker system in which the high-and low-frequency components are separated at a low power level in the amplifier.



Courtesy University Loudspeakers, Inc.

Figure 58 — A typical dual-voice-coil unit for use as middle speaker in a stereo arrangement.

speaker is usually required only to reproduce the lower frequencies, which are not as directional, the dual voice-coil speaker is usually a woofer. It is normally used with additional left and right speakers, which must reproduce only the frequency components of frequencies above approximately 200 Hz.

SUMMARY

Stereo signal generation starts with a minimum of two microphones placed to pick up a left signal and a right signal. These are known as the L and R signals. Using these two L and R signals, an L+R signal may be obtained, and by phase inversion, an L−R signal may be obtained. With the use of proper filtering, plus the generation of an additional carrier called the 38 kHz subcarrier, two signals may be transmitted. The L+R signal is transmitted on the center frequency of the FM station, while the L−R signal is transmitted 38 kHz higher than the center frequency of the FM center frequency.

Only the lower and upper sidebands of the L−R signal are transmitted, by suppressing the subcarrier frequency of 38 kHz. As this subcarrier frequency must always be present for demodulation at the receiver, a pilot subcarrier of 19 kHz is transmitted. The 19 kHz is doubled to 38 kHz, and it is mixed at exactly the correct frequency and at exactly the correct phase, in order to provide the proper Hi-Fi reproduction.

Troubleshooting stereo equipment should follow a systematic procedure. Some of the same techniques used in servicing AM and FM receivers are applicable in stereo repair, but the most important step is to analyze the difficulty before starting any actual work. By reviewing the operation of a receiver and inspecting the schematic diagram, it is quite possible that the area where the trouble exists can be pin-pointed before performing any actual repair work.

The recording of stereo programs on discs follows the Westrex system. The cutting stylus making the record is acted upon by two motions that are positioned 90° to each other. One motion is produced by the left signal and the second motion is actuated by the right signal. It is the resultant of the two motions that *cuts* on each side of the groove in the record.

A pickup arm that is balanced lightly works in an opposite manner, and generates a left and a right signal when the needle follows the groove in the stereo record.

Speakers should be enclosed in cabinets that prevent cancellation of the sound produced by the rear surface of the speaker. This can be accomplished by the proper design of baffles or labyrinths. The size and length of the air path that the sound must follow must be considered by the designer.

Speakers are designed to respond to different ranges of frequencies. The low frequency speaker is supplied with only low frequencies from the amplifier. These low frequencies are separated through a crossover network that eliminates the high frequencies. The design of the crossover network also guides the high frequencies to a speaker designed to faithfully reproduce the high frequencies.

TEST

Lesson Number 78

IMPORTANT

Carefuly study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-078-1.

1. **Starting with an L and an R signal, it is possible to get an**
   A. (L+R) and an (L−R) signal using a pulse generator.
   6 B. (L+R) and an (L−R) signal using a phase inverter.
   + C. (R+L) and an (L+R) signal using a phase inverter.
   8 D. inductance L, and a resistance R.

2. **The 19 KHz pilot subcarrier used in FM stereo transmission**
   A. is suppressed at the transmitter.
   B. is also used to key the sound detector in television receivers.
   10 C. is picked out and fed to a doubler to develop the 38 KHz subcarrier in an FM stereo receiver.
   D. is shunted to ground to prevent SCA interference in an FM stereo receiver.

3. **The tube acting as a phase inverter in Figure 17 will cause nonlinearity if resistor R34**
   15 A. increases in value.
   B. is replaced by a wire-wound resistor.
   C. was not dependent on R31.
   D. none of the above.

4. **An SCA signal**
   A. can produce "Birdies" in the FM stereo signal.
   B. is used to synchronize the scanning control amplifier.
   15 C. can always be heard on an FM monophonic FM receiver.
   D. all of the above.

5. **To make the Westrex recording system one whose groove modulation is more lateral than vertical, the**
   A. phase of the stereo receiver needs to be the only one that is reversed.
   29 B. T vector must be longer.
   C. vector phase must be reversed.
   D. phase of one of the signals driving the stereo record cutter is reversed.

6. **The force of pickup needles should be light and a reasonable maximum pressure should not be greater than**
   35 A. 45 degrees.
   B. four grams.
   C. one mil.
   D. twenty grams.

7. **The basis for the operation of the moving-coil dynamic speaker is the**
   A. cone shape.
   B. maximum mechanical mass.
   41 C. frequency range of a tweeter or a woofer.
   D. interaction between a permanent magnet and a voice coil.

8. **Audio transformers used for impedance matching are**
   A. usually constructed with Alnico magnets.
   B. used to match the moving voice coil to the impedance of the permanent magnet.
   42 C. required to match the low impedance of the voice coil to the high impedance of the output circuit.
   D. used in matching the high impedance of the voice coil to the low impedance of the output circuit.

9. **The sound from the front of a speaker**
   A. is in phase with the sound from the rear of the speaker.
   45 B. is of opposite phase to the sound from the rear of the speaker.
   C. can only be of low frequency.
   D. none of the above.

10. **Divider networks can use smaller components if the frequency separation is done**
    A. with transformers using Alnico.
    B. at a low power level, but the tweeter is connected to the low frequency output, and the woofer is connected to the high frequency output.
    55 C. at a low power level, but a low-pass and a high-pass filter are usually used.
    D. with unequal stages of amplification.

Notes

Notes

Portions of this lesson from
Hi-Fi Stereo
Servicing Guide
by Robert Q. Middleton
Hi-Fi Stereo Handbook
by William F. Boyce
Courtesy of Howard W. Sams, Inc.

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

KNOW WHERE YOU ARE GOING

All of us work more easily, more happily, and more successfully when we know where we are going, why we want to go there, and how to reach our destination.

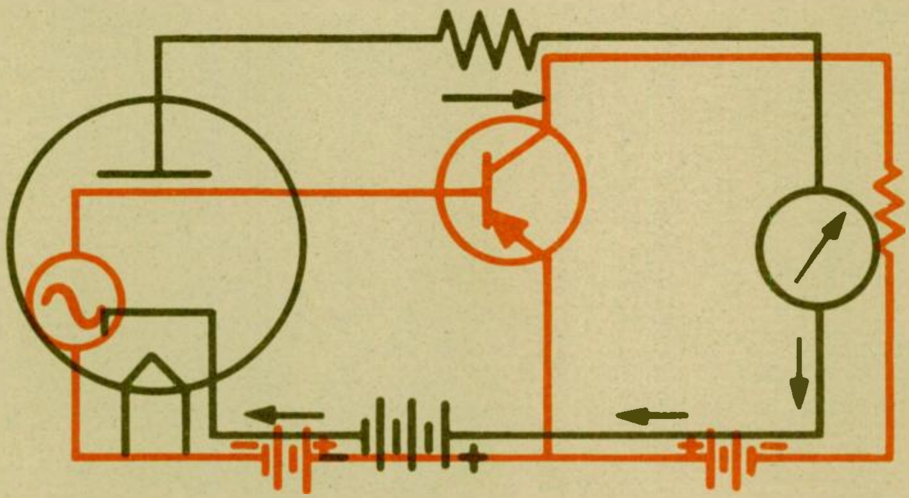
The way you start out in the business or professional world is likely to shape your entire future. Yet, for most people, where their life work begins and ends is often left up to chance.

You are lucky, as you have decided where you are going and you are doing something about it. Just keep up your progress—put your knowledge to work whenever you have the opportunity—search for new areas where your knowledge can be used—and you will be well on your way to a very successful career.

S. T. Christensen

LESSON NO. 79

CIRCUIT THEORY AND FUNDAMENTALS OF TV



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-079

407

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

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Contents

CIRCUIT THEORY AND FUNDAMENTALS OF TV

INTRODUCTION

Television is defined as the *instantaneous transmission and reproduction of scenes and images through the medium of electrical impulses or radio waves.* In the early development of television the image was only transmitted a few miles. With advances in technology the transmission distance was increased. Today it is possible to view a live scene from around the world, or even as far away as the moon on a television receiver.

Television is not restricted to the entertainment medium, but is also finding wide usage in other fields. Television monitoring systems are becoming commonplace in hospitals where they allow visual monitoring of many patients by one attendant. Television systems are also being used in security systems to allow visual coverage of many areas by one person.

As television branches out into the many fields opening up, there will become an increasing need for TV Service Technicians to maintain this equipment. A competent TV Service Technician must be well versed in mechanics as well as electronics. This lesson will cover the basic television system.

THE TELEVISION SYSTEM

A block diagram of a standard television system is shown in Figure 1. There are three main divisions in this diagram. The top division represents the video or picture section of the transmitter. The central division represents the audio or sound section of the transmitter. The lower division represents the television receiver.

In the video section of the transmitter the camera tube provides a means of converting light rays from an object on which the camera is focused into electrical impulses. Light from the object is focused on the light sensitive surface (called the mosaic) in the camera tube by a lens system. The camera tube contains an electron gun, which generates and controls a stream of electrons. The gun directs the narrow stream of electrons in such a manner that it traverses (scans) the mosaic line by line. As the beam strikes a spot in the mosaic it generates a small electrical impulse

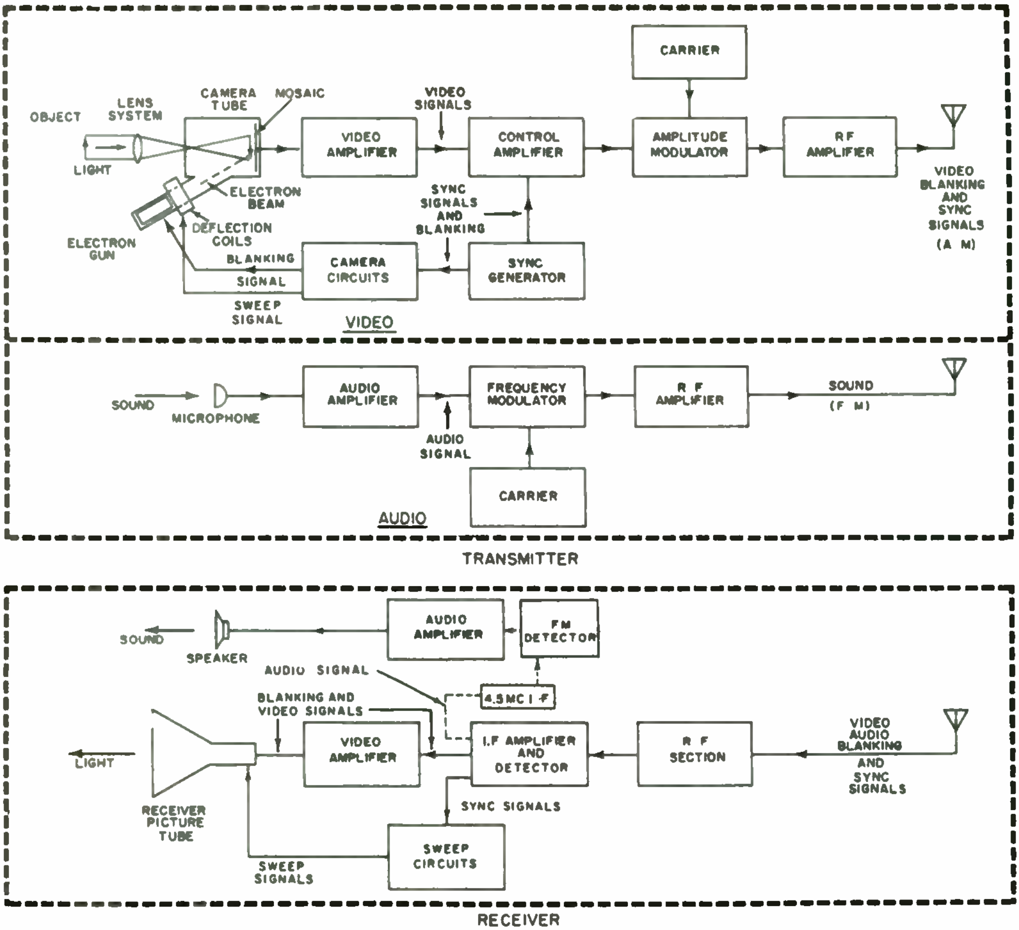


Figure 1 — Block diagram of a Television System.

which corresponds to the lightness or darkness of that particular tiny portion of the image. The electrical impulses generated in this manner are sent to the video amplifier.

Video amplifiers are designed to amplify a wide range of frequencies, and the weak electrical impulses from the camera tube are amplified by the amplifier and fed to a control amplifier.

The control amplifier combines the video, sync, and blanking signals, all in proper sequence into a single continuous input to the amplitude modulator.

Circuits in the sync generator produce synchronizing (sync) and blanking pulses. These pulses are applied to the control amplifier and become a portion of the transmitted signal. Horizontal synchronization makes the horizontal scanning at the receiver occur at the same time as the horizontal scanning at the camera. Vertical synchronization makes the vertical scanning at the receiver keep in step with the vertical scanning at the camera.

Sync and blanking signals are also fed to the camera circuits, which develop the necessary control signals for the electron gun and the sweep voltages for the deflection coils (both horizontal and vertical).

In the carrier, the principal circuit is an oscillator designed to produce a steady, continuous radio frequency (RF) signal. Its frequency is fixed, and is designated by the Federal Communication Commission (FCC) for the TV station in which it is to be used.

In the amplitude modulator, the carrier signal is modulated by the video, sync, and blanking pulses. The composite (total) signal is then amplified by the RF amplifier and fed to the antenna for radiation into space.

The sound portion of the television signal is transmitted by a frequency modulated RF carrier. The sounds are picked up by a microphone, amplified by the audio amplifier, and fed to the frequency modulator section. The sound carrier frequency is varied according to the frequency of the audio signal that is being picked up by the microphone. The frequency modulated signal is then amplified by an RF power amplifier and fed to the antenna for radiation into space.

The radiated video and sound frequencies are picked up at the receiving antenna. This signal contains the video, audio, blanking and sync signals. These signals are converted to an intermediate frequency in the RF section. The IF is then amplified and fed to the video amplifier, sweep circuits and the sound IF section.

The video amplifier builds up the video and blanking signals and applies them to the picture tube. The sync signals are fed to the sweep circuit. The sound IF is fed to the sound section where it is detected, amplified and applied to the speaker. The video and sweep circuits combine to present the image on the picture tube screen.

In this lesson we will study the basic theory and fundamentals of monochrome (black and white) television. In future lessons these circuits will be dealt with in more detail.

FUNDAMENTALS OF THE CATHODE RAY TUBE

The CRT (cathode ray tube) is nothing more than an indicating device. Just as a loudspeaker converts electrical impulses into sound vibrations, the CRT changes electrical signals into patterns of light.

CRT's are made in numerous sizes and shapes for many special purposes. The CRT is the backbone of television, for without it, television would be impossible. CRT's are also found in computer data systems and oscilloscopes.

Cathode-ray tubes are divided into two broad classes, *electrostatic* and *electromagnetic* tubes. Basically, this classification deals with the means employed to deflect (move) the electron beam across the flourescent screen. Each class of tube has its advantages and limitations which dictate why it was chosen for a specific use.

The Electrostatic CRT

The electrostatic CRT uses an electric field to control the electron beam. This field is built up, by the application of AC or DC voltages, between a pair of plates called *deflection plates.* Electrostatic tubes are generally small in size having screens from one to ten inches in diameter. Electrostatic tubes find widespread use in radar systems, in medical electronics and in the oscilloscope. As most people find the electrostatic tube easiest to understand, it will be described first. The basic construction of an electrostatic tube is shown in Figure 2.

The filament of the tube is heated by an AC current, and the filament in turn heats the cathode. The cathode is coated with barium or strontium oxide which emits large amounts of electrons. (When the cathode is heated, it *boils off* electrons.) A high positive voltage is placed on the *accelerator anode* and this attracts the negatively charged electrons and keeps them moving in a stream toward the front face of the tube. The electron stream also passes through the grid and the *focusing anode,* toward the high positive potential of the accelerating anode. When the elec-

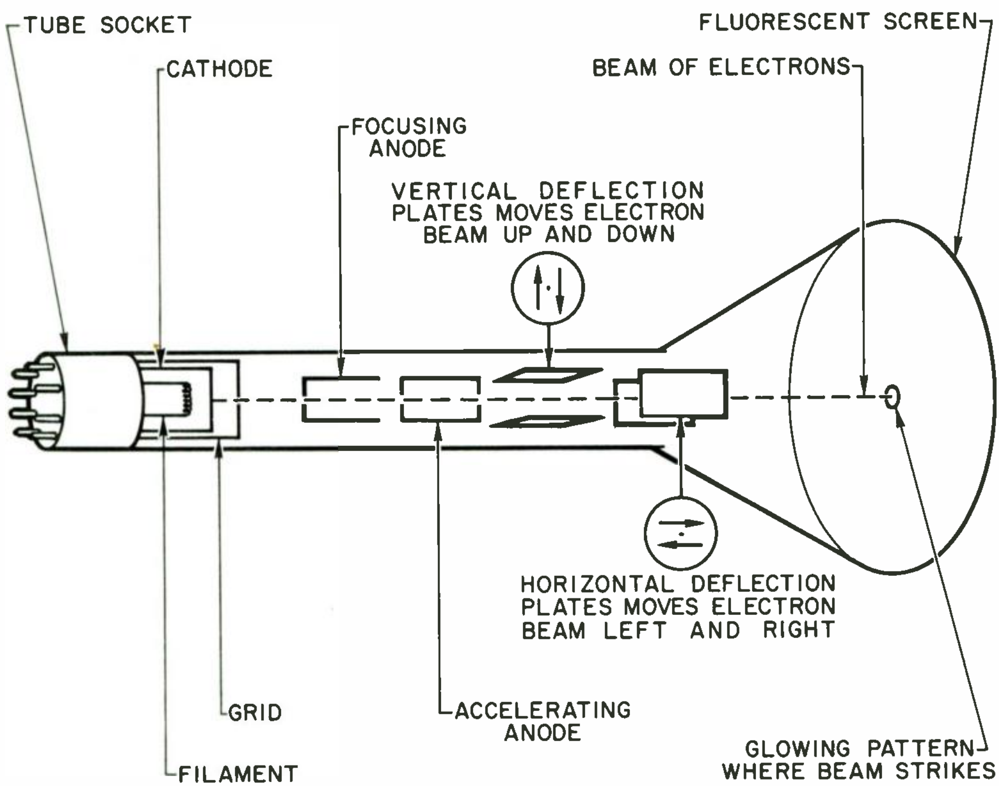


Figure 2 — The Electrostatic CRT.

trons reach the accelerating anode they are traveling at such a high speed that they continue on to the screen. The screen is coated with a chemical substance that glows when struck by electrons. This glowing action is called *fluorescence.*

The composition of the chemical substance used to coat the screen is very important and is determined by the application the CRT is to be used in. Investigators have found that different chemicals, when struck by electrons, will each *glow* in a specific color and for a different length of time. The length of time a chemical glows after being struck by an electron is called the *persistence* of the chemical.

The human eye retains an image for 1/15 of a second after the image is formed on the retina. This characteristic of the eye is utilized in moving pictures and television. Actually, this retentivity makes moving pictures and television possible. The persistence of the chemical used to coat the screen of the CRT should equal the retentivity of the human eye.

In a general purpose oscilloscope, a chemical having a "medium" persistence and a "green" screen is used. Black and white television receivers employ a white screen having a medium persistence. Various mixtures of chemicals fit into this category, including a combination of zinc sulphide and zinc beryllium silicate.

Electron Gun. The electron gun consists of the filament, cathode, control grid, focusing anode and accelerating anode and these elements control the number of electrons that reach the screen.

Filament heats the cathode.

Cathode surrounds the filament and emits electrons when heated.

Control Grid is a round grid that surrounds the cathode and controls the number of electrons in the electron stream. This control is achieved by varying the negative voltage applied to the grid.

Focusing anode narrows the electron stream and focuses it into a sharp beam.

Accelerating anode increases the speed of the electron beam. A high positive DC voltage is applied to the accelerating anode.

The electron beam leaving the *electron gun* is sharply focused and travels at a high speed. The sharply focused electron beam passes through a pair of flat electrodes which are in a horizontal plane with respect to the tube. When a DC voltage is applied to these plates, the electrons will be attracted to the more positive plate causing the beam to be deflected up or down. Because these plates move the electron beam in a vertical (up or down) plane they are called the *vertical deflection plates.*

Next the electron beam passes through the *horizontal deflection plates.* These are located in the vertical plane and cause the electron beam to move either left or right, depending on which plate is at the most positive potential. Thus, by applying a voltage on the horizontal and vertical deflection plates we can change the direction of the electron beam and the point at which the electrons will strike the screen.

The deflection system, electrostatic in this type of cathode-ray tube, consists of two pairs of metal plates, mounted at right angles to each other, and placed inside the neck of the CRT. Figure 2 shows the location of the plates. When a difference of potential is applied to the plates, an electrostatic field is developed between the plates. This field acts upon the electron beam and controls the point at which it will arrive at the screen. Figure 3 shows a simplified arrangement of the front screen and deflection plates for explanatory purposes.

In Figure 3A, all plates are at the same potential and no field exists to act upon the beam, so the beam arrives at the center of the screen. In Figure 3B, a positive potential is applied to the top plate, resulting in the beam moving towards the top of the screen. The greater the amplitude of positive potential, the farther the beam moves away from the center toward the positive potential.

In Figure 3C, a positive potential is applied to the bottom plate and the beam moves toward the bottom of the screen. In Figure 3D, the positive potential is applied to the right horizontal deflection plate, and the beam moves right. In Figure 3E, the positive potential is applied to the left horizontal deflection plate and the beam moves left. In Figure 3F, a positive potential is applied to the left horizontal deflection plate and the top vertical de-

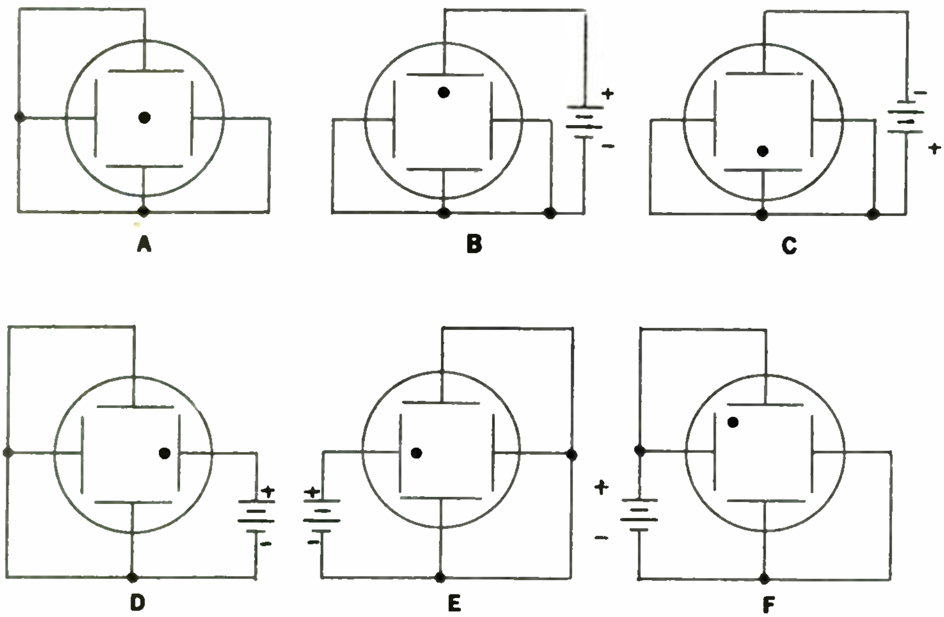


Figure 3 — Simplified CRT beam deflection.

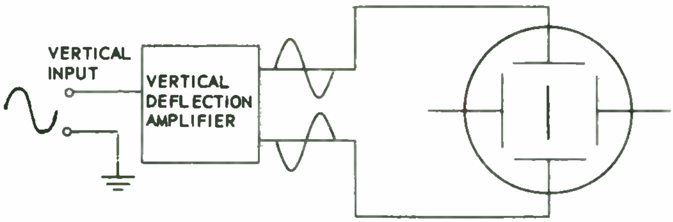


Figure 4 — Vertical deflection.

flection plate causing beam movement to the upper left. By controlling the amplitude of voltage on one plate with respect to the others, the beam can be positioned on the screen.

In Figure 4, with a sine wave applied to the vertical signal input terminal, the vertical deflection amplifiers amplify this signal and deliver two sine waves of opposite polarities to the vertical deflection plates. This will result in beam movement up and down at a rate determined by the sine wave frequency. Usually, this beam movement is so rapid that the eye cannot follow it, and instead the eye sees just a bright vertical line.

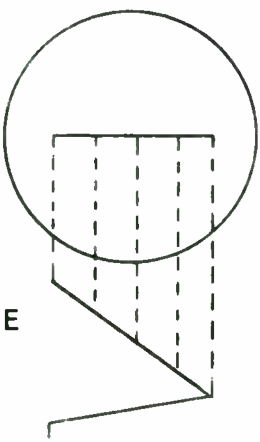


Figure 5 — Horizontal deflection.

Figure 5 shows the results of applying a sawtooth waveform to the horizontal deflection plates. At the start of the sweep, the beam is at the left side of the screen. As sawtooth amplitude increases, the beam moves to the right until the sawtooth reaches its maximum amplitude. At this time, the sweep is ended, sawtooth amplitude drops down rapidly, pulling the beam back to the left. Thus, by applying a sawtooth waveform to the horizontal plates, a horizontal line is formed on the screen.

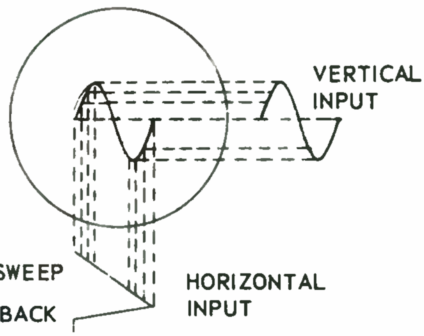


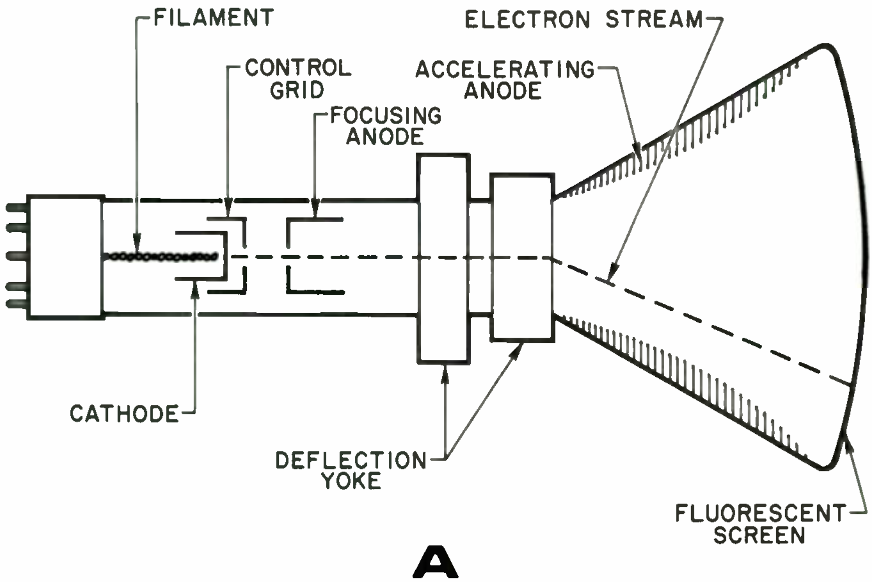
Figure 6 — Sinewave reproduction.

Figure 6 shows results of applying a sawtooth to the horizontal deflection plates and a sine wave to the vertical deflection plates. As the sawtooth moves the beam from left to right, the sine wave simultaneously acts upon the beam to pull it up and down. The combined result of these two actions is the visual reproduction of the sine wave. Notice the necessity of applying a sawtooth waveform to the horizontal deflection plates. If any other waveform were used, such as a sine wave, the beam would not move at a constant or linear rate from left to right, and the waveform applied to the vertical deflection plates would not be faithfully reproduced.

The Electromagnetic CRT

The electromagnetic CRT is simpler in construction than the electrostatic, since it does not contain deflection plates. The electromagnetic CRT still contains the electron gun although the focusing anode may be missing. In this type of CRT focusing is accomplished by external magnets. The electron gun functions in the same manner as it did in the electrostatic CRT.

The electromagnetic tubes may be subdivided into two classes: those employing electrostatic focusing and magnetic deflection,



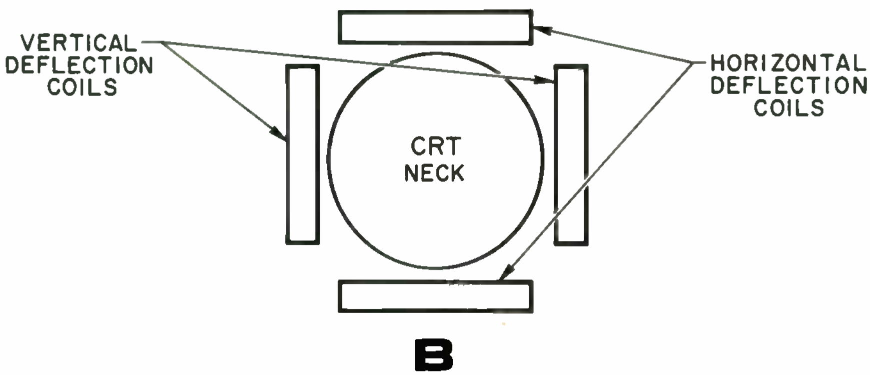


Figure 7 — Electromagnetic CRT.

and those employing magnetic focusing and magnetic deflection. Most television receivers use electrostatic focusing and magnetic deflection.

The electromagnetic CRT shown in Figure 7A shows the deflection yoke mounted on the neck of the tube. The deflection yoke consists of two sets of coils: the horizontal deflection coils and the vertical deflection coils. Currents passing through these coils set up a magnetic field that deflects the electron beam.

Figure 7B shows the placement of the deflection coils in relation to the CRT. In contrast to electrostatic deflection, the horizontal deflection coils are located on the top and bottom. The vertical deflection coils are located on the sides of the CRT. The influence on the electron beam by magnetic fields is at right angles.

The stream of electrons leaving the electron gun, may be considered to be electrons traveling in a solid conductor when direct current is applied. This direct current (electron beam) sets up a magnetic field as shown in Figure 8A. Using the left hand rule for conductors we can find the direction of this magnetic field.

In electromagnetic deflection the beam deflection is accomplished by the interaction between the magnetic field around the electron beam and the magnetic field built up in the deflection coils. Figure 8C shows how vertical deflection is accomplished. A current is applied to the vertical deflection coils which sets up a magnetic field between the coils. On the top of the electron beam the two magnetic fields are additive. On the bottom of the electron beam the fields oppose each other and are subtractive. This causes the beam to be deflected down. Figure 8D shows the vertical deflection coils with the input reversed. This reverses the magnetic field, which reverses the electron beam deflection. Note the electron beam deflection is 90° from the direction of the magnetic field acting upon it. A sawtooth waveform of current, applied to the horizontal deflection coils will cause the electron beam to move in a straight line across the screen. If a sawtooth waveform of current is applied to the vertical and horizontal deflection coils simultaneously, the electron beam will be deflected gradually down the screen by the vertical coils and gradually across the screen by the horizontal coils. This combination forms the *raster* on the screen.

The control grid controls the number of electrons that pass through the grid and strike the screen. In the television receiver the video (picture) signal is applied to the grid-cathode circuit of the CRT and changes the evenly glowing raster into a pattern of light and dark segments which make up the picture. The video signal is synchronized with the deflection circuits so the camera and receiver are scanning the correct spot at the correct time. The grid can cut-off the electron beam, which will produce a dark spot on the screen or it can allow a large number of electrons

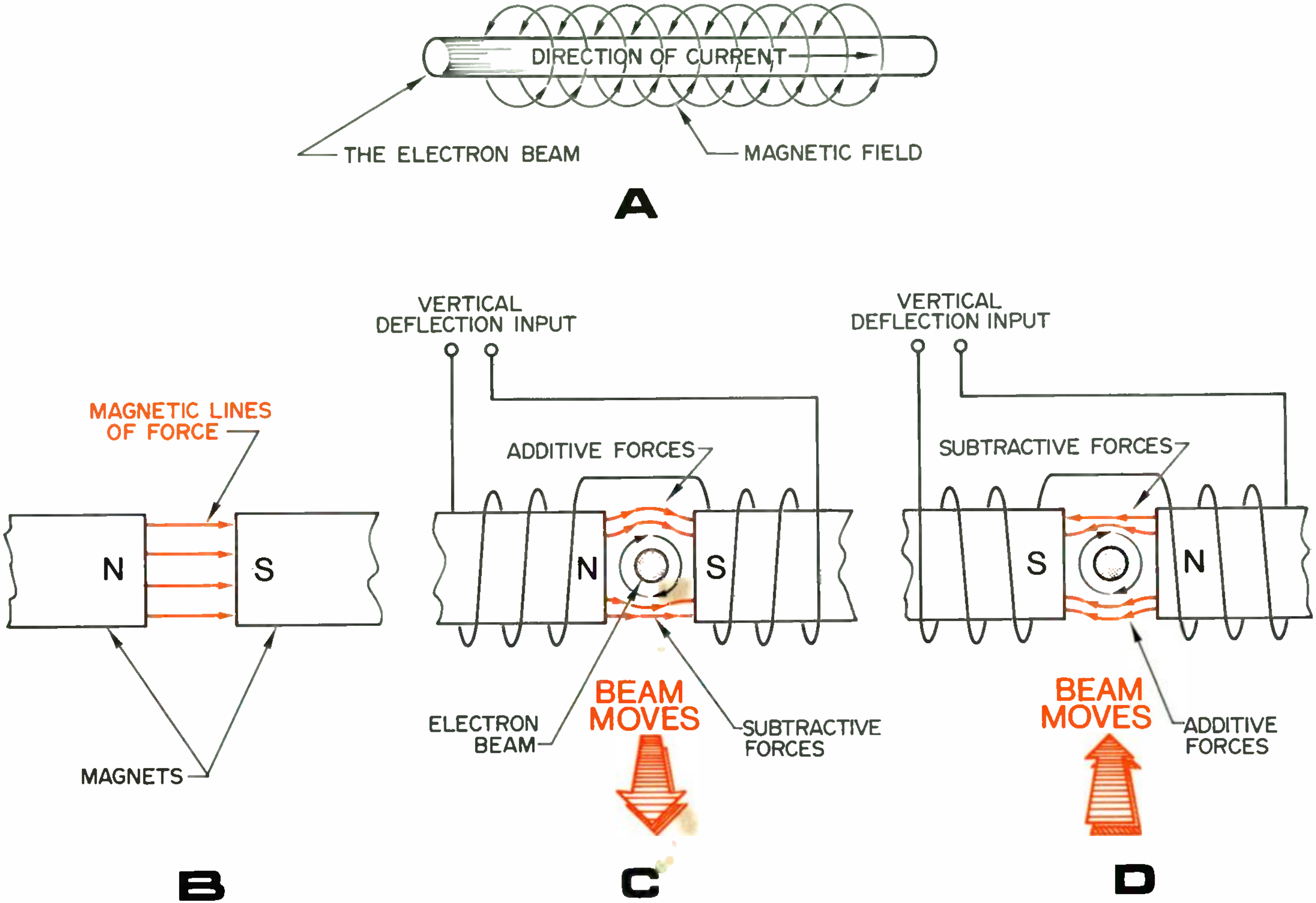


Figure 8 — The effect of a magnetic field on the electron beam.

through, which will cause a bright spot on the screen. By controlling the grid potential we can, therefore, control picture brightness.

SCANNING

If a picture from a photoengraving (for example, a halftone in a newspaper) is examined with a magnifying glass, it is easily determined that it is composed of a large number of dots. The lightness or darkness of the picture or areas within the picture is determined by the separation between the individual dots.

The television picture is formed in a similar manner. The major difference is that in the photoengraving all of the elements are presented individually, one after the other, but in such a quick succession that the observer sees the picture as a whole. To transmit images in this manner it is necessary to employ a system of *scanning*. The image is scanned by an electron beam in a systematic manner, so that during a period of time all parts of the image have been scanned by the electron beam.

The principle of scanning can be illustrated by the following example. Assume that you have a flashlight that can produce a very narrow beam of light and you wish to view a picture on the wall of a dark room. Because of the narrow beam of the light, you can only view a small portion of the picture at one time. If you can manipulate the light very fast, you can view the picture in the same manner as the picture would be produced in television. To do this you would start in the upper left hand corner of the picture and move the beam to the right along the top of the picture. When the right hand edge is reached, turn off the beam and swing it rapidly to the left and one spot width lower. Turn the light on and again sweep it rapidly to the right. Each sweep of the light is a scan line, and in commercial television there are 525 lines to a picture. Thus, when you reach the bottom right hand corner of the picture, you have completed a frame and the light is turned off and moved to the upper left hand corner of the picture to start the scanning process over again.

As stated previously, the eye retains an image for a fraction of a second (about 1/15 of a second) after the image is formed on the retina. If the entire scan of the picture is completed in 1/15 of a second you would view the picture in its entirety. Actually, it is this characteristic of the human eye, called *persistence of vision*, that makes television possible.

INTERLACED SCANNING

Moving picture films are composed of a series of individual pictures that are shown on the screen in quick succession. The illusion of motion comes about because the figures are displaced slightly in each succeeding frame. If enough frames are shown per second, the figures appear to move because of the rapid sequence of the frames and the persistence of vision. At approximately 15 frames per second the motion appears continuous, but there is an objectionable flicker. By increasing the frame frequency to 24 frames per second there is some flicker but it is less objectionable. By using a shutter arrangement that cuts off the light while the frame is moved into position and once more while the frame is stationary, we increase the frame frequency to 48 frames per second. At 48 frames per second the flicker is hardly noticeable.

In television, the same problem is encountered. To keep flicker from becoming objectionable, 30 complete frames are shown per second. Flicker is further reduced by the use of "interlaced scanning," which has the same effect as increasing the frame frequency to 60 frames per second.

Interlaced scanning is illustrated

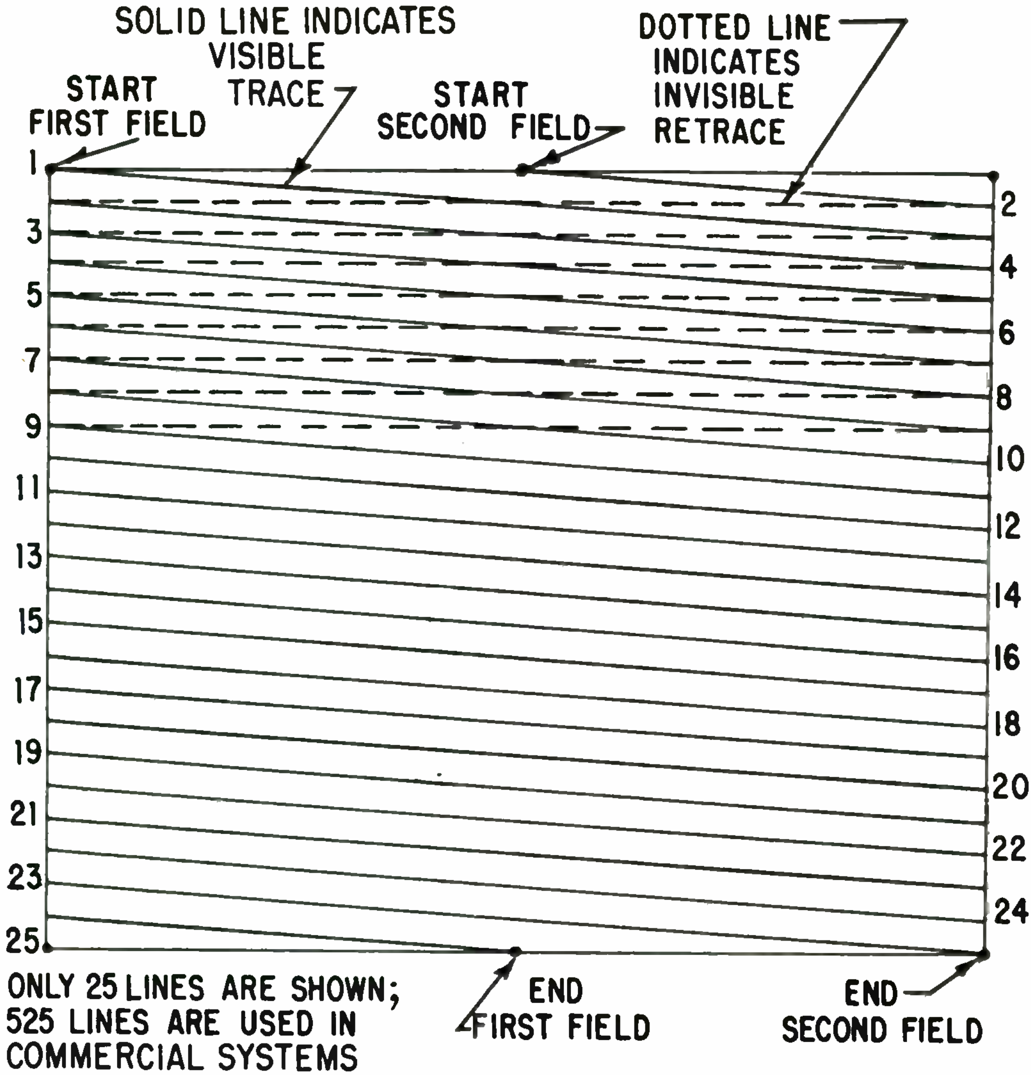


Figure 9 — Interlaced scanning.

in Figure 9. To reduce flicker by means of interlaced scanning, the electron beam scans the odd numbered lines and then the even numbered lines. Thus, two scans (fields) are necessary to complete one frame. The sweep for the first field begins on the left side of line 1. The beam moves across the screen at a slight downward angle. At the end of line 1 the electron beam is blanked out and returned to the left side of line 3. The electron beam scans line 3 at a slight downward angle. At the end of line 3 the electron beam is cut-off and returned to the left side of line 5. The period of time that the electron beam is cut-off while it is being returned to the left side of the screen is called horizontal retrace time. This process is continued until the middle of line 525 (only 25 lines are shown in Figure 9) is reached. Therefore, 262.5 lines are scanned in the first field. When the beam reaches the middle of the last line it is blanked out and returned to the middle of line 2, where the trace begins for the second field. This period of time, when the electron beam is cut-off and returned to the top of the screen, is called vertical retrace. The even-numbered lines are then scanned until the end of line 524 is reached. At this instant the electron beam is blanked out and returned to the beginning of line 1. The entire sequence is then repeated.

In order to keep the movement of the electron beams in both camera and receiver tubes in step, horizontal and vertical synchronizing pulses are transmitted by the transmitter. To ensure the trace is blanked out during the horizontal and vertical retrace periods, blanking pulses are transmitted. These blanking pulses cut-off the electron beam.

HORIZONTAL AND VERTICAL SCAN FREQUENCY

The raster is that part of the picture tube screen which is illuminated by the electron beam as it traces across and down the tube face. In most modern sets the picture width to height ratio is 4 to 3. This is called the *Aspect Ratio.* The raster could be 12 inches × 9 inches, 20 inches × 15 inches or any measurements that conform to the aspect ratio. This ratio produces a well proportioned picture.

There are 525 lines in one frame, and 30 frames are scanned in one second. This means a total of 15, 750 lines are scanned each second (525 × 30 = 15,750). Therefore, the horizontal scan frequency (number of horizontal lines scanned in one second) is 15,750 Hz and the horizontal oscillator is adjusted for a frequency of 15,750 Hz. The vertical oscillator frequency is set at 60 Hz and is employed to move the line trace down the face of the tube. When the trace reaches the bottom of the tube face, the vertical oscillator voltage drops to zero and returns the trace to the top of the tube face. During this time a blanking pulse arrives at the grid and cuts off the picture tube until the scan reaches the top. This takes approximately 850 microseconds. The horizontal oscillator is still operating during the vertical retrace which consumes about 40 horizontal lines. Therefore, only about 485 lines of raster actually carry picture information.

BANDWIDTH REQUIREMENTS

If one line of horizontal scan has a large number of changes in shading, as in a checkered pattern, then fine detail is required or the checks will appear as a gray color. Since a change from black to white means a signal amplitude change above and below a reference point, it represents 1 cycle of a frequency. In a fine checkered pattern it is possible to have 500 different changes in signal amplitude in 1 line. This would mean there are 250 cycles per line (1 cycle = 2 signal intensity changes). In 1/30 of a second 525 lines are scanned making a total of 15,750 lines per second. Multiplying 15,750 and the number of cycles derived from the 500 element pattern, we would obtain:

$$250 \times 15{,}750 = 3{,}837{,}500 \text{ Hz}$$

This indicates that in order to pass the fine details of the picture and provide good horizontal resolution (distinction between picture elements), a bandwidth of at least 3.84 MHz (approximately) is required. In the standards set for todays television receivers a bandwidth of 4 MHz is allowed for the picture signal. This bandwidth gives satisfactory resolution.

THE COMPOSITE SIGNAL

In a standard radio broadcast a carrier frequency is used to transmit the signal. The signal is impressed on the carrier by a process called modulation. If a tone of 1 kHz is impressed on a carrier it produces sidebands of 1 kHz above and 1 kHz below the carrier frequency. This carrier frequency then requires a total bandwidth of 2 kHz.

It has been established that for good picture quality a bandwidth of 4 MHz is required. If a 4 MHz signal is used to modulate a carrier frequency it would produce a signal with a total bandwidth of 8 MHz as shown in Figure 10. Transmitting this signal would require a large amount of power and would occupy a large part of the frequency spectrum. Since the same information

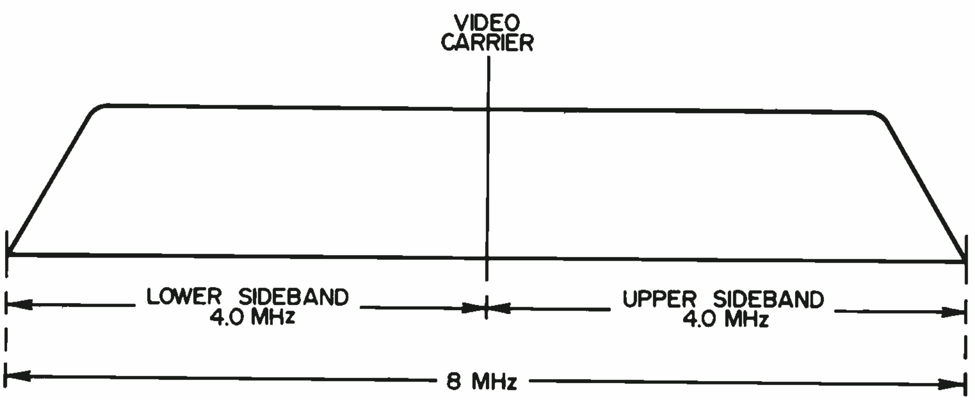


Figure 10 — Double sideband transmission of video signal.

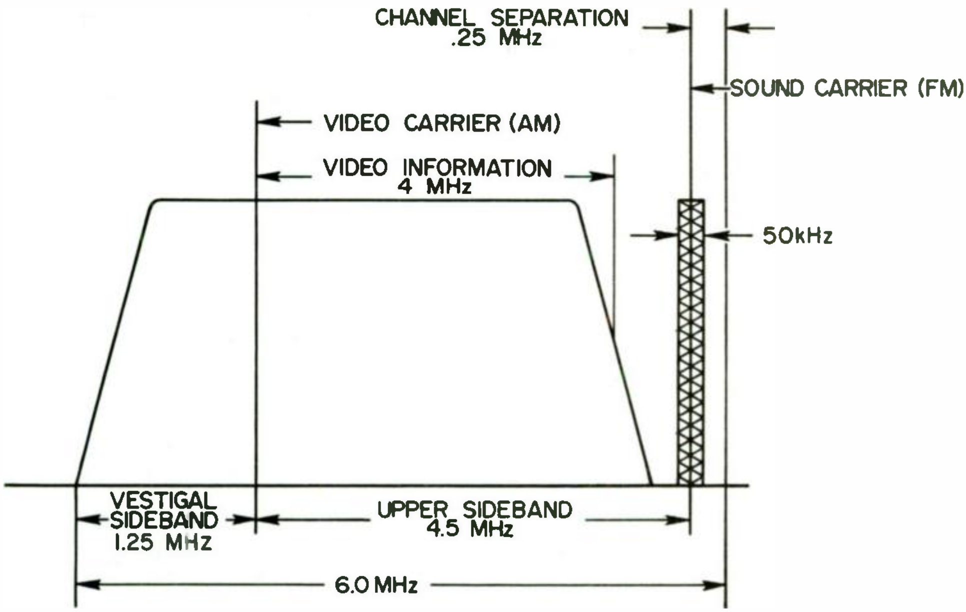


Figure 11 — Vestigial sideband transmission.

is contained in both sidebands it is senseless to transmit both sidebands. A method of transmission called ***vestigial sideband transmission*** (Fig. 11) was devised. In vestigal sideband transmission all but 1.25 MHz of the lower sideband is suppressed. This decreases the bandwidth required for the signal to 5.75 MHz leaving .25 MHz separation between channels. It would seem that we could suppress the entire lower sideband, but then serious distortion would occur. The total bandwidth that is allocated for each television channel signal transmission is 6 MHz.

4

The FCC (Federal Communications Commission) has assigned a portion of VHF (Very High Frequency) and a portion of UHF (Ultra High Frequency) band for television transmission. The VHF channels are divided into two bands. Channels 2 through 6 are in the low-band VHF and are located between 54 and 88 MHz. The high-band VHF, channels 7 through 13 are located between 174 and 216 MHz. Seventy additional channels (channel 14 through 83) were added in 1952 and are located between 470 and 890 MHz in the UHF band. The frequency allocations for all 82 channels are given in Figure 12.

In contrast to normal radio broadcast that only contain sound information, the television transmission must contain video (picture) and audio (sound) information. This will require two carrier frequencies. The picture carrier is amplitude modulated (AM) and the sound carrier is frequency modulated (FM). The picture carrier contains video, horizontal synchronizing pulses, vertical synchronizing pulses and blanking pulses. The horizontal and vertical sync pulses keep the respective sweep oscil-

CHANNEL	BAND	VIDEO CARRIER	SOUND CARRIER
2	54-60	55.25	59.75
3	60-66	61.25	65.75
4	66-72	67.25	71.75
5	76-82	77.25	81.75
6	82-88	83.25	87.75
FM	88-108	--	--

VHF HIGH BAND

CHANNEL	BAND	VIDEO CARRIER	SOUND CARRIER
7	174-180	175.25	179.75
8	180-186	181.25	185.75
9	186-192	187.25	191.75
10	192-198	193.25	197.75
11	198-204	199.25	203.75
12	204-210	205.25	209.75
13	210-216	211.25	215.75

UHF BAND CH 14 - 83

CHANNEL	BAND	VIDEO CARRIER	SOUND CARRIER
14	470-476	471.25	475.75
15	476-482	477.25	481.75
16	482-488	483.25	487.75
17	488-494	489.25	493.75
18	494-500	495.25	499.75
19	500-506	501.25	505.75
20	506-512	507.25	511.75
21	512-518	513.25	517.75
22	518-524	519.25	523.75
23	524-530	525.25	529.75
24	530-536	531.25	535.75
25	536-542	537.25	541.75
26	542-548	543.25	547.75
27	548-554	549.25	553.75
28	554-560	555.25	559.75
29	560-566	561.25	565.75
30	566-572	567.25	571.75
31	572-578	573.25	577.75
32	578-584	579.25	583.75
33	584-590	585.25	589.75
34	590-596	591.25	595.75
35	596-602	597.25	601.75

CHANNEL	BAND	VIDEO CARRIER	SOUND CARRIER
36	602-608	603.25	607.75
37	608-614	609.25	613.75
38	614-620	615.25	619.75
39	620-626	621.25	625.75
40	626-632	627.25	631.75
41	632-638	633.25	637.75
42	638-644	639.25	643.75
43	644-650	645.25	649.75
44	650-656	651.25	655.75
45	656-662	657.25	661.75
46	662-668	663.25	667.75
47	668-674	669.25	673.75
48	674-680	675.25	679.75
49	680-686	681.25	685.75
50	686-692	687.25	691.75
51	692-698	693.25	697.75
52	698-704	699.25	703.75
53	704-710	705.25	709.75
54	710-716	711.25	715.75
55	716-722	717.25	721.75
56	722-728	723.25	727.75
57	728-734	729.25	733.75
58	734-740	735.25	739.75
59	740-746	741.25	745.75
60	746-752	747.25	751.75
61	752-758	753.25	757.75
62	758-764	759.25	763.75
63	764-770	765.25	769.75
64	770-776	771.25	775.75
65	776-782	777.25	781.75
66	782-788	783.25	787.75
67	788-794	789.25	793.75
68	794-800	795.25	799.75
69	800-806	801.25	805.75
70	806-812	807.25	811.75
71	812-818	813.25	817.75
72	818-824	819.25	823.75
73	824-830	825.25	829.75
74	830-836	831.25	835.75
75	836-842	837.25	841.75
76	842-848	843.25	847.75
77	848-854	849.25	853.75
78	854-860	855.25	859.75
79	860-866	861.25	865.75
80	866-872	867.25	871.75
81	872-878	873.25	877.75
82	878-884	879.25	883.75
83	884-890	885.25	889.75

Figure 12 — U.S. Television Channel Frequencies.

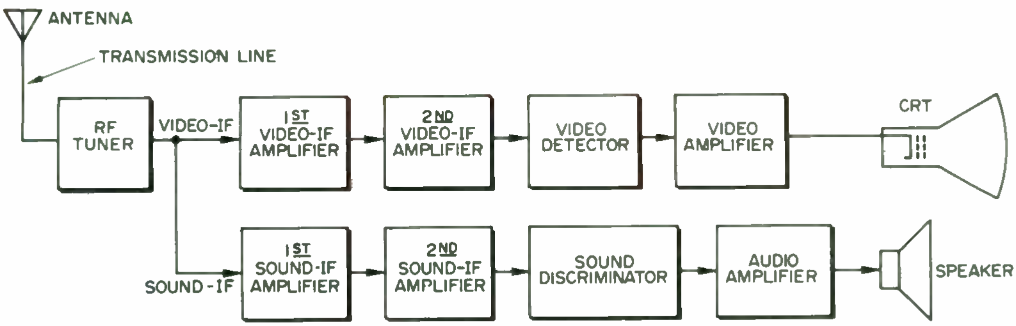


Figure 13 — The dual-channel television receiver.

lators of the television receiver synchronized with the television camera. The blanking pulses cut off the picture tube during retrace. The sound carrier contains only the sound information. The sound carrier is limited to a total carrier deviation of 50 kHz.

THE MONOCHROME TELEVISION RECEIVER

In its simplest form the television receiver could be considered to be two radio receivers. One FM receiver for sound information, and one AM receiver for picture information. The audio signal is amplified and converted to sound waves by the speaker. The video (picture) information is amplified and converted into a visible image on the CRT.

There are two types of monochrome television receivers, the dual channel and the inter-carrier type. In early television the dual channel receiver was used quite frequently. Modern televisions are the inter-carrier type.

The dual channel receiver block diagram shown in Figure 13 shows how it's name was derived. In this receiver there are different channels for the sound and the video. The composite signal is received by the antenna and fed by the transmission line to the tuner. The tuner amplifies the signal received and changes it into IF (intermediate frequency). At the output of the RF tuner the audio and video signals split. The video IF signal is amplified, detected and applied to the CRT. The sound IF is amplified, detected and applied to the speaker.

Figure 14 shows the inter-carrier receiver. In the inter-carrier receiver, the sound and video pass through the entire IF stage and the video detector. The video detector separates the video signal from the IF. After passing through the video detector, the sound signal is separated and sent to the audio channel where it is further amplified and then applied to the speaker. The video amplifier amplifies the video signal before applying it to either the grid or cathode of the CRT.

In both types of receivers the video signal is applied to the sync and deflection circuits where the sync pulses are separated from the video signal. The sync pulses are then fed to the deflection circuits,

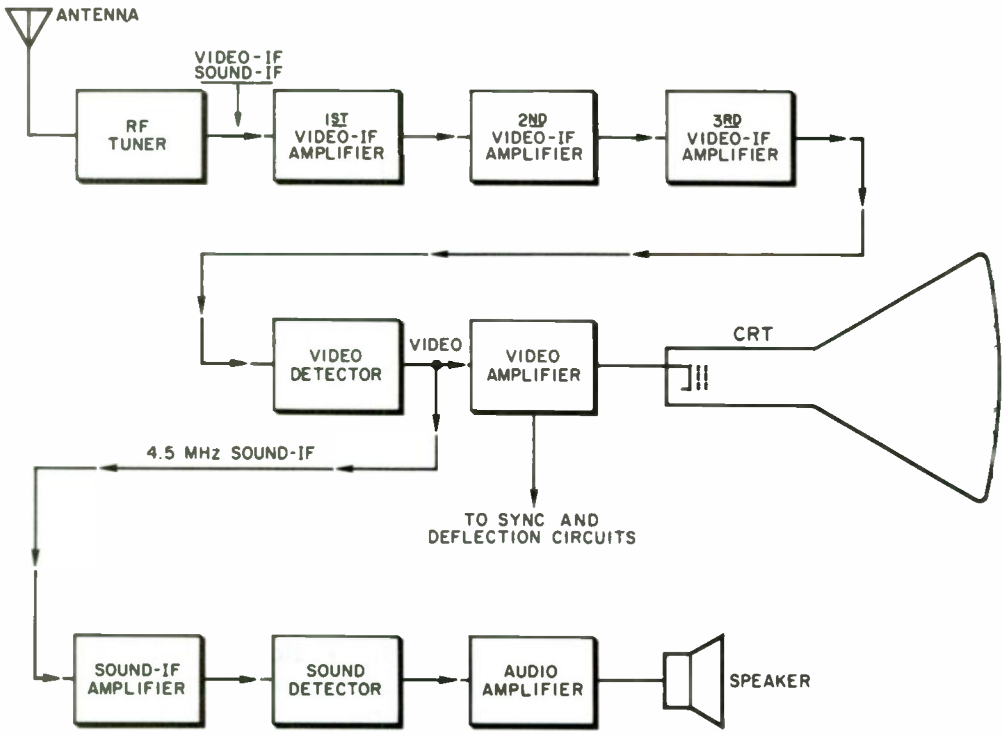


Figure 14 — The intercarrier type television receiver.

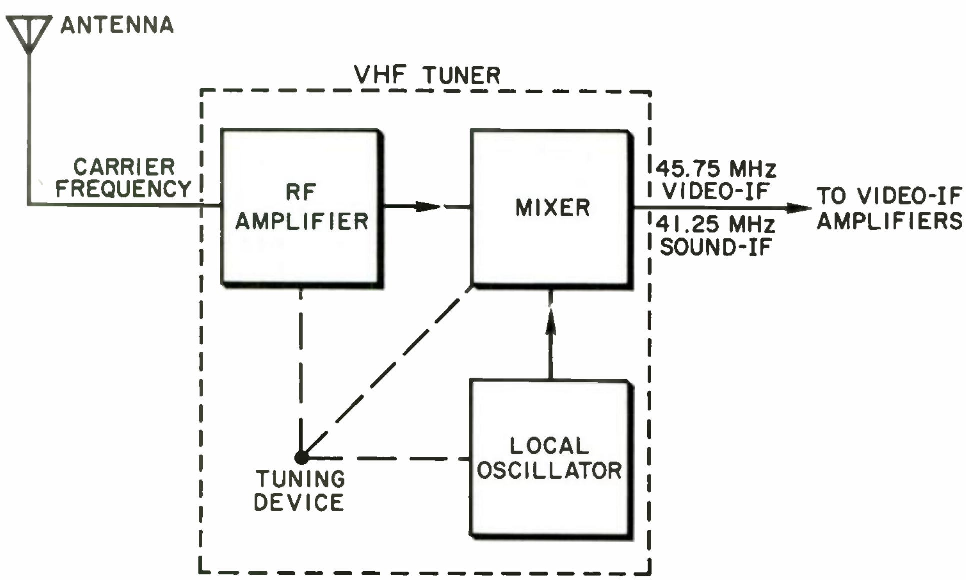
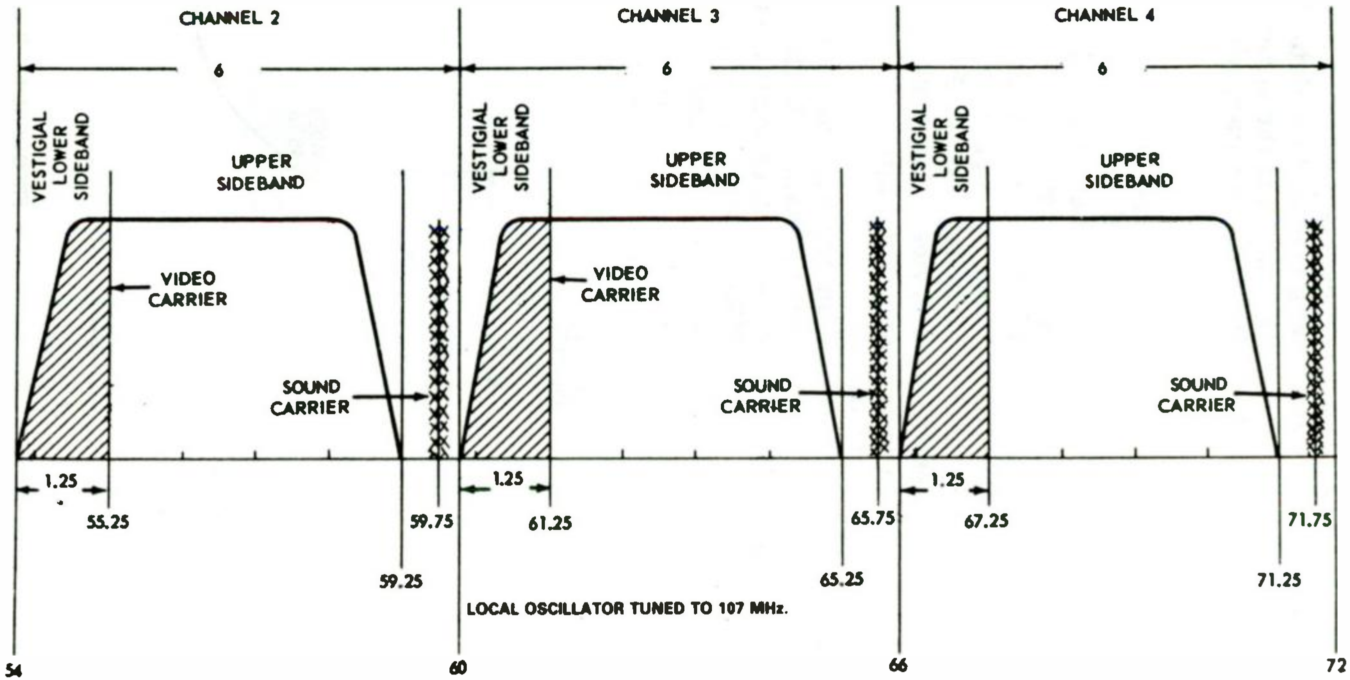


Figure 15 — Block diagram of a VHF tuner.



NOTE: ALL FREQUENCIES SHOWN ARE IN MHz.

Figure 16 — RF spectrum for TV channels 2, 3, and 4.

where they control the frequencies of the respective oscillators. The deflection circuits produce saw-tooth current waveforms, which are applied to the horizontal and vertical deflection coils to control the scan of the electron beam.

RF TUNERS

Television carrier frequencies span a wide spectrum of frequencies. In the television receiver we desire to receive one channel at a time. We must, therefore, be able to tune to the desired carrier frequency and for this purpose we use the *tuner*. The tuner enables us to select the desired carrier frequency, amplify the carrier and then convert the carrier frequency to local IF.

A block diagram of a VHF tuner is shown in Figure 15. The RF amplifier selects and amplifies the desired carrier. This signal is then fed to the mixer where it is hetrodyned with the local oscillator frequency. The output of the mixer is the local IF of the receiver, which is fed to the IF amplifier.

The video-IF is normally 45.75 MHz and the sound-IF is 41.25 MHz in most modern television receivers. Notice that the video-IF is 4.5 MHz higher than the sound-IF. When the signal was transmitted the sound was 4.5 MHz higher than the video. An example of this is shown in Figure 16.

In the example it is desired to receive channel 3. The carrier frequency for channel 3 is 60 to 66 MHz. The video carrier is 61.25 MHz and the sound carrier is 65.75 MHz. When a station or channel is selected by the channel selector,

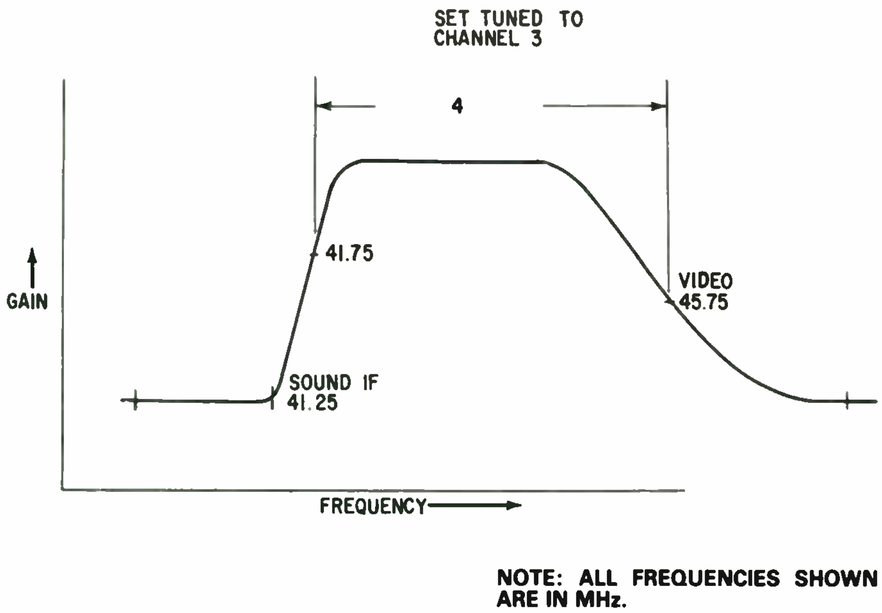


Figure 17 — Video IF response curve.

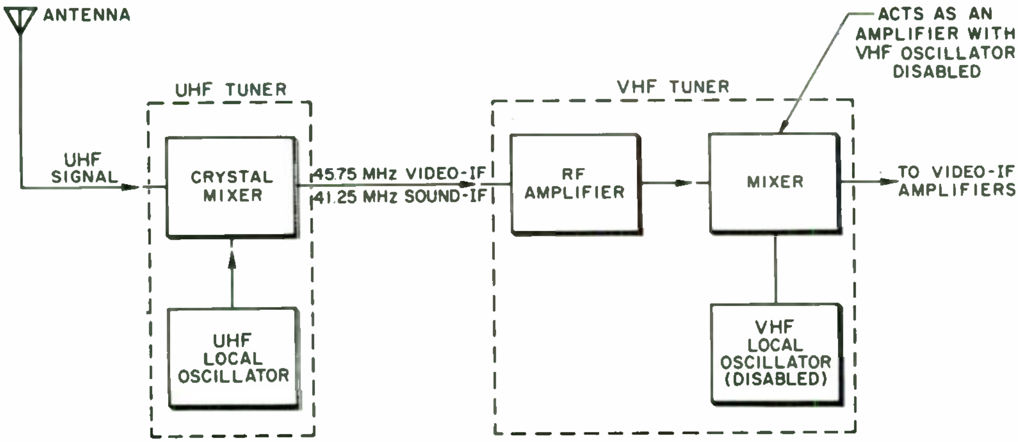


Figure 18 — Block diagram of a UHF tuner and a VHF tuner in UHF mode.

the tuning device tunes the RF amplifier and the local oscillator to a certain frequency. When channel 3 is selected the local oscillator frequency is set to 107 MHz. In the mixer the video carrier (61.25 MHz) is hetrodyned with the local oscillator frequency (107 MHz). This produces the beat frequency, for the video-IF, of 45.75 MHz (107 − 61.25 = 45.75 MHz). The sound carrier (65.75 MHz) beats with the local oscillator frequency to give a sound-IF of 41.25 MHz (107 − 65.75 = 41.25 MHz). The video and sound are still separated by 4.5 MHz, but now the video-IF is the higher frequency. The frequency response curve of Figure 17 shows the video-IF and sound-IF separation.

The local oscillator must supply a voltage of sufficient amplitude to the mixer to produce a strong IF signal. The local oscillator must also be very stable. The maximum allowable frequency shift of the oscillator that will still produce a good quality picture is one-tenth of one percent. It is difficult to obtain this degree of accuracy in an oscillator, so most receivers employ a variable inductor or a variable capacitor to change the frequency of the local oscillator when needed. This is known as the *fine tuning* and is located on the front of the receiver for viewer adjustment.

The UHF signal is received in a slightly different manner than VHF. When UHF is selected on the VHF tuner, the VHF oscillator is disabled (Fig. 18). The tuning device selects the desired carrier frequency and also sets the UHF local oscillator to the desired frequency. The UHF signal is fed to the crystal mixer in the UHF tuner where it is hetrodyned with the local UHF oscillator frequency, to give the local IF (usually 45.75 MHz for video and 41.25 MHz for sound). This IF signal is then fed to the RF amplifier in the VHF tuner and then to the mixer in the VHF tuner which is now acting as an amplifier. This is because the VHF oscillator is disabled. From here it is coupled to the first IF stage in the receiver. Hence, the VHF tuner acts as two IF amplifiers when UHF is selected.

VIDEO-IF AMPLIFIER

The video-IF amplifier must receive only the video-IF and sound-IF desired and amplify them. Actually this section should be called the IF amplifier because it amplifies both the video-IF and the sound-IF in modern intercarrier type receivers. Video-IF amplifier is a carry-over from the dual-channel receivers of early television, when sound and video used different IF amplifiers.

Because of the many frequencies that are encountered in the tuner, the output contains many different frequencies. These frequencies are produced by the adjacent channel frequencies hetrodying with the local oscillator frequency. The video-IF stages must attenuate all but the desired IF signals. To accomplish this we use traps, which are nothing more than LC filters that are tuned to the frequencies it is desired to attenuate. The IF amplifier must also amplify the entire IF signal.

The purpose of the superhetrodyne type receiver is to prevent the need to completely realign the entire receiver whenever we tune to a different carrier frequency. For this purpose the intermediate frequency (IF) was devised. The received signal is changed to IF in the tuner. Therefore, the IF amplifiers only need be aligned for the intermediate frequency. In most television receivers the IF is 20 MHz or 40 MHz. The video-IF is 45.75 MHz and the sound-IF is 41.25 MHz, maintaining the 4.5 MHz separation. The higher IF (40 to 45 MHz) causes less local oscillator interference, as well as decreases the effects of interference from other sources such as FM or short-wave transmitters and diathermy interference.

The bandpass requirements of the television receiver have been discussed and established to be about 4 MHz. This is an extremely wide bandwidth over which to maintain a relatively high gain. Since bandwidth and gain are inversely proportional, different methods of aligning the IF-strip were devised. The *overcoupled* method or the *stagger-tuning* method are used to lower the Q, thereby increasing the bandwidth [Bandwidth (BW) = Resonant Frequency (Fo)/Quality (Q)]. You must have the receiver manufacturers requirements before you attempt to align the IF-strip of a receiver. Each manufacturer has its own alignment requirements. For greater gain the receivers employ 2 or 3 stages of IF amplification. In some older receivers there are 4 video-IF stages. After amplification the video-IF is coupled to the video detector.

VIDEO DETECTORS

The video signal must be separated from the video-IF before it can be applied to the CRT. The video detector's function is to separate the video signal from the video-IF with very little loss of signal. To accomplish this the video detector must have a bandwidth wide

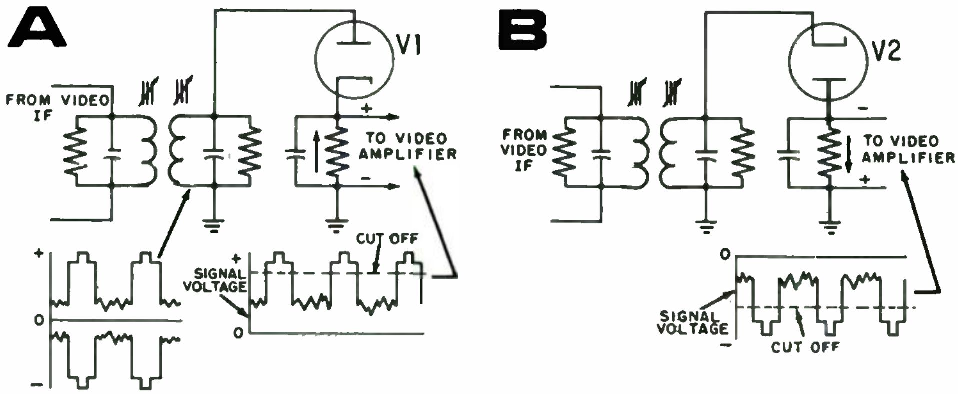


Figure 19 — Diode Video detectors.

enough to pass the 4 MHz video signal.

Since the video signal is an AM signal, it must be demodulated by the process of rectification. A diode may be used for this purpose and it may be a crystal diode or a vacuum tube diode. Because the crystal diode has a low dynamic resistance and is easy to mount it has found wide use in the modern receiver.

Two simple video detectors are shown in Figure 19. They both use vacuum tube diodes. The difference between the two detectors is the polarity of the output signal, which is a result of where the input signal is applied to the detector. In Figure 19A the input is applied to the plate of the diode. Therefore, the tube will conduct only on the positive portion of the input signal. At this time the plate will be positive in respect to the cathode and the tube will conduct, causing current to flow in the direction shown and voltage to be dropped across the cathode resistor. When the input is negative the tube will not conduct and the output of the video detector will be zero. Figure 19B shows the same detector connected for a negative output.

Whether we desire a negative or a positive video signal depends upon the number of video amplifier stages employed and the means of applying the signal to the CRT. The signal may be applied to the CRT on the cathode or the grid. If applied to the cathode of the CRT, the video signal must have a positive polarity, if applied to the grid the signal must be negative.

In Figure 20, the block diagram of a receiver's video amplifier stage and the input to the CRT is shown. This receiver has only 1 video amplifier. The output of the video detector is of a negative polarity. When the signal is amplified by the video amplifier, a phase inversion occurs and the output is of a positive polarity. The positive polarity video signal is connected to the cathode of the CRT. If 2 stages of video amplification had been used then 2 phase inversions would have

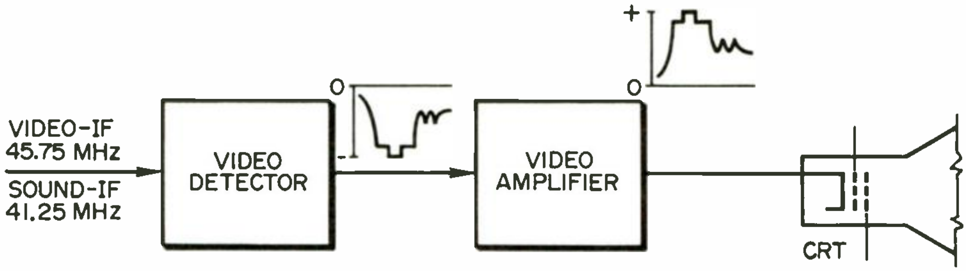


Figure 20 — Video detector with negative polarity output.

occurred and the video signal would have been of a negative polarity. This negative polarity would have been applied to the control grid of the CRT, or we could change the video detector wiring so the output would be of a positive polarity. After two phase inversions in the two video amplifiers the signal would be positive again and it could then be applied to the cathode of the CRT.

THE VIDEO AMPLIFIER

The video detector applies the video signal to the video amplifier. The video signal must be amplified before it is applied to the CRT. The video amplifier is designed to pass a wide band of frequencies without discrimination. The normal resistance coupled amplifier has a flat response of only a few thousand cycles. The frequency of the video signal could be as low as 30 Hz or as high as 4 MHz. Therefore, we desire a flat response over a bandwidth of 4 MHz for the video signal. The low frequency components of the video signal include blanking pulses, the vertical sync pulses (60 Hz) and the horizontal sync pulses (15,750 Hz). The high frequency components comprise the fine detail of the picture on the picture tube screen. If all of these frequency components are not properly amplified in the video amplifier, a distorted image is produced. The distortion may appear as a lack of fine detail, a lack of image sharpness in large objects, or a lack of contrast. The video amplifier should have a bandwidth of at least 4 MHz.

To increase the bandwidth the value of the plate load resistor is decreased, because with frequencies as high as 4 MHz the tube capacitance would act as a shunt to ground if a large plate load resistor were used. This alone is not sufficient and *peaking coils* are employed to increase the high frequency response. A small inductor is inserted in series with the plate load resistor. The value of this inductor is chosen so that it will neutralize the distributed capacitance of the circuit. In other words, the inductor and the distributed capacitance of the circuit form a parallel resonant circuit, that is resonant at the frequency where the response curve begins to fall off appreciably. In a parallel resonant circuit, Z is maximum at resonance. Therefore, the output will be maximum, increasing the frequency response of the amplifier. This is called shunt compensation.

Series compensation could be

used and entails adding a small inductor in series with the coupling capacitor. This forms a series resonant circuit with the distributed capacitance of the circuit. At resonance, increased current flows through these capacitances, (Z in series LC circuits is minimum at resonance) and larger voltages are available at the input to the amplifier.

The loss of gain and phase distortion that occurs at low frequencies may be compensated for by dividing the plate load resistor into two sections and bypassing one section with a capacitor. At low frequencies the reactance of the capacitor is high and the plate load includes both sections of the resistor giving better gain at low frequencies. At high frequencies the reactance of the capacitor is lower and the capacitor will effectively bypass that part of the plate load, causing a proportionately lower output.

If the video signal is direct coupled to the CRT, the DC component of the video waveform is maintained. It is important to maintain this DC for reference for the blanking pulses and also for the correct level of background illumination in the picture.

One method of maintaining the DC component is to direct couple the plate load of the video amplifier to the CRT. This can be accomplished by bypassing the coupling capacitor with a resistor. Another method is to employ *DC restoration* at the input to the CRT. There are several different methods of DC restoration and they will be discussed in a later lesson.

SYNCHRONIZING CIRCUITS

We have discussed getting the video signal to the picture tube. Equally important is synchronizing the various circuits of the transmitter with the receiver to give the desired picture. The blanking pulses, horizontal and vertical synchronizing pulses are amplified in the video-IF stages along with the video signal.

The video information is applied to the cathode or the control grid of the CRT. The video signal modulates the electron beam, producing varying degrees of black through white information on the screen. The blanking pulses are of such amplitude that they cut-off the electron beam in the CRT when a retrace is begun. The sync pulses are higher in amplitude than the blanking pulses and are always located on top of the blanking pulse. In Figure 21 we see a composite video signal. The blanking level is set so that it will cut-off the electron beam in the CRT. The composite video signal begins with a horizontal trace in progress. The video signal is varying in amplitude, causing a corresponding change in the light intensity of the CRT screen. At the end of the horizontal line a blanking pulse arrives and the signal is increased to the blanking level. This cuts off the electron beam in the CRT and a retrace is begun. During the retrace period the electron beam is returned to the left side of the screen. At this time the blanking

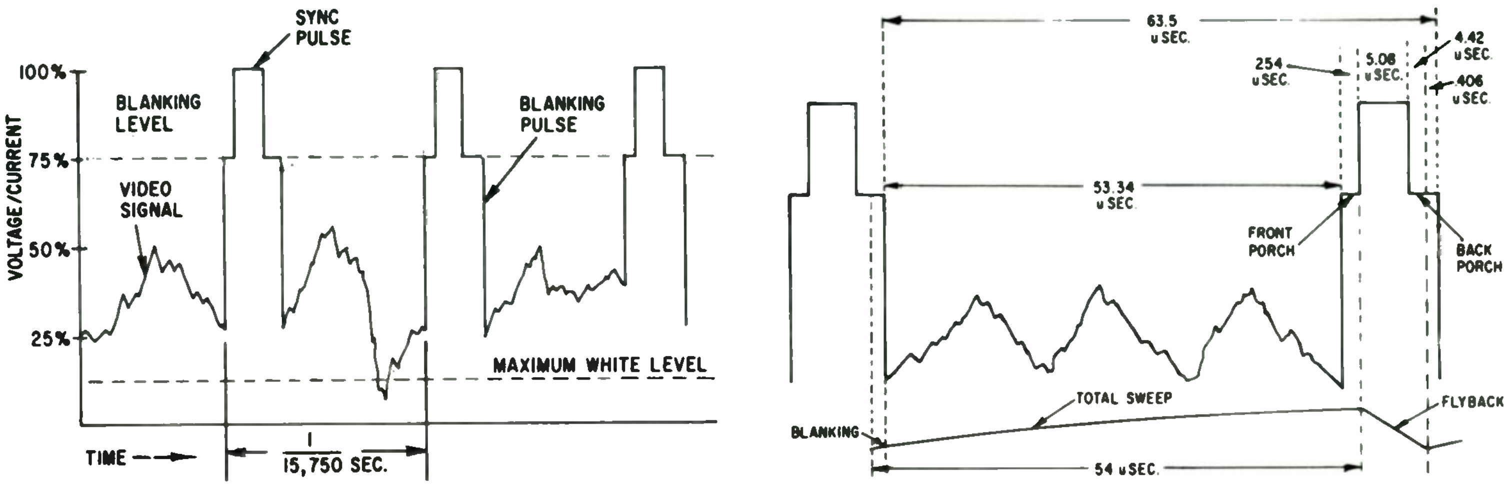


Figure 21 — Composite video waveform and time allocations.

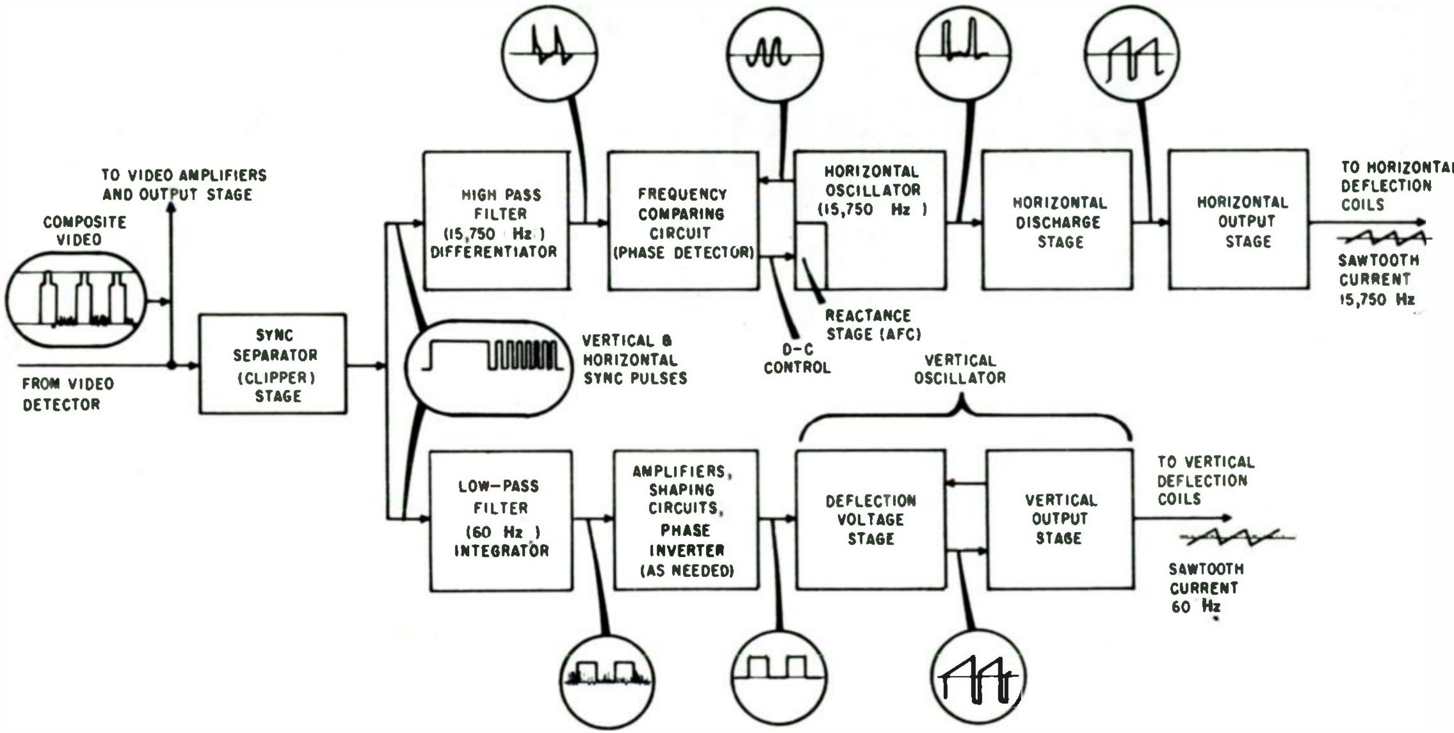


Figure 22 — Block diagram of synchronizing circuits.

signal is removed and the signal decreases to the video level and a new trace across the screen is begun.

The horizontal and vertical sweep circuits control the sweep of the electron beam across the screen of the CRT. The sweep of the electron beam must be synchronized with the video signal. If the sweep circuits are not synchronized it is possible for a retrace to be in progress while video information is being displayed on the screen. Then during the trace portion of the signal the blanking pulse would be present and the screen would be black. Sync pulses are transmitted with the composite video signal to keep the television camera and the receiver sweep circuits synchronized. Figure 21 also shows the time required for each portion of the signal.

The Sync Separator

After detection in the video detector the composite video signal is fed to the *sync separator*. The vertical and horizontal sync pulses are removed from the composite video signal and filtered. They are then shaped and applied to their respective oscillators to keep the oscillators synchronized with the camera sweep circuits. A block diagram of the sync circuits is shown in Figure 22.

Sync separation or clipping may be accomplished by a circuit employing a diode, triode, or pentode. The most commonly used sync separation circuit contains the triode. Sync separation is quite easy, because the sync pulses always ride on top of the blanking pulses. If we use the circuit shown in Figure 23, we bias the triode so that it is cut-off until a signal larger in amplitude than the blanking pulse arrives at its input. The only signals that are amplified by the triode would be the sync pulses.

Because of the difference in frequency of the vertical and horizontal sync pulses they may be sepa-

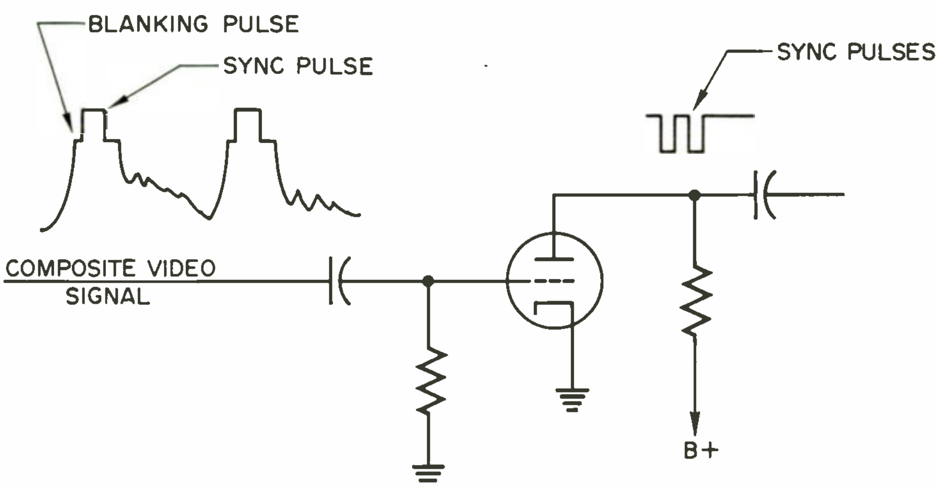


Figure 23 — Triode sync separator.

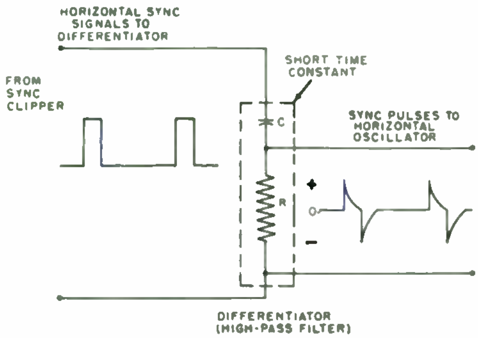


Figure 24 — Differentiator for horizontal sync pulses.

rated by filters. For separation of the horizontal sync pulses we would use a high pass filter called a differentiator. The horizontal frequency (15,750 Hz) is high in relation to the vertical frequency (60 Hz). Figure 24 shows a differentiator circuit used for horizontal sync pulse separation. The circuit has a short time constant and will respond to the high frequency horizontal pulses, producing an output across the resistor (R).

A low pass filter is used to pass and shape the vertical sync pulse. The vertical retrace requires a large amount of time. The horizontal oscillator is very unstable and without application of the horizontal sync pulses could drift very far from the horizontal frequency. For this reason the vertical sync pulse is serrated (chopped into pieces) and it will supply the sync pulses to the horizontal oscillator during the long period of vertical retrace. Figure 25 shows an integrator circuit that is used for separation of the serrated vertical pulse. The time constant of this circuit is long. It will not be affected by the horizontal or equalizing pulses because they are of short duration and the capacitor (C) will discharge between them. The serrated vertical pulse duration is long and will not allow the capacitor to discharge in the short period of time between the serrations. These six pulses will combine to produce a vertical pulse of long duration across the capacitor. Sixty of these pulses occur in one second.

After being separated and

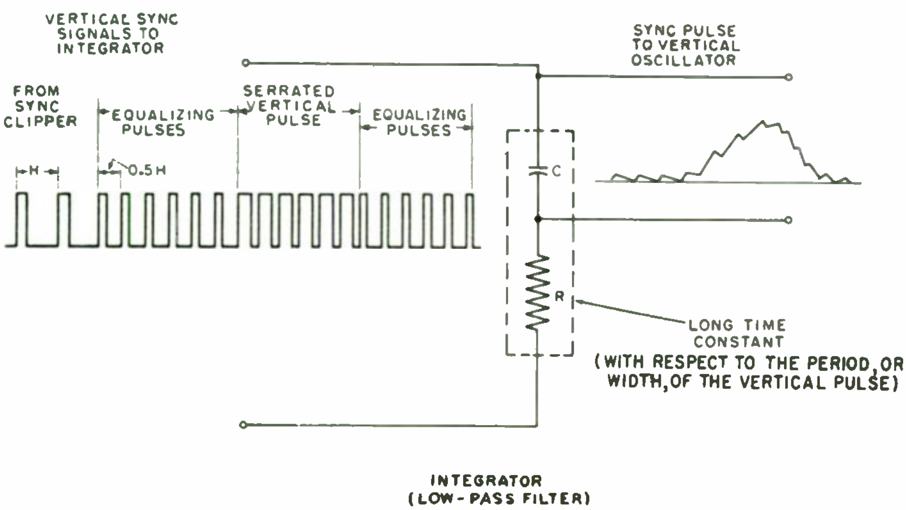


Figure 25 — Low-pass filter for vertical sync pulses.

shaped, the horizontal and vertical sync pulses are applied to the horizontal and vertical sweep oscillators.

Horizontal Sweep Circuits

The horizontal sync pulse is applied to the frequency comparing circuit, where it is compared with the output of the horizontal sweep circuit. Together they produce a DC correction voltage that is applied to the horizontal oscillator. This correction voltage maintains the horizontal oscillator frequency (15,750 Hz) in synchronization with the television transmitter.

The horizontal oscillator output is a sawtooth waveform. The sawtooth waveform must be amplified and applied to the deflection coils in a manner that will cause the electron beam to be deflected (swept) horizontally across the face of the picture tube.

The oscillators that are used in the sweep circuits are the type that can be locked in (synchronized) with an injected frequency. These include multivibrators and blocking oscillators, which are the two most commonly used. The sawtooth waveform produced in the horizontal oscillator is applied to the horizontal output stage where it is amplified. The sawtooth waveform is then applied to the horizontal deflection coils which cause the electron beam to be gradually moved across the screen.

In modern television receivers this horizontal waveform is also fed from the output stage of the horizontal sweep circuit to the high voltage system (Fig. 26). The high voltage system supplies the ac-

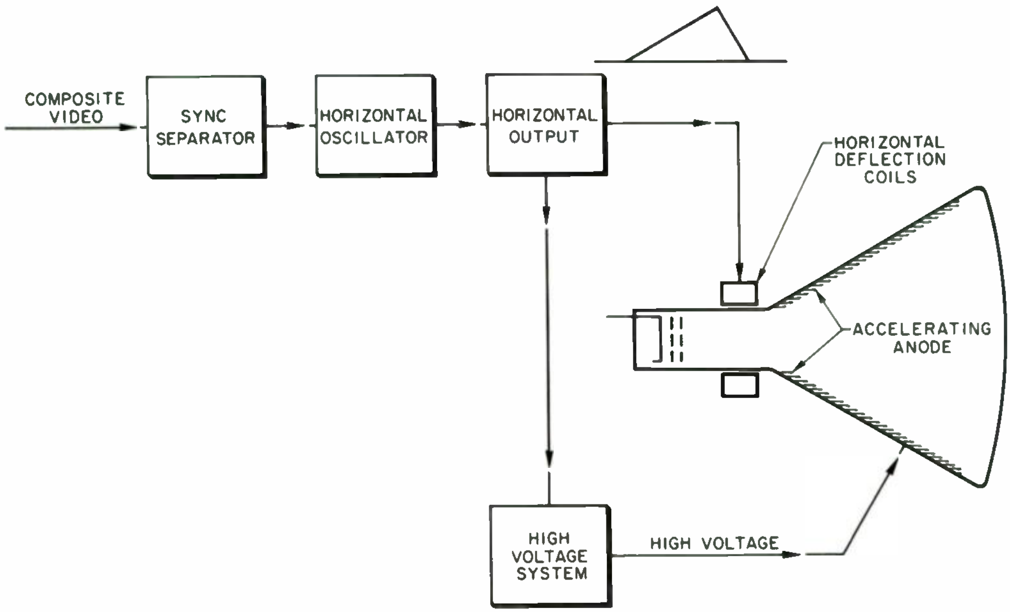


Figure 26 — Block diagram of horizontal sweep and high voltage circuits.

celerating anode of the CRT with a voltage of 10,000 to 30,000 volts. If the horizontal sweep system fails, there will be no high voltage applied to the accelerating anode so no raster will be produced on the face of the picture tube. (The electrons will not be attracted to the screen).

This is an aid in localizing the trouble with a malfunctioning receiver. If there is no raster (screen is not illuminated), but sound is present then the high voltage system is generally malfunctioning. If the high voltage system checks out, then the trouble must be in the circuit that supplies the high voltage system (the horizontal sweep circuit).

7 There is an added advantage with this type of high voltage system (Flyback High Voltage). If there were no horizontal deflection and high voltage was present on the accelerating anode, then the electron beam would continue to strike the screen. There would be a bright vertical line in the center of the screen with the remainder of the screen dark (horizontal drive line). If this condition occurs for a long period of time, the phosphorous screen could be damaged. With the flyback high voltage system, if there is no horizontal deflection, then there is no high voltage on the accelerating anode. Therefore, no electrons will reach the screen, there will be no raster and the screen will not be damaged.

Vertical Sweep Circuits

The vertical sync pulse is applied to the input of the vertical oscillator. The vertical oscillator is normally a blocking oscillator or a multivibrator. The vertical sweep circuit produces a sawtooth current waveform which slowly moves the electron beam from top to bottom on the CRT screen. This must be accomplished sixty times in one second.

Previously it was mentioned that the vertical sync pulse is serrated. At the end of 262.5 lines of horizontal scan it is necessary to blank the electron gun for a vertical retrace to take place. The blanking is accomplished by a blanking pulse, the retrace is accomplished by the vertical oscillator which allows the sawtooth of current to drop to zero. This vertical retrace requires a large amount of time. The horizontal oscillator must be fed synchronizing pulses so it will not drift off frequency during this retrace interval.

From the transmitting point this presents the problem of transmitting horizontal sync pulses and vertical sync pulses at the same time. This problem was solved by the use of equalizing pulses and by serrating the vertical pulse. The equalizing pulses and the serrated vertical pulse are shown in relation to the horizontal sync pulse in Figure 27. The last horizontal line of a field (scan) is followed by six equalizing pulses. The frequency of these pulses is 31,500 Hz (twice the horizontal frequency). This is the second harmonic of the horizontal frequency. The horizontal oscillator characteristics allow it to be tripped by the harmonic frequency of

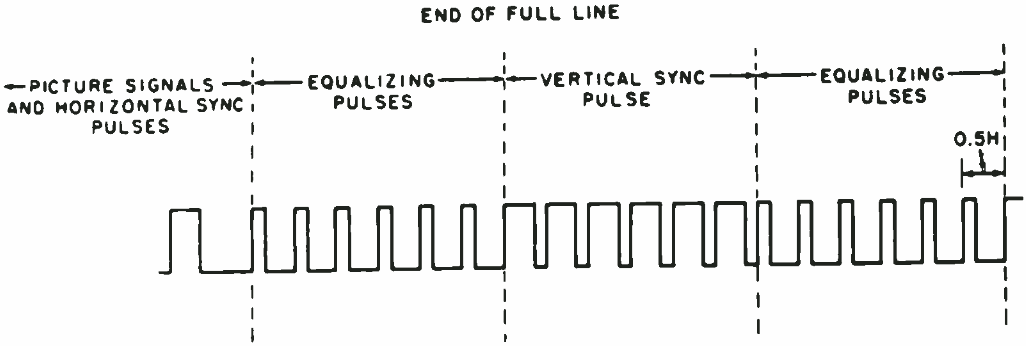


Figure 27 — Equalizing and serrated vertical sync pulses.

the horizontal frequency. Either the odd or even equalizing pulse will synchronize the horizontal oscillator. These equalizing pulses are followed by the serrated vertical sync pulse which maintains the horizontal oscillator on frequency during vertical retrace. The serrated vertical pulse is followed by six equalizing pulses. These equalizing pulses will keep the horizontal oscillator on frequency while allowing for the discharge time of the vertical oscillator. When this series of equalizing and serrated vertical pulses are applied to the integrator circuit they form the vertical sync pulse (shown in Figure 25). The vertical sync pulse is applied to the vertical oscillator to maintain synchronization with the transmitter.

At the end of the vertical retrace period the electron beam has been returned to the top of the CRT screen. The horizontal trace from left to right and the relatively slow vertical trace from top to bottom are started again. This action continues for 262.5 horizontal lines. The composite signal during this period consists of video information and the horizontal blanking and sync pulses. At the end of 262.5 lines of horizontal scan the equalizing pulses and serrated vertical pulse arrive to key the vertical oscillator and initiate a vertical retrace.

The serrated vertical pulse is formed into a long sawtooth waveform and applied to the vertical oscillator. The sawtooth waveform is then applied to the vertical output stage where it is amplified and transformer coupled to the vertical deflection coils.

Loss of vertical oscillation will produce a bright horizontal line in the center of the raster. Generally, a picture that rolls up or down has a problem in the vertical oscillator. If the picture has reduced height, the problem is generally in the vertical output stage. These and other problems with the vertical sweep circuits will be covered in a later lesson.

CRT CIRCUITS

DC Restoration

The video signal is coupled from the video amplifier to the control grid or cathode of the CRT. If a coupling capacitor is used to couple the video signal to the CRT, then the DC component of the signal will be lost. Loss of the DC component will cause a pronounced loss of picture quality. The DC component is the reference for the video signal and it controls the blanking level and the average level of background illumination.

If direct coupling were used between the video amplifier and the CRT then the DC level would be impressed on the CRT. But, a very well regulated power supply is required. A higher B+ voltage must also be applied to the cathode if the grid is to be negative in respect to the cathode. Direct coupling between the video amplifier and the CRT is seldom used. The average brightness of one scanned line may differ widely from the average brightness of another scanned line, as indicated in Figure 28A. The average DC component depends on the average brightness of a scanned line. A low DC component in the negative direction means that there is a high level of brightness during that line. A high DC component in the negative direction means that there is a low level of brightness during that line. The average DC component sets the blanking level. In Figure 28A the blanking level is the same no matter what the average level of brightness of the video signal. This ensures that the blanking pulse will cut-off the electron beam dur-

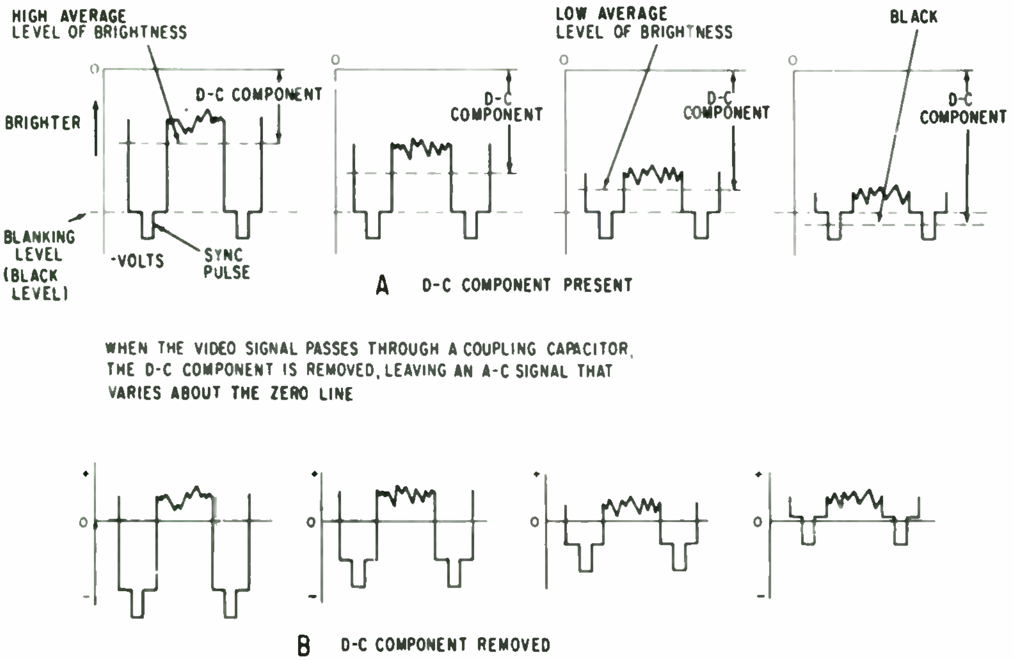


Figure 28 — Video signal with and without DC component.

ing retrace and that the average level of background brightness is the same.

Figure 28B shows the video signal with the DC component removed. The average level of brightness varies about the zero line. The blanking level varies about the zero line and the CRT would not be cut-off during some of the retrace periods and retrace lines would be visible on the screen.

Most receivers employ capacitance coupling between the video amplifier and the CRT. To offset the lack of DC restoration, the capacitor is of a large value to maintain a charge for a long time, thereby, giving a more constant picture level. With this system the vertical sweep signal must be applied to the control grid to maintain the CRT cut-off during vertical retrace. This is known as retrace blanking.

Two simplified DC restorers are shown in Figure 29. The function of each circuit is to restore the DC

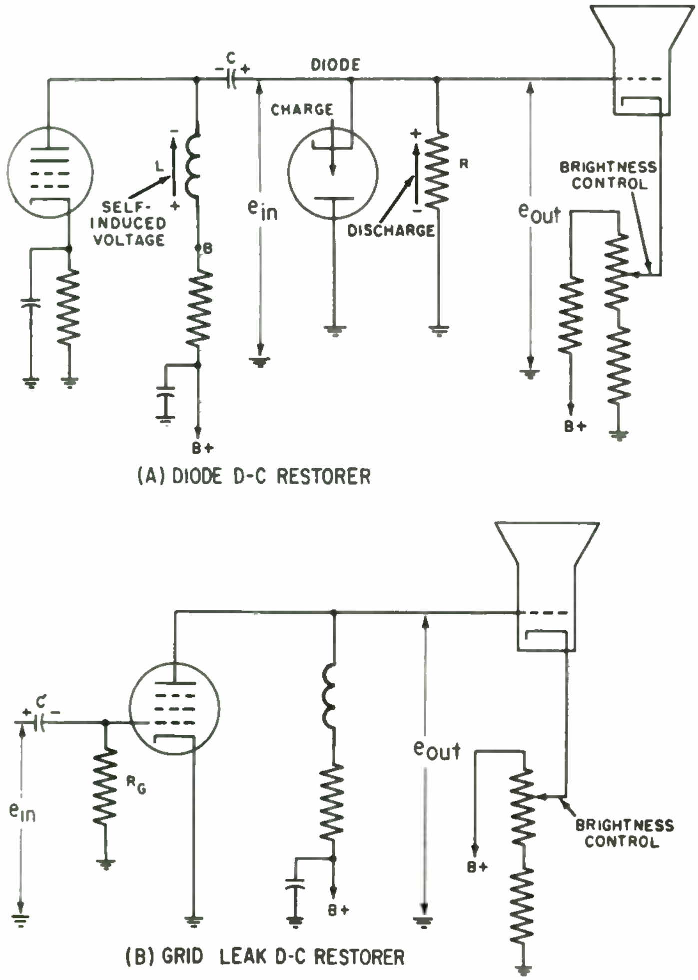


Figure 29 — Simplified DC restorers.

component that was lost when the video signal passed through the coupling capacitor between the video amplifier and the CRT. DC restoration is accomplished by adding to the instantaneous AC signal enough DC voltage to bring the blanking voltage level to the cut-off point.

High Voltage Supply

The accelerating anode (called the second anode) of the CRT must have a high positive voltage applied to it. A common method of obtaining this high voltage is called the *flyback* method. The flyback system uses the collapsing field of the horizontal deflection yoke to introduce a high voltage pulse into the high voltage transformer. The high voltage transformer is an auto transformer that steps up the voltage. This high voltage is rectified and filtered before it is applied to the CRT.

The most important component of the flyback system is the high voltage transformer. The high voltage transformer also gives the repair technician more problems than any other component of the high voltage system. The voltage in the high voltage section may be as high as 30,000 volts and is a constant hazard to repairmen. For this reason it is enclosed in a section called the high voltage cage.

THE SOUND SYSTEM

The intercarrier and dual channel receivers have been discussed. The dual channel receiver is not in use today so we will discuss the intercarrier receiver sound system.

In the intercarrier receiver (Fig. 30) the video and sound use the same IF strip for amplification (video-IF is 45.75 MHz and audio-IF is 41.25 MHz). The video-IF is demodulated in the video detector. A hetrodyne action occurs in the video detector between the two IF's producing a beat frequency of 4.5 MHz. This 4.5 MHz contains the sound information and is the sound-IF. This signal is picked off by a 4.5 MHz trap and transformer coupled to the sound-IF amplifier where it is amplified.

The audio information must be

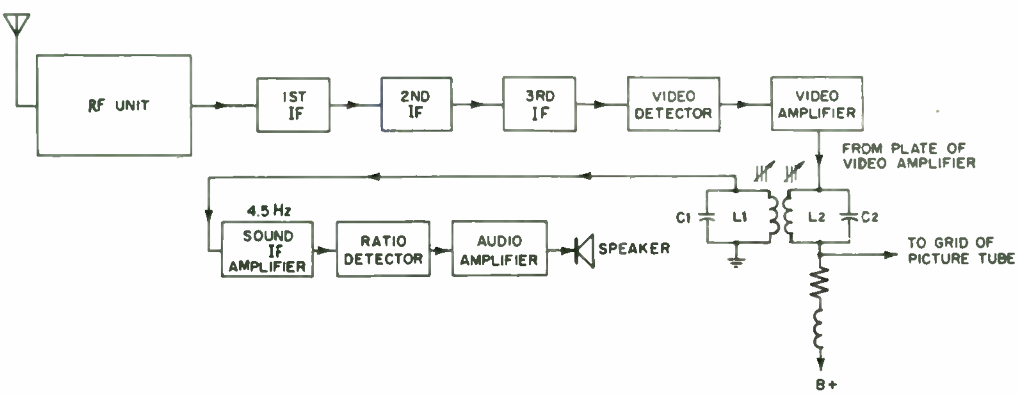


Figure 30 — The intercarrier sound system.

extracted from the sound-IF. This is accomplished by the audio detector. The audio detector is either a ratio-detector or a discriminator and is similar to the FM detector used in an FM receiver. After detection the audio signal is amplified by the audio amplifier and applied to the speaker to produce the desired sound.

SUMMARY

We have learned that the video and sound signals are transmitted in almost the same manner as radio transmissions. The video signal is AM and the audio signal is FM. These two signals are imposed on a carrier frequency. The carrier frequency is transmitted from an antenna as in a radio broadcast.

The television receiver tunes to the desired carrier frequency (channel). This is accomplished by the tuner. The RF signal is amplified and converted into a video-IF and an audio-IF by the tuner. Both signals pass through the IF strip where they are further amplified. The signals are then applied to the video detector, where the video signal is separated from the IF. While video demodulation is taking place the sound-IF is also being formed in the video detector. The video signal is amplified and coupled to the cathode or grid of the CRT where it produces the desired levels of brightness on the CRT screen.

The video signal is also applied to the sync separator where the horizontal and vertical sync pulses are separated and applied to their respective oscillators to maintain synchronization with the television camera. The horizontal and vertical sweep circuits supply the deflection coils with sawtooth current waveforms that cause the electron beam to be gradually deflected down and to the right. This deflection of the electron beam forms the raster on the CRT screen.

In the sound channel the sound-IF is amplified and detected. The audio signal is then amplified and applied to the speaker to produce the desired sound.

TEST

Lesson Number 79

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-079-1.

1. **What type of deflection is used in television receivers to deflect the electron beam in the CRT?**
   A. Electrostatic deflection.
   9 B. Photoelectric deflection.
   C. Electromagnetic deflection.
   D. Radiation deflection.

2. **Interlaced scanning was developed for use in the television system to**
   A. prevent flicker.
   12 B. prevent retrace lines.
   C. provide DC restoration.
   D. increase contrast.

3. **What are the horizontal and vertical scan frequencies?**
   A. 15,750 Hz and 525 Hz
   B. 3.58 MHz and 50 Hz
   13 C. 15,750 Hz and 60 Hz
   D. 7,875 Hz and 30 Hz

4. **What is the bandwidth allocation for each television channel (assigned by FCC)?**
   A. 8 MHz
   15 B. 2 kHz
   C. 41.25 MHz
   D. 6 MHz

5. **It is desired to receive channel 3 in the VHF band. To what frequency is the local oscillator set? (Hint: Video-IF is 45.75 MHz.)**
   A. 120.5 MHz
   21 B. 107 MHz
   C. 45.75 MHz
   D. 41.25 MHz

6. How is the synchronizing of the horizontal oscillator maintained during the long time interval required by the vertical sync pulse?

A. The horizontal oscillator is very stable and will stay on frequency for long periods of time.

29 B. The vertical sync pulse is serrated, which provides sync pulses for the horizontal oscillator.

C. A crystal controls the oscillation frequency of the horizontal oscillator.

D. The flyback transformer is used to supply sync pulses to the horizontal oscillator during this period.

7. In a television receiver employing the "flyback" type of high voltage system, a loss of high voltage could be caused by

A. the vertical oscillator not operating.

31 B. no audio amplifier output.

C. the horizontal oscillator not operating.

D. decreased output from the video amplifier.

8. What is the purpose of the DC restorers shown in Figure 29?

A. To supply the B+ voltage for the receiver.

B. To replace the DC component that is lost when the video signal is capacitively coupled to the CRT.

34 C. To bias the sync separator so that only the sync pulses will be passed by the triode.

D. To supply the CRT with a high voltage for the accelerating anode.

9. The 4.5 MHz sound-IF is formed by

A. a heterodyne action between the two IF's (video-IF is 45.75 MHz and sound-IF is 41.25 MHz) in the video detector.

35 B. the beat frequency produced by the mixer in the local oscillator.

C. the ratio detector in the sound strip.

D. the tuned circuits in the video-IF strip.

10. What type or types of modulation are used for the television transmission system?

A. Video and sound are FM.

B. Sound is AM and video is FM.

C. Video and sound are AM.

D. Sound is FM and video is AM.

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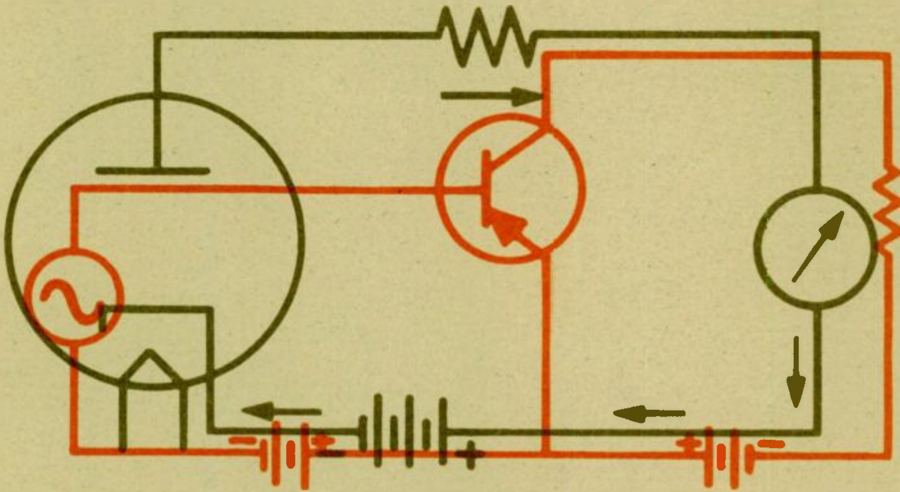
S. T. Christensen

LESSON NO. 80

ANALYSIS OF TV CIRCUITS



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
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ADVANCE SCHOOLS, INC.
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Contents

ANALYSIS OF TV CIRCUITS

INTRODUCTION

The development of television brought many new concepts into the field of electronics. Many circuits that were used in other equipment were modified for use in the television receiver. The TV repair-technician must have a basic understanding of the many circuits that are used in the television receiver. From this basic knowledge, the repair technician can analyze circuit malfunctions of almost any make of receiver. The TV repair-technician should also keep abreast of the many new developments that are occurring daily in the field of television.

In this lesson we will analyze some of the different circuits that are used in television receivers. All makes and models of television receivers may not use the circuits described in this lesson, but generally use these circuits with slight variations in receiver design. Remember, the input to all television receivers is the same and the outputs are the same. The inputs are the carrier frequencies for video and sound, the outputs are the picture tube screen display and the sound from the speaker.

In this lesson we will discuss the composite video signal, sync separators, basic RC circuits, Automatic Gain Control, and the high voltage systems used in television receivers.

THE COMPOSITE VIDEO SIGNAL

The composite video signal contains all the information needed to reproduce the picture. Included is the video from the camera unit, synchronizing pulses to synchronize the transmitted signal with the receiver, and blanking pulses to obliterate the retrace signals from the picture tube. The video signal is combined with the blanking pulse (Fig. 1); the sync pulse is placed on top of the blanking pulse.

In the composite video signal, successive values of voltage and current amplitudes are shown against values of time during the scanning of three horizontal lines. During the time when blanking and sync pulses are being transmitted, no video is appearing. The overall signal amplitude is divided into two parts: the lower 75 percent is for the video, and the upper 25

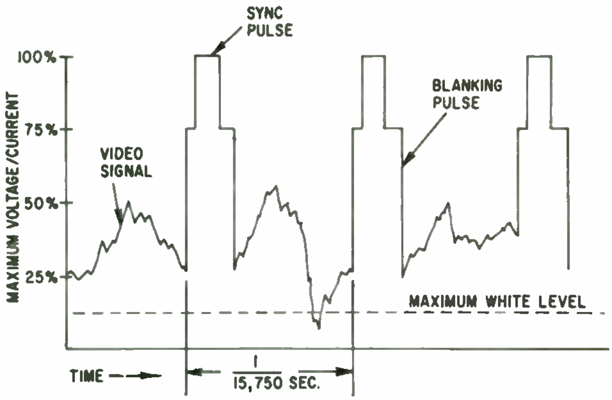


Figure 1 — The composite video signal.

percent is devoted to synchronizing pulses. Standardization is necessary to insure that the transmitted signal is suitable for all receivers.

The lowest amplitudes correspond to the whitest parts of the picture. The picture becomes blacker as amplitude increases toward 75 percent. This standard of transmission is called *negative transmission,* which is defined as decreasing signal amplitude for increasing light intensities. As the level reaches 75 percent, the grid cuts off the picture tube and the absence of light establishes the blackest level, which is the case when the blanking level occurs.

Details of the horizontal blanking and sync pulse are shown in Figure 2. The interval of the complete scan is 63.5 microseconds since horizontal frequency is 15, 750 Hz. The horizontal blanking pulse is 10.16 microseconds, or about 16 percent of total sweep. The sync pulse, superimposed on the pedestal, occupies 5.08 microseconds or one-half the blanking time.

The part of the pedestal just before the sync pulse (0.254 microsecond) is called the *front porch;* the portion following the sync pulse (4.826 microseconds) is called the *back porch.* The front porch blanks the right side of the picture screen just before the sync pulse begins. Flyback occurs with the leading edge of the sync pulse and continues for 4.42 microseconds of the back porch. The next sweep starts, but the left side of the screen is blanked for 0.406 microsecond of the starting sweep. This action strives to maintain a straight left edge.

The vertical blanking pulse blanks the picture during retrace time when the electron beam has completed one field and is returned to the top ready to start the next field. Immediately following the last active line, the video signal is brought up to the black level by the vertical blanking pulse in preparation for the vertical retrace.

So far in the discussion little has been said about the special form of the combined synchronizing pulses.

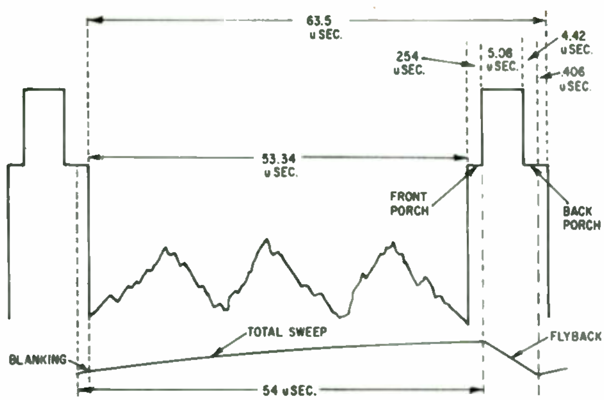


Figure 2 — Composite video time allocations.

The form and the timing of the synchronizing pulses are such that the horizontal and vertical oscillators are triggered at exactly the right instant to keep the sweep in the camera tube and the sweep in the picture tube locked in step. Because the horizontal oscillator must be triggered during the vertical sync pulse (to prevent the horizontal oscillator from drifting out of control), the vertical pulse is serrated, as shown in Figure 3; that is, the vertical pulse is chopped into six pieces. The fluctuations resulting from serrations do not affect the operation of the vertical oscillator, but serve only to keep the horizontal oscillator properly triggered.

In addition to the serrations in the vertical pulse, equalizing pulses are necessary before and after each vertical pulse. The necessity for the equalizing pulses, labeled E in Figure 3B, may be explained as follows:

First, it is assumed that no equalizing pulses are used, as in Figure 3A. If the vertical pulse is inserted at the end of the field, which occurs simultaneously with the end of a full horizontal line (part 1), the firing potential of the vertical oscillator is reached at the correct time to produce the desired interlaced scan.

If the vertical pulse is inserted at the end of a field, which occurs simultaneously with the end of a half horizontal line (part 2), the firing potential of the vertical oscillator is reached too early. This results from the fact that the slight charge on the capacitor in the triggering circuit of the vertical oscillator (due to each horizontal pulse) does not have time to leak off before the vertical pulse arrives. The residual voltage across this capacitor, plus the voltage due to the vertical pulse, causes the vertical oscillator to fire too soon.

Second, the situation is corrected, as shown in Figure 3B, by the use of equalizing pulses. The buildup of the vertical pulse across the capacitor now begins at the same point regardless of whether the vertical pulse arrives at the end of a full line or at the end of a half

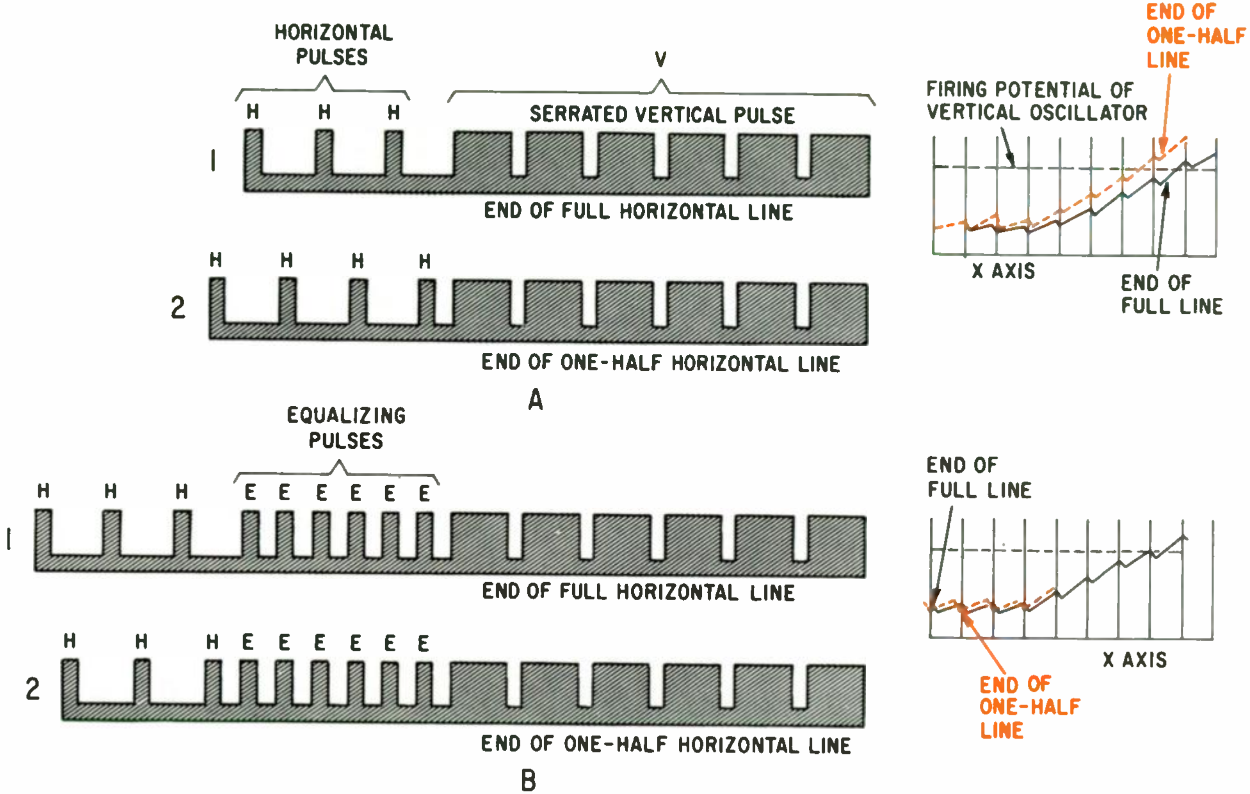


Figure 3 — Synchronizing Pulse Waveforms. A- Without equalizing pulses. B- With equalizing pulses.

line. In other words, the equalizing pulses cause the potential on the capacitor to be at the same level (at the same time the vertical pulse arrives) regardless of whether the vertical pulse occurs at the end of a half line or at the end of a full line. Although not shown in the figure, equalizing pulses are also used after the vertical pulses.

SYNCHRONIZING CIRCUITS

The detected composite video signal (contains synchronization pulses, blanking pulses, and video) is applied to the control grid or cathode (depending on phase) of the picture tube. The video information intensity modulates the scanning electron beam producing varying degrees of black through white information on the screen. The blanking pulses cut the picture tube off to prevent a visual indication of retrace. The sync pulses are present but have no effect since they are present during the time the picture tube is cut off and only drive the tube beyond cut off.

2

After detection the composite video signal is also fed to a sync separation or clipper stage. The vertical and horizontal sync signals are removed from the composite video signal and filtered. Following this, the pulses are amplified and reshaped according to the needs of the synchronization and sweep systems. A block diagram of the synchronization circuits is shown in Figure 4 with the associated pulse waveforms.

3

The horizontal sync signal fires the horizontal oscillator at exactly the right instant to maintain the proper synchronization between the horizontal sweep in the receiver picture tube and the horizontal sweep in the transmitter camera tube. The output of the horizontal oscillator is formed into a sawtooth waveform; it is then amplified and applied to the horizontal deflection coils.

The vertical sync signal fires the vertical oscillator at the right instant to maintain the proper synchronization between the vertical sweep in the receiver picture tube and the vertical sweep in the transmitter camera tube. As in the case of the horizontal oscillator output, the vertical oscillator output is formed into a sawtooth waveform (modified into a trapezoidal waveform); it is then amplified and applied to the vertical deflection coils.

SYNC SEPARATORS

Sync separation, or sync clipping, may be accomplished by the use of circuits employing diodes, triodes, pentodes or transistors. All methods of sync separation involve the fact that during transmission the blanking level is maintained at 75% of the maximum carrier deviation. The sync pulses occupy the top 25% of the carrier wave. The problem of sync separation is merely a problem of clipping the top 25% of the composite video waveform without passing any of the video signal.

The Diode Sync Separator

A simplified circuit of a diode sync separator is shown in Figure 5. During the time the sync voltage

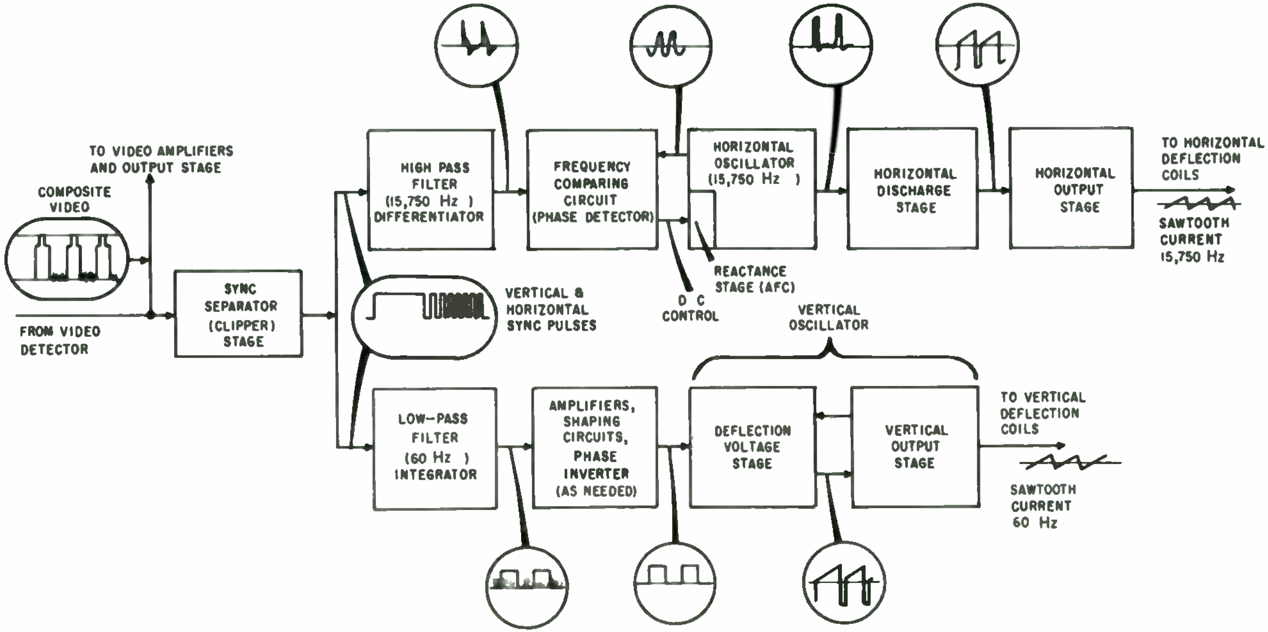


Figure 4 — Block diagram of synchronizing circuits.

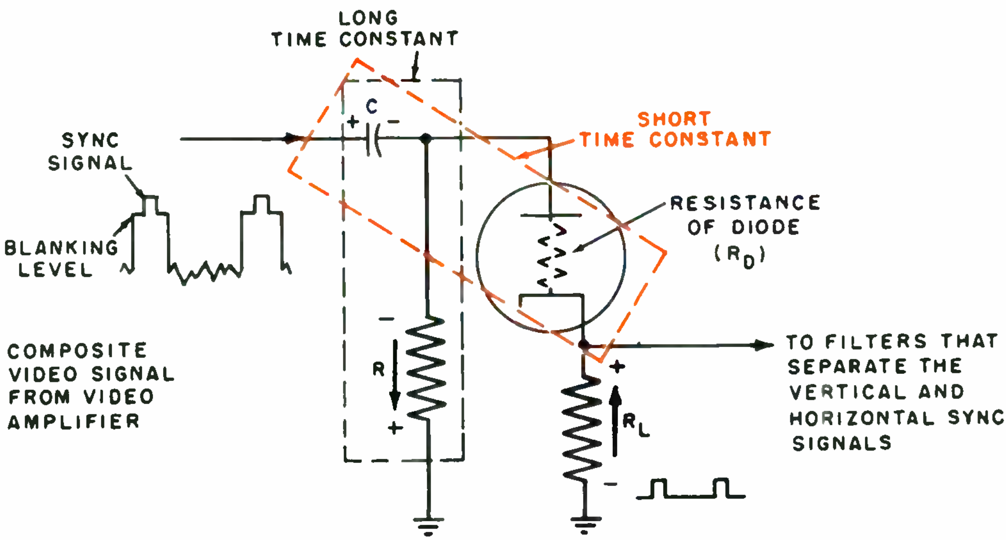


Figure 5 — Diode sync separator.

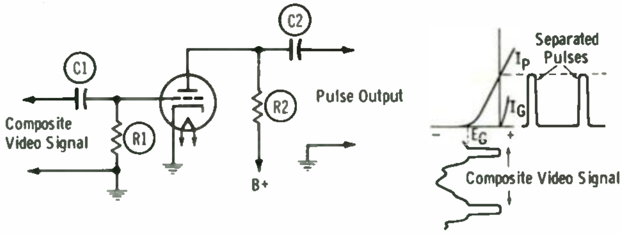
is applied to the input, the diode plate is positive with respect to the cathode, and capacitor C is charged through the low resistance of the conducting diode. Between pulses, capacitor C discharges through R and thus maintains a negative bias between plate and ground; this cuts off all signals up to the blanking level. The bias is maintained at approximately the blanking level, and only the sync signal causes pulses of current to flow through R_L, across which the output is taken.

The output pulses consist of the horizontal sync pulses, the equalizing pulses, and the serrated vertical sync pulses. These pulses are fed to filter circuits that separate the vertical sync pulses from the horizontal sync pulses.

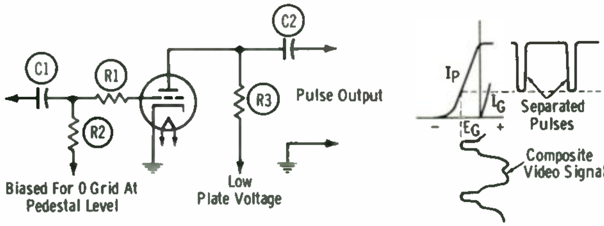
The Triode Sync Separator

In most present day tube type receivers, triodes (and in some cases pentodes) are employed, rather than the diode circuit just discussed. The choice of tube type depends on the sync pulse amplitude requirement, polarity requirement, and point in the circuit at which separation is accomplished. Generally, these multi-element tubes allow some voltage gain to be realized in the separation process. In certain circuits, leveling or limiting can also be realized. Two basic types of triode sync separating circuits are shown in Figure 6.

The circuit of Figure 6A uses grid rectification of the video signal to bias the control grid, so that plate current cut off occurs at the desired level. This action is similar to the one just discussed for the diode circuit in Figure 5. Two additional actions are found in this circuit; the sync pulses are large enough to drive the grid positive, and the lowered grid resistance limits the input signal by loading, and some amplification of the sync pulse occurs because of the amplifying properties of the triode.



A Grid cutoff by signal rectification.



B Separation by positive grid and plate-current saturation.

Figure 6 — Triode sync-separation circuits.

In Figure 6B the operating conditions are quite different from those of the circuit in Figure 6A. The tube is biased from an external voltage source, through resistors R_1 and R_2, until it just starts to draw grid current at the black or pedestal level. The input signal is inverted in polarity from that of the preceding example. The sync pulse portion of the video input signal is the most negative. The plate voltage is made so low that the plate current is saturated at a near zero grid voltage. The portion of the video input signal which is more positive than the desired clipping level lies in the saturation region and produces no further rise in plate current. For this reason, limiting or leveling occurs at this saturation point. The negative grid voltage from the sync pulse portion of the input signal causes a drop in plate current, as shown in the waveform drawings of Figure 6B. So that the circuit action can be better illustrated, the amplitude of the sync input pulses has been limited in the drawing. If their amplitude were extended to beyond the grid cut off point, limiting would also occur because of plate current cut off, and the output pulses would still be uniform, but larger in size. Series resistor R_1 in the grid circuit limits the amount of grid current that can conduct over any one frame. This limiting prevents a long-time blocking condition from developing because of an excessive charge on capacitor C_1.

The Transistor Sync Separator

Figure 7 shows a transistor sync separator circuit. This sync separator is followed by a sync amplifier to increase the amplitude of the sync signals before they are applied to their respective oscillators.

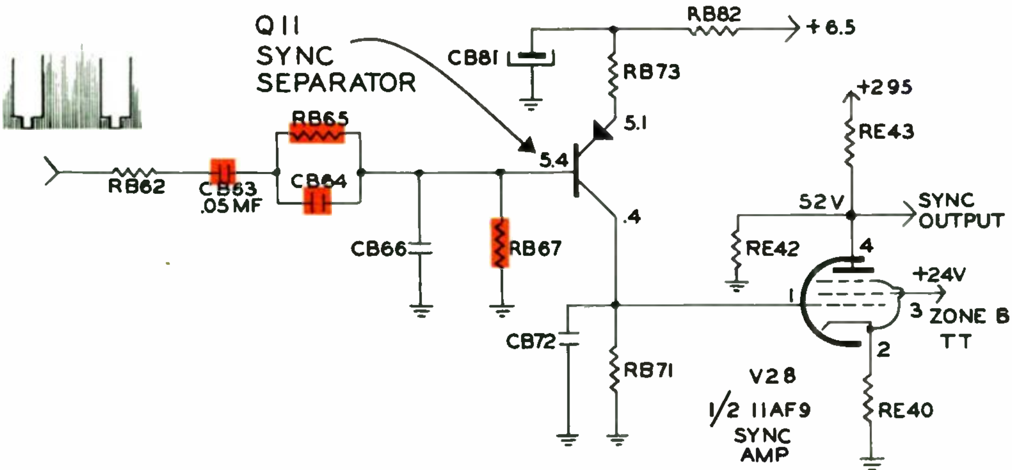


Figure 7 — Transistor sync separator. (Courtesy of Montgomery Ward).

The following circuit description was taken from a training course provided by Montgomery Ward for its TV repair-technicians. Sync separator (Q11) drives a tube type sync amplifier (V28) 11AF9. The tube stage serves as an amplifier and, under certain conditions, behaves as a noise limiter and sync cleaner. The video signal is coupled from the 1st video collector to the base of Q11 by capacitor CB63. Q11 is a PNP operating inverted. Without signal, the stage is reverse biased. The incoming sync signals drive the base-emitter junction of Q11 into strong forward bias (conduction). A reverse bias charge is built and stored on CB63 during this time. During the line scan, some of CB63's charge bleeds off through RB67, producing a near-forward bias condition on the base. Since the sync is of greater amplitude than the video, only the negative sync tips will be great enough to overcome and effect the residual charge and turn on Q11. Therefore, the signal at the collector will only be the sync pulses, free of video. CB64 and RB65 are noise immunity components, and they permit the base bias to recover rapidly if noise alters the charge on CB63. The sync pulse is directly coupled to the sync amplifier (V28) where it is further amplified. The sync amplifier will easily saturate due to the low plate voltage. The sync signal is taken from the plate and fed to the vertical and horizontal circuits.

REVIEW OF THE CHARGE AND DISCHARGE OF AN RC CIRCUIT

Ohm's law states that the voltage across a resistance is equal to the current through it times the value of the resistance. This means that a voltage will be developed across a resistance ONLY WHEN CURRENT FLOWS through it.

A capacitor is capable of storing or holding a charge of electrons. When uncharged, both plates contain the same number of free electrons. When charged, one plate contains more free electrons than the other. The difference in the number of electrons is a measure of the charge on the capacitor. The accumulation of this charge builds up a voltage across the terminals of the capacitor, and the charge continues to increase until this voltage equals the applied voltage. The charge in a capacitor is related to the capacitance and voltage as follows:

$$Q = CE,$$

in which Q is the charge in coulombs, C the capacitance in farads, and E the difference in potential in volts. Thus, the greater the voltage, the greater the charge on the capacitor. Unless a discharge path is provided, a capacitor keeps its charge indefinitely. Any practical capacitor, however, has some leakage through the dielectric so that the charge will gradually leak off.

A voltage divider containing resistance and capacitance may be connected in a circuit by means of a switch, as shown in Figure 8A. Such a series arrangement is called an RC series circuit.

If S1 is closed, electrons flow counterclockwise around the circuit containing the battery, capacitor, and resistor. This flow of electrons ceases when C is charged to the battery voltage. At the instant current begins to flow, there is no voltage on the capacitor and the voltage drop across R is equal to the battery voltage. The initial charging current, I, is therefore equal to $\frac{E_S}{R}$. Figure 8B shows that at the instant the switch is closed, the entire input voltage, E_S, appears across R, and that the voltage across C is zero.

The current flowing in the circuit soon charges the capacitor. Because the voltage on the capacitor is proportional to its charge, a voltage e_c, will appear across the capacitor. This voltage opposes the battery voltage; that is, these two voltages buck each other. As a result, the voltage e_r across the resistor is $E_s - e_c$, and this is equal to the voltage drop (i_cR) across the resistor. Because E_S is fixed, i_c decreases as e_c increases.

The charging process continues until the capacitor is fully charged and the voltage across it is equal to the battery voltage. At this instant, the voltage across R is zero and no current flows through it. Figure 8B shows the division of the battery voltage, E_S, between the resistance and capacitance at all times during the charging process.

If S_2 is closed (S_1 opened) in Figure 8A, a discharge current, i_d, will discharge the capacitor. Because i_d is opposite in direction to i_c, the voltage across the resistor will have a polarity opposite to the polarity during the charging time. However, this voltage will have the same magnitude and will vary in the same manner. During discharge the voltage across the capacitor is equal and opposite to the drop across the resistor, as shown in Figure 8C.

An RC voltage divider that is designed to distort the input voltage waveshape is known as a *DIFFERENTIATOR* or *INTEGRATOR,* depending on the location of the output taps. The output from a differentiator is taken across the resistance, and the output from an

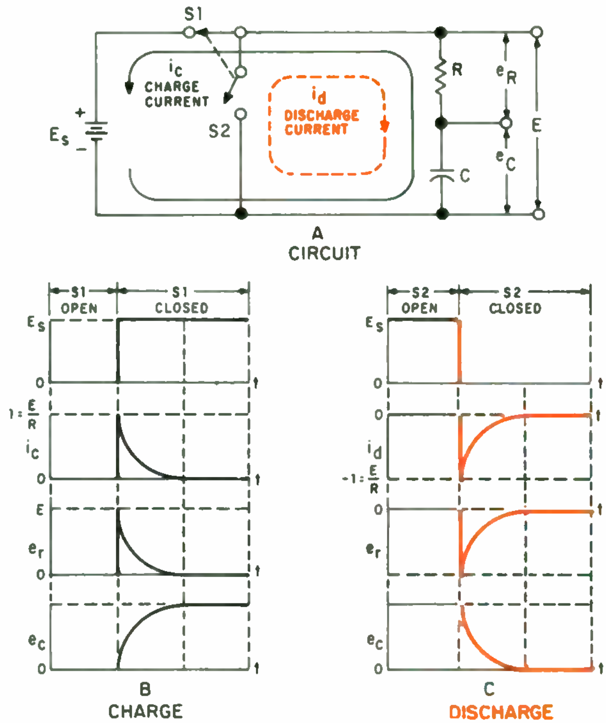


Figure 8 — Charge and discharge of an RC series circuit.

integrator is taken across the capacitor. Such circuits will change the shape of any complex alternating-voltage waveshape that is impressed on them. The amount of change depends on the value of the time constant of the circuit as compared to the period of the input waveform. However, neither a differentiator nor an integrator can change the shape of a pure sine wave.

SEPARATION OF THE VERTICAL AND HORIZONTAL SYNC PULSES

The methods used to separate the synchronizing pulses from the composite video signal have already been discussed. Now we must separate the horizontal and the vertical sync pulses so that they may be applied to their respective oscillators. The amplitude of both sync pulses are the same, so clipping cannot be used to separate the pulses from each other. The major difference between the vertical and horizontal sync pulse is their repetition rate. The repetition rate of the horizontal sync pulse is 15,750 pulses per second and that of the vertical sync pulse is 60 pulses per second. This difference in repetition rate allows pulse separation by the use of filters. A high pass filter is used for horizontal sync pulse separation and a low pass filter is used for the vertical sync pulse separation.

Horizontal Sync Pulse Separation

The differentiation circuit is used for horizontal sync pulse separation. This circuit is shown in Figure 9. Differentiation means the breaking down of a quantity into small parts. The differentiator (high pass filter) has a very short time constant.

The horizontal sync pulse has a period of 5.08 microseconds and the period of 1 horizontal line is 63.48 microseconds. The RC differentiating circuit has a time constant of from 1 to 2 microseconds. The output of the differentiator is taken from across the resistor R.

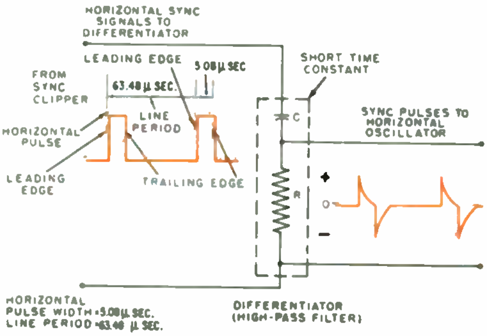


Figure 9 — Differentiator circuit for horizontal sync pulses.

The leading edge of the square wave input sync pulse causes a rapid charge of the capacitor C through resistor R. Maximum current flows through R causing the voltage across R to rise immediately to maximum (Emax = ImaxR) as shown in Figure 9. As the capacitor charges the current through R decreases at a linear rate causing the voltage across R to decrease. After 5 microseconds the trailing edge of the horizontal sync pulse arrives and attempts to discharge the capacitor C. The first instant maximum current flows through R, again causing maximum voltage drop across R, but now the voltage is of a negative polarity. As the capacitor discharges, the voltage across R decreases. When the capacitor is completely discharged the voltage across R is zero until the next horizontal sync pulse arrives.

Two spikes were formed from one input pulse, hence, the name differentiator. Only one spike in each pair (for example, the positive spike) is needed to trigger the horizontal oscillator. The other spike of the pair occurs at a time when the oscillator is insensitive to triggering pulses.

The vertical sync pulse has a much longer period than the horizontal sync pulse. As previously discussed the vertical sync pulse is serrated (cut into pieces) to maintain the horizontal oscillator in synchronization during the long period of vertical retrace. There are six equalizing pulses before and six after the serrated vertical pulse.

The serrated vertical pulse and equalizing pulses are shown in Figure 10. The repetition rate for the equalizing pulses and for the serrated vertical pulse is 31,500 pulses per second. This is twice the repetition rate of the horizontal sync pulse. The outputs of the differentiator, when the inputs are the equalizing and serrated vertical pulses, are also shown in Figure 10. In this example, two positive spikes occur in a horizontal line period, because of the higher repetition rate of the equalizing pulses only the spikes marked with an "A" will

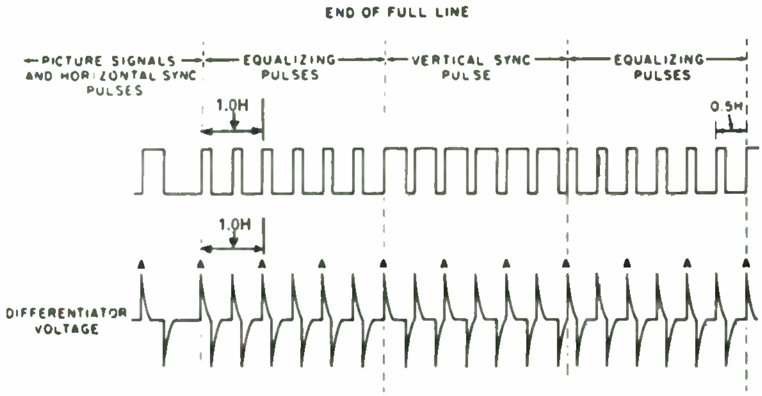


Figure 10 — Output of the differentiator for the serrated vertical pulse.

trigger the horizontal oscillator. The other spikes occur at a time when the horizontal oscillator is insensitive to triggering pulses and, therefore, will have no effect upon the horizontal oscillator.

Vertical Sync Pulse Separation

The integration circuit used for separation of the vertical sync pulses is shown in Figure 11. The integrating action that is used to sort the vertical sync pulse from the horizontal sync pulse is just the opposite of the differentiating action just discussed. Integrate means to combine a number of small elements to form a whole. The output of the integrating circuit is taken across the capacitor. The time constant of the integrating circuit is long and is normally equal to the duration of the horizontal sync pulse. The horizontal sync pulse will charge the capacitor a small amount, but the long period between horizontal sync pulses will allow the capacitor to discharge. Therefore, the horizontal sync pulse produces no useful output.

The equalizing pulses will have no effect upon the output of the integrator as shown in Figure 11. The capacitor C will charge slightly with the equalizing pulse but will discharge in the relatively long time between equalizing pulses. The period of one serration of the vertical pulse is 27.3 microseconds and the serrated vertical pulse will produce a greater charge across the capacitor than the horizontal or equalizing pulses. The period between serrated vertical pulses is only 4.44 microseconds which is not long enough to allow the capacitor to discharge before the next serrated vertical pulse arrives. The charge is accumulated across the capacitor as each serration of the vertical pulse adds to the previous voltage on the capacitor. The voltage across C continues to increase during the interval of the vertical pulses. The dotted line indicates the level at which this voltage is sufficient to trigger the vertical os-

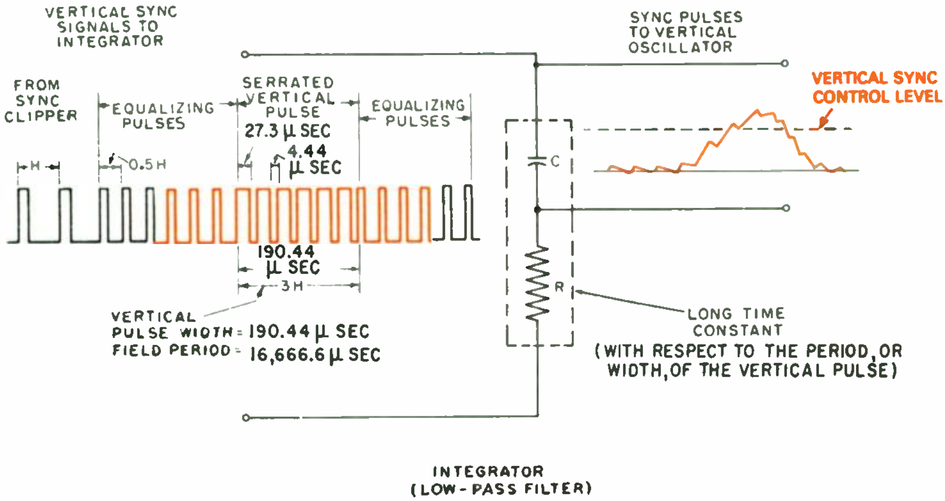


Figure 11 — Integrator used for vertical sync pulses.

cillator. This level is usually reached after 2-1/2 serrated vertical pulses. This output is then applied to the vertical oscillator.

After being separated and shaped, the horizontal and vertical sync pulses are applied to the horizontal and vertical sweep oscillators, respectively, so that they may be triggered at the correct instant to synchronize the receiver with the transmitter. Both the vertical and horizontal sweep oscillators, when fed into the correct circuits, produce current sawtooth waveforms.

The sawtooth waveforms produced by the horizontal sweep oscillator are amplified and applied to the picture tube in a manner that will cause the electron beam to be deflected (swept) horizontally across the face of the tube. Likewise, the waveforms produced by the vertical sweep oscillator cause the electron beam to be deflected (relatively slowly) from the top to the bottom of the picture tube.

Multivibrators and blocking oscillators are two types of resistance-capacitance oscillators that are commonly used in the sweep circuits (vertical and horizontal) of television receivers. At this point it may be helpful to review the previous lessons on multivibrators and oscillators.

AUTOMATIC GAIN CONTROL

Automatic gain control (AGC) minimizes the effect of changes in signal strength at the receiver antenna. The gains of the RF and IF stages are so regulated that a strong signal is amplified less than a weak signal. As a result, the quality of the TV picture tends to be relatively constant.

6

Variations in signal strength are of two types, variations between signals received on different channels, and variations occurring from time to time on the same channel.

Both strong and weak channels are available in many locations. If

AGC is provided in the receiver, the contrast control does not need to be reset each time a new channel is tuned in. AGC also compensates for extremely strong signals received in powerful station areas.

The AGC system levels out most of the periodic amplitude variations which would cause fading on a particular channel; therefore, a steady picture is obtained, even in moderate fringe areas. The rapid flutter caused by airplanes flying near the path of the transmitted signal is also corrected as much as possible through AGC action.

Rectified AGC

A typical AGC circuit composed of a simple filter network can be seen in the schematic in Figure 12A. The filter is composed of R_4 and C_1. The time constant of this filter circuit is approximately 0.15 second.

The performance of this system can be refined by the use of a special AGC diode and a charging time constant shorter than the discharging time constant. A circuit with these modifications will not be affected by variations in scene brightness. Such variations cause shifts in the amplitude of the carrier in the television signal.

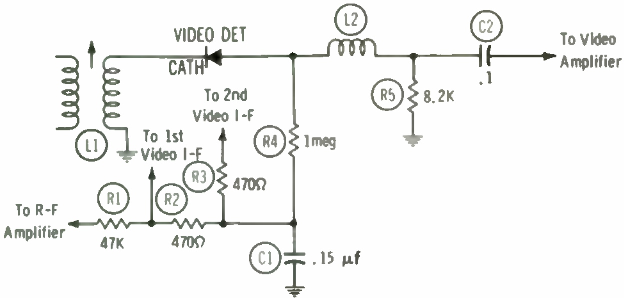
The average value of voltage of a video signal is obviously not an absolutely true indication of signal strength. If the AGC voltage were developed from this average voltage, the AGC filter output would tend to increase during the transmission of scenes containing many large, dark objects or a dim background.

The only portion of the composite video signal which has a constant amplitude regardless of picture content is the sync pulse signal. If the strength of the received signal does not change, a consistent peak value of voltage is reached by the tips of these pulses. This peak is comparable to the maximum voltage attained during 100 percent modulation of a carrier by an audio signal. Improved AGC action will be obtained if the AGC filter capacitor can be charged to this peak voltage and if most of this charge can be maintained between pulses.

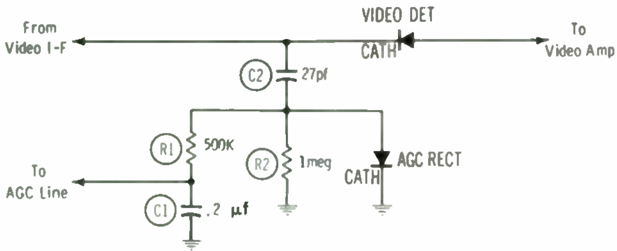
If the charging and discharging time constants of the AGC filter are of nearly equal lengths, the system can never build up a charge approaching the peak amplitude of the signal voltage. The discharging time constant can be lengthened in order that a greater charge can be retained on the filter capacitor. This feature has been included in the circuit in Figure 12B.

Resistor R_2 in Figure 12B corresponds to R_5 in Figure 12A, but the value of the resistor in Figure 12B has been increased to one megohm. As a result, the charging time constant is 0.1 second, but the discharging time constant is increased to 0.3 second.

A separate diode must be used to rectify the AGC voltage if a resistor of high value is used in the discharge circuit of the AGC capacitor. The reason for this requirement will be clear if it is noted in



A Agc circuit composed of a simple filter network with a time constant of approximately 0.15 second.



B Agc circuit with improved action obtained by a lengthened time constant in the discharge path.

Figure 12 — Schematics of simple AGC systems.

Figure 12A that the voltage applied to the video amplifier is developed across R_5. Most of the high frequency portions of the video signal would be lost if that resistor were large in value because the shunting effect of stray capacitance in the video amplifier input would be exaggerated. R_2 in Figure 12B can be as large as necessary because the video detector diode is separate from the AGC diode.

It should be repeated that AGC action can be obtained without special concern for changes of brightness in the picture. However, correcting this condition is important enough that many of the relatively simple AGC systems and all of the more complex ones develop the AGC voltage from the peak voltage of the sync pulses.

Amplified AGC

An improvement of the basic AGC system was the addition of an amplifier tube to boost the amplitude of the rectified AGC voltage. A two stage, amplified-AGC circuit can develop an adequate control voltage when the changes in amplitude of the video signal are so slight that a simple AGC system would not respond to them. Amplified AGC is, therefore, more efficient than ordinary simple, or filtered, AGC.

An amplified-AGC circuit is shown in simplified form in Figure 13. An almost pure DC voltage that is positive in polarity is produced across C_1 and R_1 when a video signal is applied to the AGC rectifier. This signal is directly coupled to the grid of AGC amplifier V1.

Since the AGC voltage is taken directly from the plate of the AGC amplifier, a negative voltage of low amplitude must be present in the plate circuit of V_1.

It is assumed that the circuit in Figure 13 can be supplied with a voltage of approximately −100 volts. A voltage equal to one-half the B− potential is applied to the cathode of the amplifier. The average grid voltage is determined by the setting of potentiometer R_2.

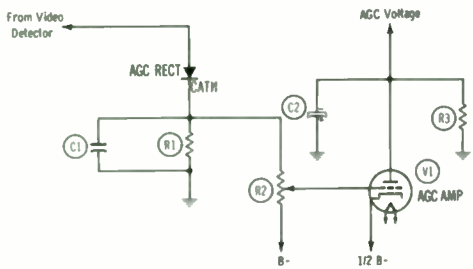


Figure 13 — Schematic of amplified AGC circuit.

This control is a voltage divider between the full B− voltage and the slightly positive voltage at the cathode terminal of the AGC rectifier diode.

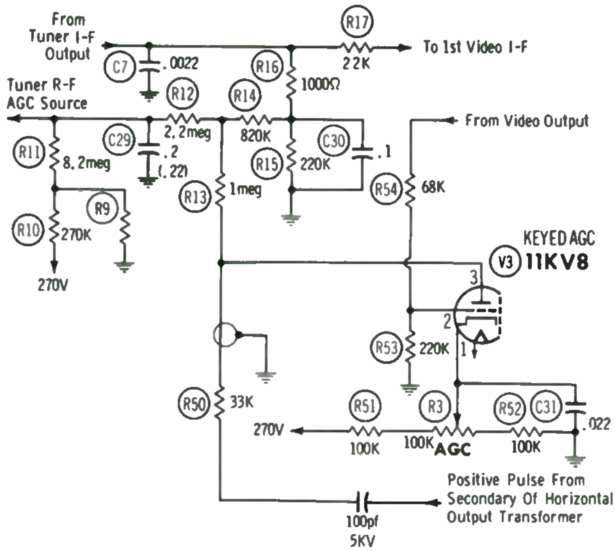
The bias on V1 automatically varies in step with the voltage developed across R_1 and C_1 by the video signal. An increase in amplitude of the incoming sync pulses causes the cathode terminal of the AGC rectifier to go in the positive direction; therefore, the voltage at the arm of R_2 is less negative than before, and the bias on V1 is reduced. Conduction increases in the amplifier. The plate voltage of V1 swings in a negative direction, and C_2 in the plate circuit is heavily charged to the polarity shown in Figure 13. The time constant of R_3 and C_2 is so long that C_2 discharges very slowly. The AGC control voltage is, therefore, nearly equal to the voltage which charges C_2.

Keyed AGC

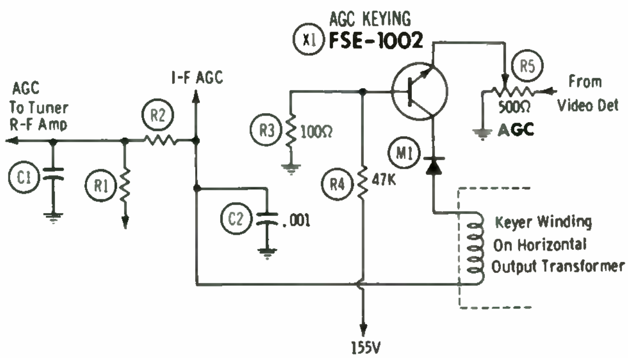
Keyed AGC is the most complex form of automatic gain control used in TV receivers; it is also the most efficient. The circuits in Figure 14 are typical of most circuits of this type. Figure 14A shows a typical AGC circuit employed in tube type receivers and Figure 14B shows its transistor counterpart. The tube circuit will be discussed first.

The AGC keying tube used in this circuit is typically a triode, but it could be a pentode. Two input signals are required. A composite video signal which contains positive going horizontal sync pulses is applied to the control grid, and positive pulses of high amplitude are coupled to the plate from a winding on the horizontal output transformer. The conduction of the tube depends on the arrival of a pulse at the plate at the same time that a horizontal sync pulse arrives at the grid. Since the plate pulses are timed by the horizontal oscillator, they have the same frequency and phase as the sync pulses if the receiver is correctly synchronized.

A short burst of conduction occurs 15,750 times each second in response to the arrival of each pulse. Since the level of the sync tips determines the bias of the keying tube during the burst of conduction, the amount of conduction that occurs during the pulses depends on the DC level reached by



A Vacuum-tube configuration.



B Transistor configuration.

Figure 14 — Typical keyed-AGC circuits.

the tips of the horizontal sync pulses at the grid. The level of the sync tips, in turn, depends on the strength of the incoming signal. The keying tube is cut off between pulses, and the plate voltage assumes a negative value proportional to the amount of conduction that takes place during the pulses. The greater the conduction, the more negative the average plate voltage. The plate voltage is passed through an RC filter, and the resultant DC voltage is applied to the RF amplifier and to one or more IF amplifiers as grid bias.

Since the keying tube is cut off in the interval between horizontal sync pulses, noise and video in the input signal cannot affect the production of AGC voltage. In addition, the keyed AGC circuit does not respond to the vertical sync pulses. The keying tube conducts only during alternate equalizing and serration pulses. The amount of conduction is not sufficient to cause a periodic rise in AGC voltage at the vertical rate of 60 Hz. Such a rise is characteristic of other AGC systems. The AGC filter in the keyed circuit, unlike the filters in other AGC circuits, does not have to be designed to remove vertical pulses from the output voltage. The time constant of the filter is, therefore, appreciably shorter in a keyed circuit than in other circuits. This is a desirable feature because it tends to make the keyed circuit largely immune to airplane flutter.

The DC cathode voltage is made several volts more positive than the average DC grid voltage in order that the keying tube will be correctly biased during conduction. The difference between the grid and cathode voltages is more important than their absolute values.

These two voltages have high positive values in most actual circuits. Regardless of this fact, the tube conducts normally because the keying pulses on the plate have a much higher positive value. The reason behind the use of a positive grid voltage is that the grid of the keying tube must be directly coupled to the stage supplying an input video signal to the AGC system. Frequently, the signal source is the plate circuit of a video amplifier, and the high voltage at the amplifier plate also appears at the grid of the keying tube. Direct coupling is used because the variations in grid voltage, which occur in response to changes in the DC level of the sync pulses, are fundamental to the operation of the AGC system. This reference level would be lost if a capacitor were inserted in the input lead to the grid of the keying tube.

As shown in Figure 14A, an isolating resistor (R_{54}) is included in the grid circuit. This resistor limits the amount of current in the circuit should the grid draw current. The impedance of the resistor isolates the input capacity of the keying tube from the video circuit; therefore, the loading effect of the AGC circuit on the video circuit is greatly reduced.

Recall that the amount of conduction through the tube is determined by the peak amplitude of the sync pulses. If the video signal is weak, the positive voltage on the grid of the keying tube will be relatively low. The difference between the grid voltage and the cathode voltage is great, and the heavily biased tube passes less than average current. Little AGC voltage is produced under these conditions because the charge on the capacitors in the plate circuit is comparatively small. On the other hand, a strong video signal develops a high grid voltage which is closer to the value of the cathode voltage. The bias on the tube is low, conduction through the tube is heavy, and considerable AGC voltage is thus produced in the plate circuit.

Figure 14B shows a typical keyed AGC circuit employed in transistor type receivers. In this circuit an NPN transistor is connected as a common emitter amplifier. The emitter receives video signal from the video detector through AGC control R_5. The base of the transistor is biased at approximately 3 volts and the collector is pulsed from a winding on the horizontal output transformer. Thus, the transistor only conducts during the flyback interval. Rectification of the pulses through diode M_1 produces approximately 5 volts at the collector of X_1.

In operation, the video detector applies a negative going video signal to the emitter. The amount of applied signal can be varied by means of AGC control R_5. The video signal increases the forward bias on the transistor causing the collector current to increase. Electrons flow from the collector through diode M_1, through the keyer winding, through R_2, and through R_1. The voltage drop across R_1 becomes more negative, and a higher negative bias is therefore applied to the IF strip and the RF amplifier in the VHF tuner. C_1, R_2, and C_2 comprise a filter for the pulse output of keying transistor X_1.

Figure 15 shows an AGC circuit and a noise inverter combined in one tube with a sync separator circuit. The input signal for the AGC section of the tube is a composite video signal with positive going sync pulses. The composite video signal is taken from the plate of the video amplifier and applied to one of the second control grids (pin 9). This signal is direct-coupled because the DC level of the sync tips is important to the operation of the AGC tube. If the composite video signal is strong, the sync tip level at pin 9 will be less negative than if the video signal were weak. In other words, a strong input signal places a relatively low bias on the left hand section of the tube. This section of the tube then conducts heavily, and the voltage on the left hand plate drops. The lower the plate voltage becomes, the more AGC voltage is produced.

Since the plate is maintained at a positive potential of approximately 35 volts in order that the tube will conduct, the AGC voltage cannot be obtained directly from the plate. Instead, it is derived in the following manner. The plate of the tube is connected to the grid of the horizontal discharge tube through a voltage divider made up of resistors R_3, R_2, and R_4. The average DC potential at the grid is -75 volts. Variations in this grid voltage are leveled off by the AGC filters. The voltages at the intermediate points on the divider can be applied directly to the AGC line. Note that the

AGC bias voltages for the tuner and for the IF strip are taken from separate points. When no input signal is being applied to the AGC section of the tube, there is a slight positive voltage at the junction of R_2 and R_4 and a slight negative voltage at the junction of R_2 and R_3. These voltages are fed to the tuner and IF stages, respectively. Both AGC voltages are driven in a negative direction when an input signal is applied to the tube, but the IF voltage always remains more negative than the tuner voltage. This arrangement amounts to a simple delay circuit for the AGC line to the tuner.

The negative potential at the grid of the discharge tube is also utilized by another voltage divider. This voltage divider is in the grid circuit of the AGC section of the tube and is composed of R_{10}, R_7, AGC control R6, and R5. A negative DC voltage is fed from the junction of R10 and R7 to the grid of the tube, and the input signal from the video amplifier is superimposed on this DC voltage. The AGC control permits the range of bias on the tube to be adjusted.

If noise pulses in the AGC signal were uncontrolled, they would cause the AGC section of the tube to conduct excessively. The voltages in the AGC system would then become too negative. The noise inverter keeps these unwanted pulses from increasing the conduction of the tube through the action of the inverted signal on pin 7. The AGC voltages are maintained at normal values even when considerable noise is present in the video signal.

The values of many of the components in the tube circuit are criti-

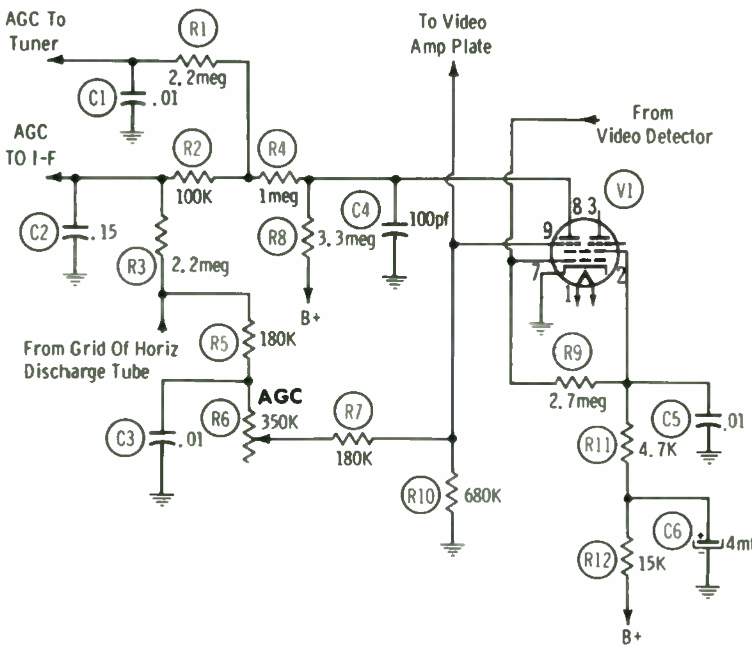


Figure 15 — A combination noise inverter, sync separator, and AGC circuit.

cal. This fact applies especially to the noise inverter. The bias on the inverter grid (pin 7) must be maintained at such a value that the sync tips will almost reach the cutoff voltage of the grid. If the bias is too low, the noise inverter will not accomplish its purpose. If the bias is too high, the tube will be driven into cutoff by each sync pulse. The latter condition would cause low AGC voltage and unstable synchronization.

No provision is made for adjusting the inverter circuit. This is actually an advantage because then the operation of the inverter cannot be upset by misadjustment of some control.

Delayed AGC for the RF Stage

Even the weakest usable input signal develops some AGC voltage, which reduces the gain of all stages controlled by the AGC system. Unfortunately, the amplitude of a weak signal at the grid of the RF amplifier is barely more than the amplitude of the noise in that stage. When reception is poor, full gain in the RF stage is essential, so that the signal-to-noise ratio can be kept high. Once the signal has been amplified above the level of the noise, it can be acted upon by AGC in the IF amplifier without bad effects.

Therefore, provisions are made for delaying the action of the AGC bias on the RF amplifier in most receivers employing keyed AGC systems. The delay circuit includes a connection through a high resistance to B+. When a weak signal is being received, the tuner bias is sharply reduced because of this B+ connection. Included in most delay circuits is a clamper diode which conducts and shorts the AGC line to ground whenever the bias voltage tends to become positive. The circuit in Figure 16 has this delay feature in the RF branch of the AGC line. The components included in the delay circuit are resistors R_1 and R_6, and clamper diode M_1.

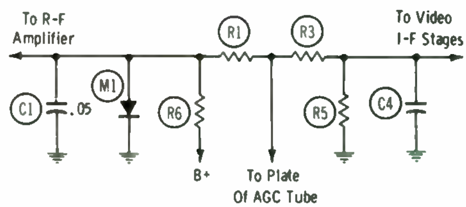


Figure 16 — AGC delay circuit.

As shown in the graph of Figure 17, the delay circuit holds the AGC bias applied to the RF amplifier to about zero until the incoming signal is strong enough to develop −4 volts of bias in the IF section of the AGC line. The RF bias appears at this signal level, increases more rapidly, and eventually becomes greater than the IF bias. When the incoming signal is strongest, the

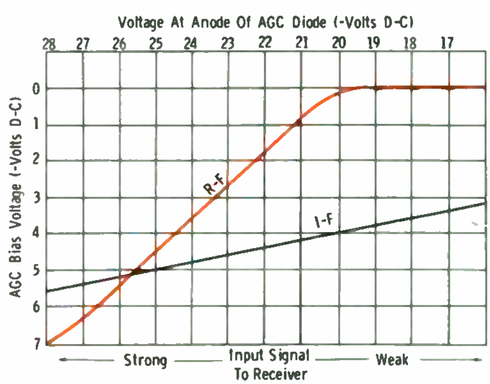


Figure 17 — Graph of the RF and IF bias voltages when an AGC delay circuit is employed.

RF amplifier is biased most heavily, and the signal is promptly reduced before it has a chance to overload any of the IF amplifiers.

HIGH VOLTAGE SYSTEMS

All television receivers must have some type of high voltage power supply. This high voltage power supply must provide a voltage of 10,000 to 30,000 volts for the 2nd anode (accelerating anode) of the television picture tube. The picture tube does not require a large amount of current and this simplifies the design of the components of the high voltage system.

Many different types of high voltage systems have been used in television. The *brute-force* high voltage power supply was used in prewar high voltage systems. It consisted of a 60 Hz step-up transformer, with a rectifier and voltage doubler. Another high voltage system was the RF (Radio Frequency) power supply. The RF power supply used an RF oscillator that produced an RF signal. This RF signal was stepped-up in a transformer and then rectified before being applied to the picture-tube. Neither of these types of high voltage systems are found in modern receivers.

Nearly all modern receivers use the *flyback* type high voltage power supply. The *flyback* method uses the collapsing field of the horizontal deflection yoke, introducing a high voltage pulse into the high voltage transformer, which is rectified, filtered and applied to the picture tube.

FLYBACK HIGH VOLTAGE SYSTEMS

The three tubes used in the high voltage system (Fig. 18) are specially constructed to supply the required voltages and currents. The horizontal output (driver) tube V1 is a pentode designed for high currents and voltage. V3 is the high voltage diode which rectifies the voltage for the picture tube. The damper tube (V2) is a diode which aids V3 in developing the extremely high voltage and in supplying the boosted B+ voltage.

A sawtooth voltage (approximately 70V) from the horizontal oscillator is coupled by C_2 and R_1 to the control grid of V1. V1 will normally use grid leak bias. Cathode bias is developed by C_3 and R_2. This is a protective bias to limit plate current in the event that the input sawtooth voltage is lost.

Plate current of V1 flows from ground through R_2, V1, L_1, L_6, V2, L_2, and L_5 to the B+ supply and back to ground. V2 must be conducting when plate current is flowing in V1 to complete the circuit. Notice that boosted B+ is being used for plate voltage of V1. C_6 blocks the DC component of the deflection amplifier from the deflection coils but passes the 15,750 Hz horizontal deflection frequency.

Horizontal Scanning and Damping

The static or neutral electron beam position is in the center of the *raster*. When V1 conducts, the linear rise in current deflects the electron beam to the right side of the raster. During this time, energy is being stored in the output circuit transformer T_1. (T_1 is made up of L_1, L_2, L_3, and L_4.) When V1 cuts off, the output circuit starts oscillating. The first half-cycle allows a fast flyback from right to left of the electron beam. After retrace has been completed, the next half-cycle is damped by V2, causing the oscillation to decay to zero. The damped current in the deflection coils again starts the beam moving from left to right.

Boosted B+ Voltage

Current flowing through V2 charges the boost capacitor (C_5) to the regular 300V B+. The AC deflection voltage across L_2 makes the plate voltage of V2 100 volts more positive during horizontal trace time. This causes C_5 to charge to 400 volts, the boosted B+ value. C_4 and L_6 form a filter network for the voltage.

High Voltage

The pulse produced in the horizontal output circuit during the first half-cycle of oscillation for the flyback is used to develop the high voltage for the picture tube. This is accomplished by stepping up the AC flyback voltage and supplying it to the plate of the high voltage rectifier (V3).

During retrace, a negative pulse of 1,000 to 2,000 volts is produced in the output circuit and is impressed into the flyback transformer secondary. V2 does not conduct during this pulse. The positive pulse present at the plate of V1 and L_1 is from 3,000 to 6,000 volts due to the step-up action from L_2. L_3 provides a step-up pulse that is from 9,000 to 20,000 volts for the plate of the high voltage rectifier (V3). When the pulse appears on the plate of V3, the tube conducts and charges C_8. Since the frequency is 15,750 Hz, the charging

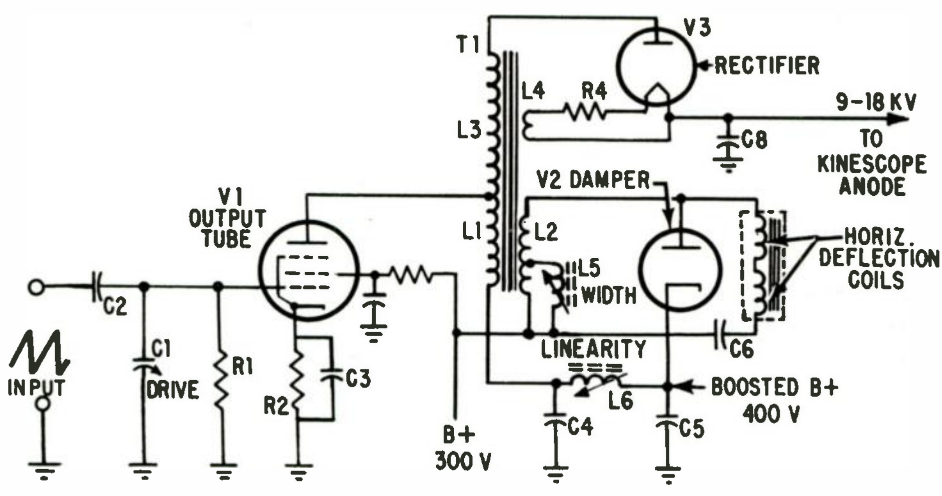


Figure 18 — High voltage power supply and horizontal deflection.

of C_8 is sufficient to provide filtering.

The drive control (C_1) varies the amount of sawtooth voltage present at the grid of V1 by acting like a voltage divider. The width control (L_5) is in parallel with part of the secondary winding L_2. Varying L_5 varies the inductance which will widen the raster.

The amount of boosted B+ voltage varies as C_5 charges and discharges. The operation of the output tube (V1) can be controlled by shifting the phase of the boosted B+ and the sawtooth grid voltage. Adjusting the linearity control (L_6) will affect the stretching of the center portion of the screen.

The adjusting of the horizontal controls has three effects; drive affects the left side, linearity affects the center, and width affects the right side of the screen.

HIGH-VOLTAGE MULTIPLICATION

In the systems previously described, a single rectifier tube was employed to obtain the high voltage required for the picture tube. With solid-state receivers, however, the voltage and current limitations of the rectifying components are such that voltage multiplication is often required in the high voltage circuit. Figure 19 shows a voltage tripler configuration employed in some of the recent transistor television receivers. The majority of solid-state receivers use subminiature tubes such as these in the high voltage rectifier circuit. Filament voltages for the tubes are obtained by induction from the flyback transformer through three separate windings.

In this circuit, tubes V1 and V3 are driven into conduction on the large positive flyback pulses and V2 conducts on the negative swings. The negative swings are coupled to the filament of V2 through capacitor C_2. All three capacitors (C_1, C_2 and C_3) are kept charged at a level that results in a DC output voltage greater than twice the value of the AC input voltage. In some transistor sets, solid-state rectifiers are used in lieu of tubes and the circuit is simplified by the absence of the filament windings.

HORIZONTAL OUTPUT SYSTEM

Television manufacturers publish training manuals for their servicemen. These training manuals provide basic circuit descriptions and alignment information for each individual receiver. The horizontal output system and the circuit description shown in Figure 20 are taken directly from a training manual produced by Montgomery Ward for its service personnel.

The horizontal output stage functions as a controlled switch, operating during the last half of line scan. Drive pulses draw electrons into coupling capacitor CF33 via grid rectifications, resulting in a high negative grid voltage. (This grid voltage is supplemented by the scan regulator system). Thus, the horizontal output system is cut-off about half the time and the other half is being driven very heavily.

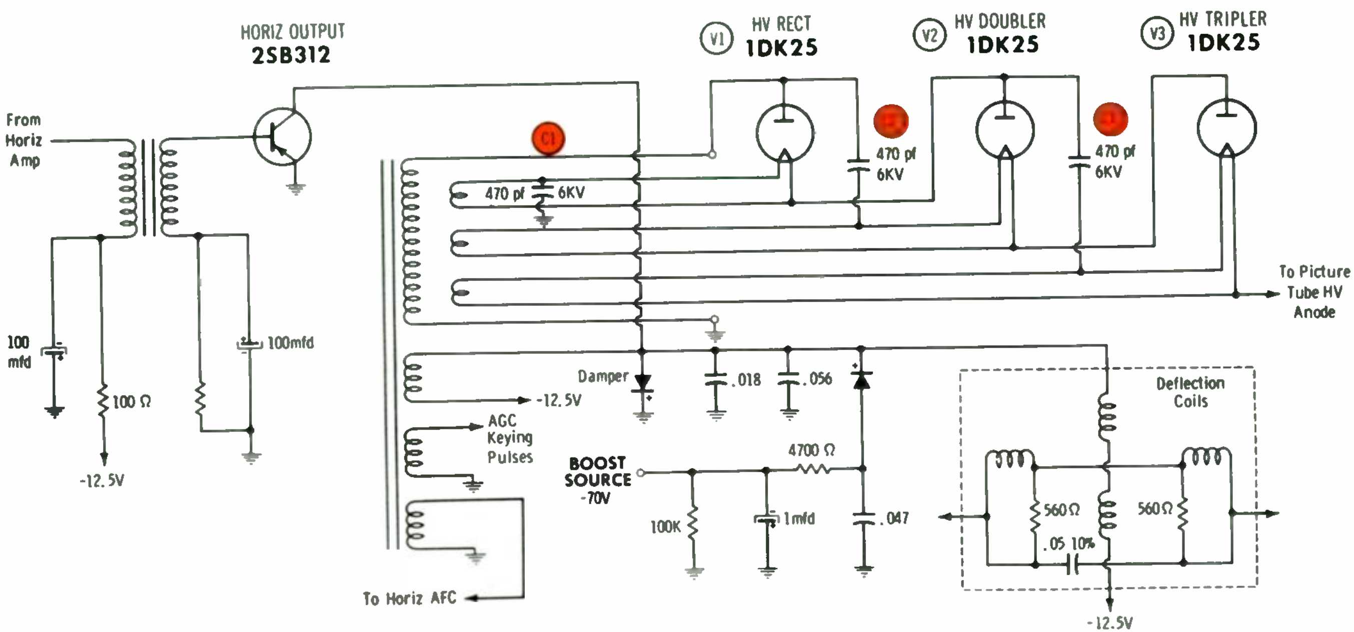


Figure 19 — Example of high-voltage multiplier circuit used in late-model transistor receivers.

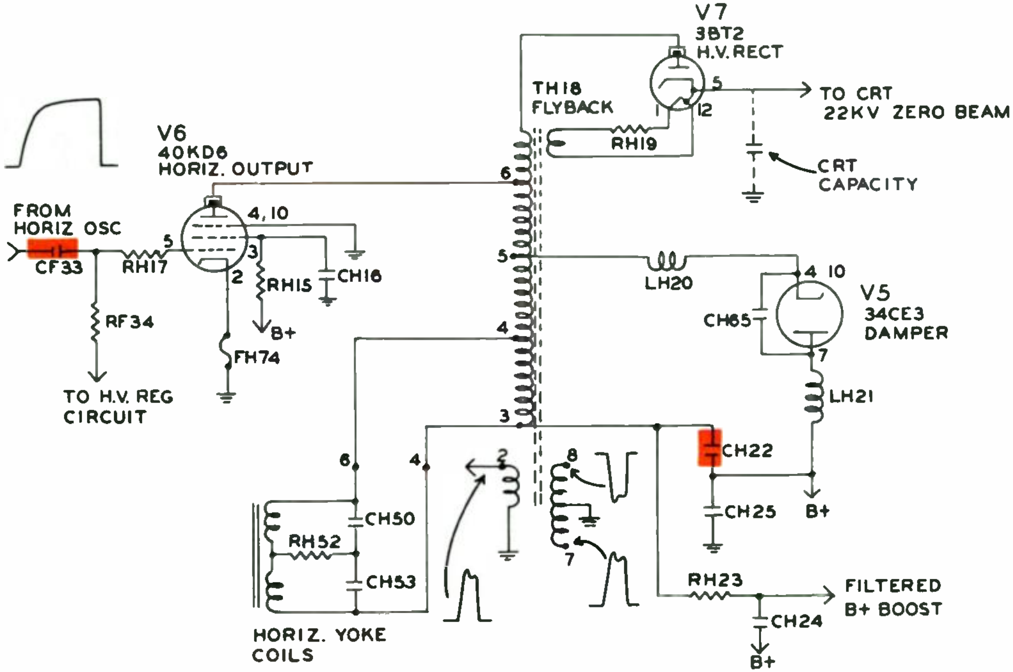


Figure 20 — Horizontal output system. (Courtesy of Montgomery Ward).

When the output tube (V6) conducts, heavy current flows through the flyback windings, primarily from the boost voltage charge stored in CH22. At the end of the line scan, the output tube stops conducting and the flyback coil field will collapse. This collapse provides the flyback pulse. This pulse is stepped up by the high voltage windings and rectified by V7 to become the high voltage for the picture tube. The picture tube internal aluminizing and external dag coating form the filter capacitor for this rectifier. The flyback magnetic field is used to supply filament current to the rectifier. As this collapsing magnetic field swings into its negative half-cycle, the damper tube becomes forward biased and strong damper current flows. At this time the damper take-off point is attempting to become AC ground instead of CH22. Thus, the yoke current will begin to increase in the same direction as when the output tube conducts. The damper will then cause the beam to sweep across the first half of the line. At the same time, CH22 is charging up to the boost level. The dampened flyback field will produce an output which will be added to the B plus. This boost is filtered and used to supply the picture tube screen voltage, the vertical oscillator plate and the vertical output bias. A fuse (FH74) in the horizontal output cathode circuit will open if some malfunction should cause excessive current drain. This fuse is also a convenient means of disabling the horizontal output system. Just take it out. The deflection yoke operates as a parasite and also contributes to the mutual inductance of the system.

SUMMARY

The composite video signal contains the video signal, blanking pulses, and sync pulses. The sync pulses ride on top of the blanking pulses and occupy the top 25% of amplitude deviation of the composite signal. The blanking and sync pulse level are carefully maintained in the receiver. Since the sync pulses occupy a set level they may be separated from the composite video signal by a clipping action. This is accomplished by the sync separator which *clips* the sync pulse off the top of the blanking pulse.

The horizontal and vertical sync pulses are separated from each other by filters. The pulses are then applied to the respective oscillators to maintain synchronization with the transmitter. Because the sync pulse is always of a constant amplitude it may be used as the reference for the automatic gain control. The AGC system maintains the picture signal at a relatively constant amplitude by applying a bias voltage to the RF and IF amplifiers to control their gain.

The high voltage power supply used in modern television receivers is of the *flyback* type. The flyback high voltage system utilizes the horizontal output pulse waveform and steps up this voltage in the flyback transformer. The voltage is then rectified, filtered and applied to the 2nd anode of the CRT. In some television receivers, the capacitance of the CRT is used as a filter for the high voltage. power supply.

TEST

Lesson Number 80

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-080-1.

1. **The horizontal and vertical sync pulses are located in the composite video waveform**
   A. on the sound carrier.
   B. on top of the blanking pulse and they occupy the upper 25% of blanking signal amplitude.
   C. in the lowest portions of the video signal amplitude changes.
   D. on the sound carrier with a period of 63.5 microseconds.

2. **Blanking pulses are combined with the video signal during transmission to**
   A. maintain the correct spacing between each successive video signal.
   B. provide sync pulses to the horizontal and vertical oscillators.
   C. turn on the picture tube in the television receiver, thereby insuring a visual indication of the retrace.
   D. cut off the picture tube in the television receiver during the retrace period.

3. **The horizontal and vertical sync pulses are separated from the composite video waveform in the**
   A. video detector.
   5 B. 4.5 MHz sound trap.
   C. sync separator.
   D. integrator circuit.

4. **The horizontal sync pulses may be separated from the vertical pulses and shaped into the desired waveforms by a/an**
   A. integrator circuit.
   12 B. differentiator circuit.
   C. diode sync separator.
   D. triode sync separator.

5. **The serrated vertical sync pulse may be separated from the horizontal sync pulses and shaped into the desired waveform by**
   13 A. an integrator circuit.
   B. a differentiator circuit.
   C. a diode sync separator.
   D. the high voltage rectifier.

6. The purpose of the automatic gain control is to
A. provide a relatively constant signal to the picture tube of the receiver.
14 B. increase the gain of the video amplifier.
C. control the frequency of the horizontal oscillator.
D. maintain the receiver sound at the relatively constant level.

7. The most complex and efficient form of AGC is *keyed AGC.* The advantage of *keyed AGC* is that
A. unlike other AGC systems the ***keyed AGC*** system increases strong signal intensity and decreases weak signal intensity.
B. the AGC voltage is keyed to occur at the correct time to suppress the video signal in the video amplifier.
C. it is keyed only by the serrated vertical sync pulse which will produce the desired rise in AGC voltage at the vertical rate.
D. noise and video do not affect the production of AGC voltage.

8. The automatic gain control system produces a bias voltage that is applied to the
A. video amplifier.
B. IF amplifier only.
C. horizontal output tube.
D. RF and IF amplifiers.

9. What type of high voltage power supply is used in the modern television receiver?
A. The *brute-force* type high voltage system.
23 B. The *RF oscillator* type high voltage system.
C. The *flyback* type high voltage system.
D. The *regulated-bridge* type high voltage system.

10. In Figure 20 the 22KV high voltage is rectified by tube V7 and then this high DC voltage is filtered by
A. the damper tube V5 which will not allow the high DC voltage to
28 fluctuate from its high positive level.
B. RH23 and CH24.
C. the capacitance that is formed by the internal aluminizing and the external dag coating of the CRT.
D. the combination of LH20, CH65, and LH21.

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"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

PLAYING THE GAME

The trained athlete must submit to the most rigid discipline. He must work many long hours, obey many rules, and deny himself many pleasures; however, he counts these things as nothing when compared with the joy of winning.

It is the same in every phase of life. If we want to be successful men and women, if we want to build a profitable business, have beautiful homes, fine churches, schools, and other organizations, we must obey the rules and play the game.

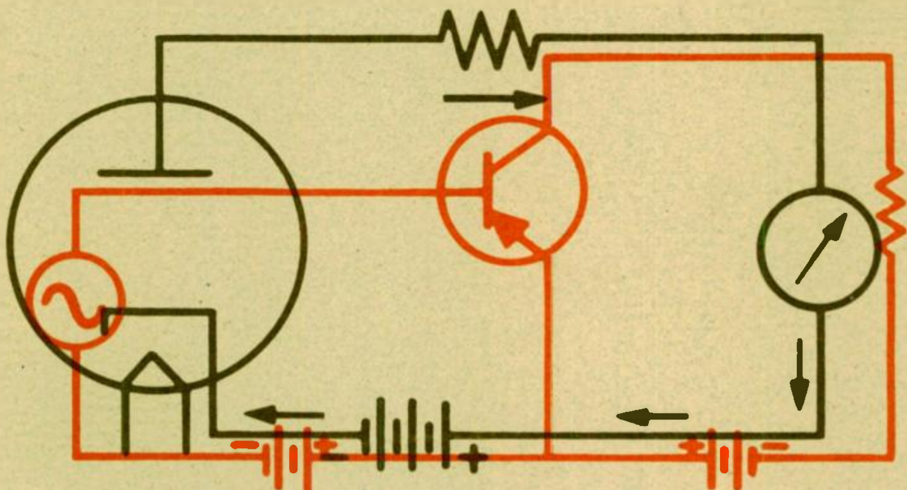
Maybe you do not know all these laws and cannot tell when you are breaking them. But here is a rule that will never fail.

There is a small set of laws which all of us know—the Ten Commandments—and every law that man has made is based on these, plus one more—the Golden Rule. . . . So when you are in doubt, ask yourself this question: Does it come under one of the Ten Laws? If you still are not sure, then ask yourself: Does it come under the Golden Rule? Is it something which I would like to have others do to me? If you will obey these eleven laws, you can be sure you will never disobey, even unknowingly, any of the laws of man.

S. T. Christensen

LESSON NO. 81

RECEIVING ANTENNAS



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-081
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Contents

RECEIVING ANTENNAS

INTRODUCTION

Antennas for the reception of TV and FM signals are designed much more carefully than the design of a long wire antenna used for the reception of AM radio signals. Radio is used here in the sense of receiving only voice and music, just as FM means Hi-Fi, and TV means sight and sound.

It is possible to receive a number of VHF channels on a single antenna, especially in a metropolitan area. As the distance increases from the transmitters to homes in the suburbs, it becomes increasingly important to have good directivity in the antenna together with additional elements to increase the signal pickup. Congested areas also require antenna designs that can eliminate ghosts and other annoying types of interference.

This lesson deals with TV and FM antennas, and the accessories that can be combined with them to insure satisfactory reception. It also describes the master system of signal distribution for multi-family dwellings.

ANTENNA CHARACTERISTICS

Dipole Antenna

A dipole antenna has two elements, or legs, as shown in Figure 1. The typical dipole is center-fed and a half wavelength long. This is the electrical equivalent of a tuned resonant circuit (an open-circuited, quarter-wave) with voltage maximums at the dipole ends, and a current maximum at the center.

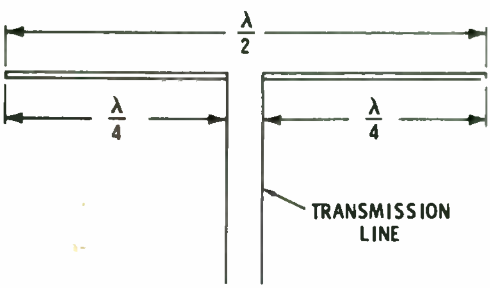


Figure 1 — A dipole antenna.

Antenna "Q"

The Q, or quality, of an antenna is a measure of its sharpness as a tuned resonant circuit. One factor which affects Q is the diameter of the antenna elements. An antenna which has a sharp resonant peak at its operating frequency, such as the thin wave dipole, is said to have a high Q (Fig. 2A). Antennas with a broad resonance curve (Fig. 2B) have a lower Q. It should be noted that a high-Q antenna is not necessarily the best for all purposes. A high-Q antenna will receive one frequency or a narrow band of frequencies quite well. A low-Q antenna will cover a wide range of frequencies equally well.

Antenna Gain

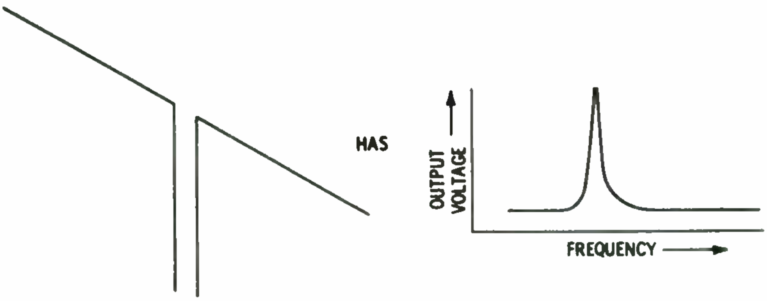
The gain of an antenna is measured by comparing the voltage produced at the terminals of the antenna with that of a thin wire dipole of the same size, operating at the same frequency, in the same location. Antenna gain is normally expressed in decibels (db), since it is essentially a ratio. The equation is the same as for any other voltage ratio:

$$\text{Antenna gain} = 20 \log_{10} \frac{V_1}{V_2}$$

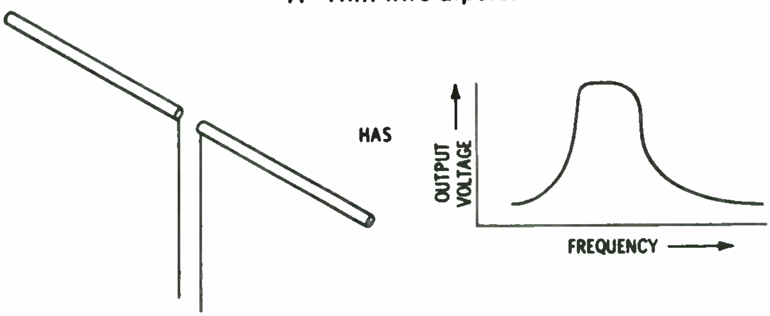
where,

Antenna gain is in decibels,
V_1 is the voltage induced in the unknown antenna, in microvolts,
V_2 is the voltage induced in the reference antenna, in microvolts.

Antenna gain is often shown in a gain curve or gain chart such as Figure 3. Usually, the zero db line indicates the gain of the thin wire dipole to which the antenna is being compared.



A Thin-wire dipole.



B Large diameter dipole.

Figure 2 — Resonance curves of dipole antennas.

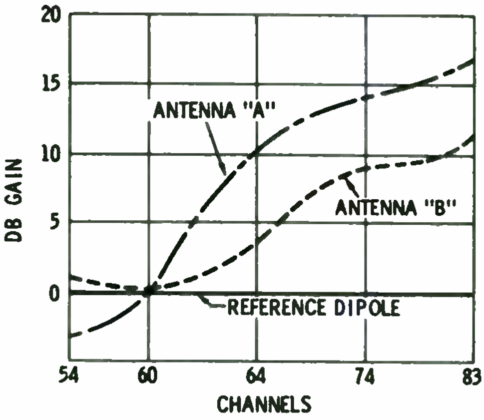


Figure 3 — Typical antenna gain curves.

Antenna Directivity

The directivity of an antenna is a
2 measure of the antenna's ability to receive signals in one direction and reject those from other directions. It is usually shown on horizontal directivity or polar patterns similar to that in Figure 4. On such diagrams the antenna is considered as being at the center of the graph. The patterns surrounding this point show the relative sensitivity or response in any given direction. Theoretically, transmitters of equal power, located at any point on the curves shown, would produce equal voltages in a given antenna. The areas surrounded by the curves are called *lobes.* This term applies to any area where there is a maximum. The largest area is called the *major lobe,* while the other maximums are called *minor lobes.* The areas where there is a minimum response, or no response, are called *nulls.* The directivity pattern of an antenna will, of course, vary with the design. Antenna engineers

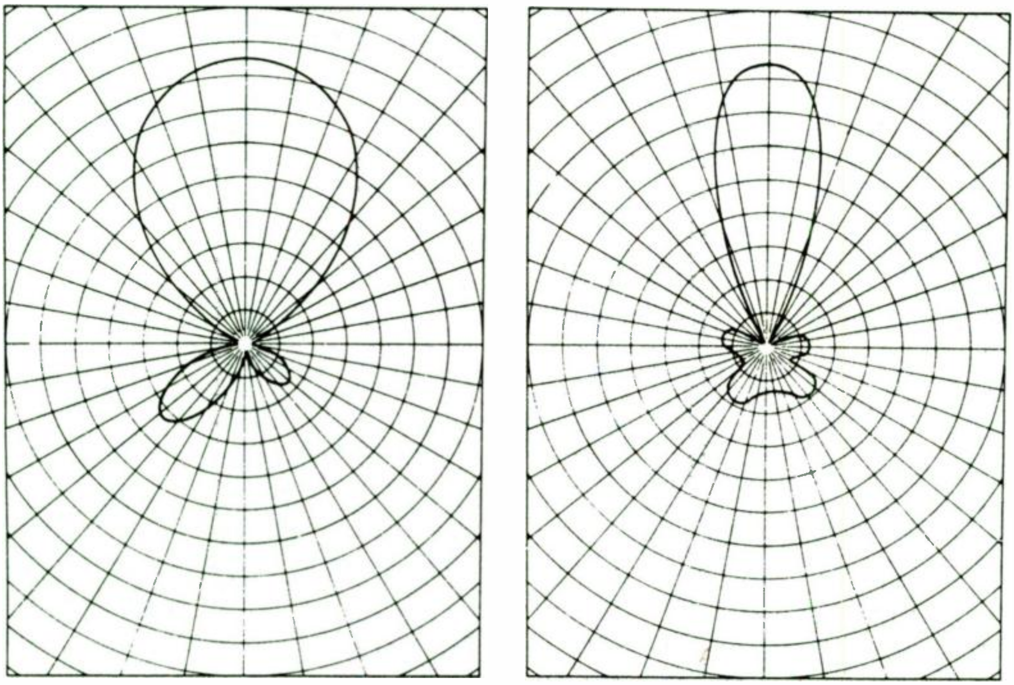


Figure 4 — Antenna directivity patterns.

spend a good part of their time making directivity patterns to show that their particular antenna is more (or less) directive than all other antennas. In general, the more elaborate arrays have a sharper directivity pattern. When studying patterns of directivity on the brochures of TV antenna manufacturers with the idea of making a comparison, here is one point to remember. The directivity pattern of an antenna will vary with frequency, just as does the gain. To use patterns as a basis for comparison, make sure that they apply to the frequency range to be used. Usually, both gain and directivity figures are based on the midpoint of the frequency range to be covered. However, gain curves usually show the variation over the entire band, while directivity patterns assume a single frequency signal has been used to determine the shape of the curve.

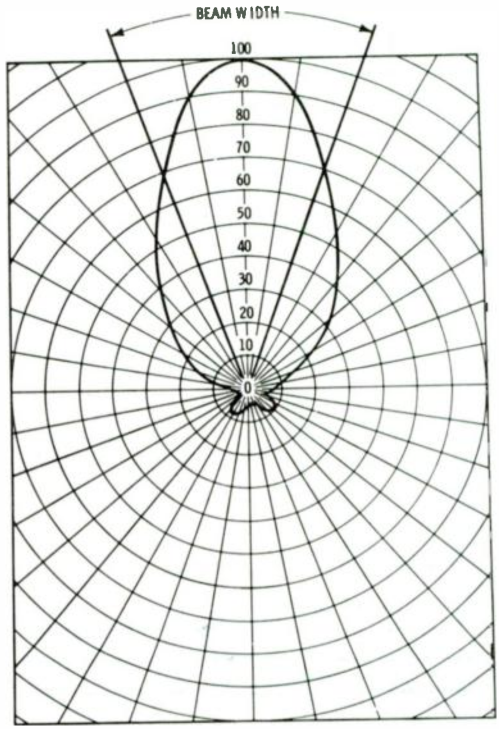


Figure 5 — Antenna beam width.

Antenna Beam Width

The beam width of an antenna is an arbitrary measure of directivity. It is measured on the major lobe of the directivity patterns, and its horizontal limits are arbitrarily set at 70% of the maximum response or sensitivity point, as shown in Figure 5. This corresponds to the practice of measuring the bandwidth of an amplifier or a tuned circuit.

Front-to-back Ratio

The front-to-back ratio of an antenna is also a measure of directivity. It is a means of expressing directivity in terms of ratio, rather than in the graphic terms of a pattern. A front-to-back ratio of 10-to-1 means that the antenna is 10 times as sensitive in one direction as it is in the opposite direction. Front-to-back ratio does not give as good a picture of an antenna's directivity as does a polar diagram, since it cannot show side lobes, minor lobes, etc.

Parasitic Array

A parasitic array is an antenna that has passive or nondriven (parasitic) elements in addition to the driven element. In TV antennas, both reflectors and directors are used in parasitic arrays (Fig. 6). A reflector is cut approximately 5% longer than the driven element

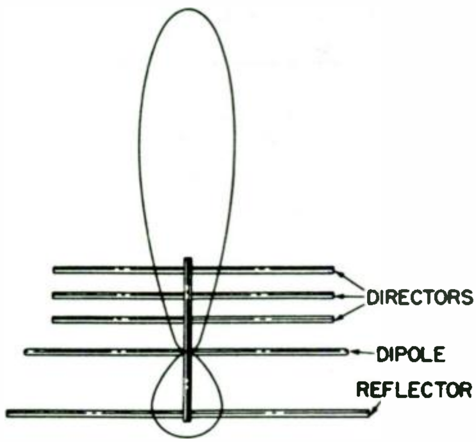


Figure 6 — A parasitic array.

(dipole), and a director is cut approximately 5% shorter. The director is placed on the signal side of the driven element, while the reflector is on the opposite side. The elements are spaced one-tenth to fifteen-hundredths of a full wavelength apart. Some of the longer parasitic arrays may have 13, 16, or even more elements (Fig. 7). All other factors being equal, the more elements an antenna has, the higher the gain and the greater the directivity (the narrower the beam width). This is not to be confused with frequency sharpness or bandwidth. Other factors being equal, the frequency sharpness is dependent on the thickness or diameter of the elements. The smaller diameter elements (thin wire) will have maximum frequency sharpness. The bandwidth, or relative Q, will broaden out as the diameter of the elements increases.

Antenna Impedance

Since an antenna is essentially a resonant circuit, it has an impedance. Most antennas are designed for a 300-ohm impedance to match a 300-ohm line. However, some antennas may have a 72-ohm impedance to match coaxial cable. Although antenna impedance is a problem for designers, it may be of interest to know that the impedance is determined primarily by the spacing between the center feed points of the dipole and by the number of parasitic elements.

Antenna VSWR

The voltage standing wave ratio (VSWR) of an antenna is actually a measure of match or mismatch between the antenna and the transmission line or lead-in. When an antenna and the lead-in are perfectly matched as to impedance, all of the energy, or signal, will be transferred from the antenna to the lead-in (or vice versa in the case of a transmitting antenna), and there will be no loss. This is quite rare in actual practice. If it should occur, it will only be at one specific frequency. At any other frequency, there will be a slight mismatch, and some of the energy will be reflected back into the line. This energy or signal will cancel part of the desired signal. If you could measure the voltage along the line, you would find that there were voltage maximums (where the reflected signal is in phase with the desired signal) and voltage minimums (where the reflected signal is out of phase, partially cancelling the desired signal). These voltage maximums and minimums are called standing waves, and the ratio of the maximum to the minimum is the standing wave ratio. A standing

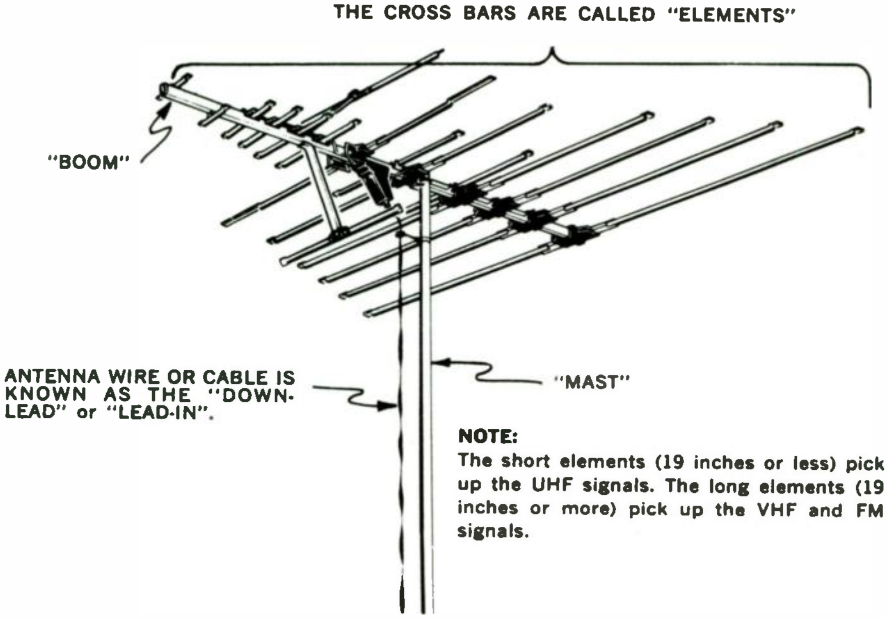


Figure 7 — An antenna for UHF/VHF. (Courtesy of Winegard Co.)

wave ratio of 1:1 means that there are no maximums or minimums (the voltage is constant at any point along the line) and that there is a perfect match between antenna and lead-in. If you have a voltage maximum of 30 volts and a minimum of 10 volts, the VSWR is 1:3 (or 3:1).

The data in Figure 8 shows the relationship of VSWR to db loss in transmission lines and compares the loss of a mismatched line to a perfectly matched line. It should be noted that any transmission line or lead-in will have some loss. The first row of Figure 8 refers to perfectly matched lines whose characteristics (not mismatch) would produce the indicated loss. As the VSWR increases, the loss increases rapidly, provided there is considerable loss incurred in a perfectly matched line. For example, in a properly terminated line whose loss is 1 db, improper termination producing a 3:1 VSWR would result in a loss of 1.5 db.

When the VSWR rating for an antenna is given, it must be related to frequency range and impedance if it is to be of any value. For ex-

VSWR	Loss (db)				
1 to 1	.5	1	2	4	8
2 to 1	.62	1.2	2.3	4.4	8.5
3 to 1	.78	1.5	2.8	5.1	9.3
4 to 1	.98	1.8	3.4	5.6	9.8
5 to 1	1.15	2.2	3.6	6.2	10.5

Figure 8 — Loss caused by standing waves on line.

ample, a UHF antenna rated at a VSWR of 1:1.3 should mean that the VSWR will not be greater than 1:1.3 over the entire UHF range from 470 to 890 MHz, when matched to a 300-ohm impedance line. Unfortunately, some manufacturers advertise a very low standing wave ratio, but they fail to specify that this is for only a very narrow frequency range.

Stacked Antennas

An antenna is said to be stacked when there are two or more driven elements connected together; or when, in effect, two or more antennas are connected together. Each driven element, with its related reflectors and directors, is called a bay. Therefore, four dipoles with reflectors, all connected together to form an antenna, would be called a four-bay stacked antenna.

ANTENNA LOCATION

The exact location of a UHF antenna is much more critical than it is for VHF. Because of the line-of-sight effect, signals may vary greatly between two adjacent locations. Even in a strong UHF signal area, an indoor antenna that gives a good picture at one end of the room may produce nothing but snow when moved to the other end. As the distance from the transmitter increases and the signal gets weaker, it becomes much more difficult to find the best spot for an antenna.

It is almost always desirable to probe for the strongest signal in a given location. Of course, if a good picture is obtained with an indoor antenna setting on top of the TV set, there are no problems. However, this is apt to be an exceptional situation, especially in areas where several UHF stations can be received. Probing is simple indoors. Just attach plenty of lead-in to the antenna and carry it around until a spot is found that gives a good picture without ghosts.

Outdoors there is considerably more work involved. Even with the smaller antennas it is no pleasure to walk around on a roof with the lead-in attempting to trip you at every step. In some areas it may even be desirable to use a field-strength meter with an easily carried antenna to probe for the strongest signal. Knowing the signal strength can be helpful when deciding the type of antenna to use. Remember, sometimes a reflection can be used in areas that are shadowed by buildings. In any case, don't fasten the antenna to the roof until the set has been turned on and it has been verified that an adequate signal is being picked up.

VHF ANTENNA TYPES

The antenna configurations used for the reception of TV channels 2 to 13 have taken many forms. As the VHF channels were the original ones assigned for TV, most of the early design work was concentrated on antennas to receive these frequencies. With the continuing increase in both the number of UHF stations, and an improvement in the quality of the programming, antennas are being designed to receive both VHF and UHF signals.

The use of these antennas, however, is limited to areas where most, if not all, stations are concentrated in one area. This concentration usually occurs in the large cities where the transmitting antennas of all of the stations use a common tower or are all on adjacent buildings.

As the distance between the TV transmitter and the receiving antenna increases, the beam width (Fig. 5) will include more stations within its area of coverage. Even with more directors the beam width will still be wide enough, generally, to include most of the transmitters if they are bunched on buildings in the central business area. An example of how the antennas change in size and complexity are shown in Figure 9. The chart lists the length of each antenna and describes its application, while the illustrations show the increase in the number of elements as the antenna becomes larger.

2 UHF ANTENNA TYPES

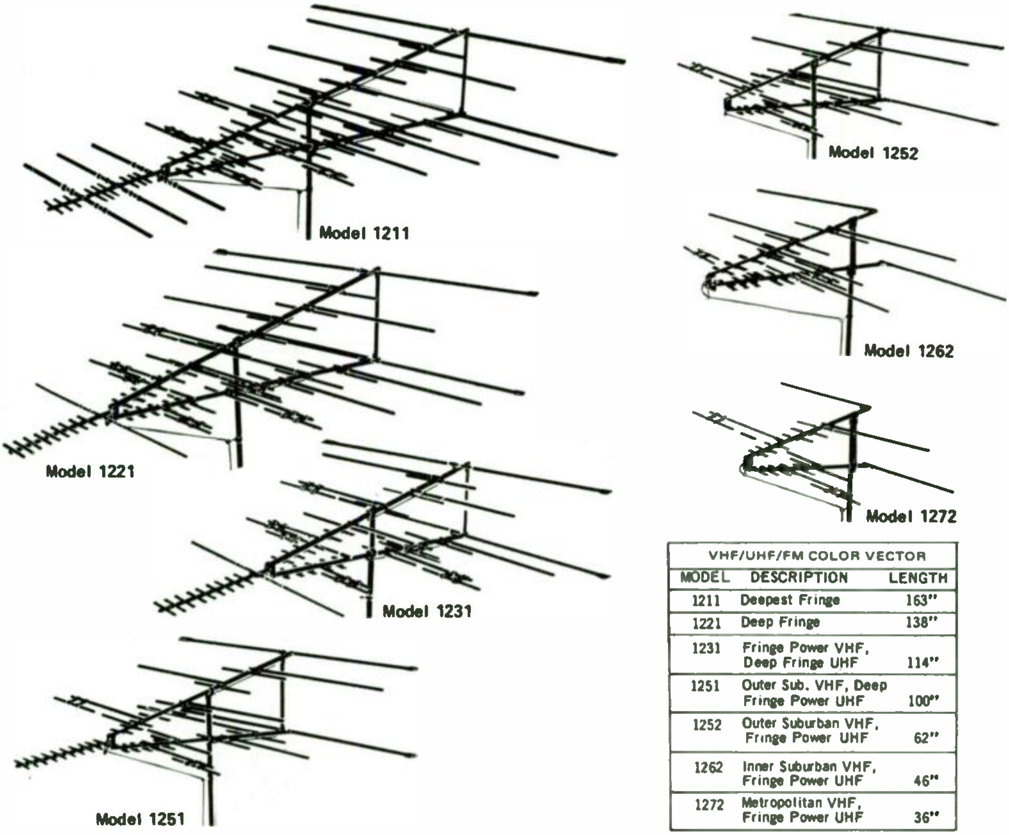
There are many (perhaps too many) types of antennas available for UHF use. Each of these has its own particular advantages and disadvantages. The following paragraphs describe the various types of UHF antennas currently available. It is not the intent to compare the antenna of one manufacturer against that of another or even to compare one type against another. It is obvious that the more elaborate arrays will give better directivity, gain, front-to-back ratio, VSWR, and will probably cost more money. It is also possible that an elaborate array is not necessary for all installations, and is a waste in strong signal areas. As in the case of VHF, there are broad-band antennas (such as the bow tie) which will provide good gain over the entire UHF range. There are narrow-band antennas (such as the Yagi) that will provide excellent gain over a small portion of the band; you can't have both at the same time. Likewise it is possible to have a highly directional antenna that will eliminate ghosts and interference by pinpointing directly on the station antenna. Don't expect this same antenna to pick up two UHF stations equally well though, unless the station antennas are in line with each other from your location.

In short, no antenna will do everything. You must select the antenna to meet the needs of the particular installation. If the signal is strong, any one of a dozen simple antennas (perhaps even an indoor antenna) will bring in a good picture. As the signal gets weaker, you must then use the high-gain antennas, and perhaps even add a booster. If there is a particular ghost or interference problem, the narrow-beam antenna will give the best results. If you are concerned with only one frequency, it is possible that a special antenna will give the best results at that frequency. In any event, here is information to help you select antennas.

Bow-Tie Antennas

The bow-tie antenna, in its various forms, is the most popular broad-band UHF version of the half-wave dipole. The triangular shape of a bow-tie is chosen to pro-

UHF/VHF/FM COLOR VECTORS

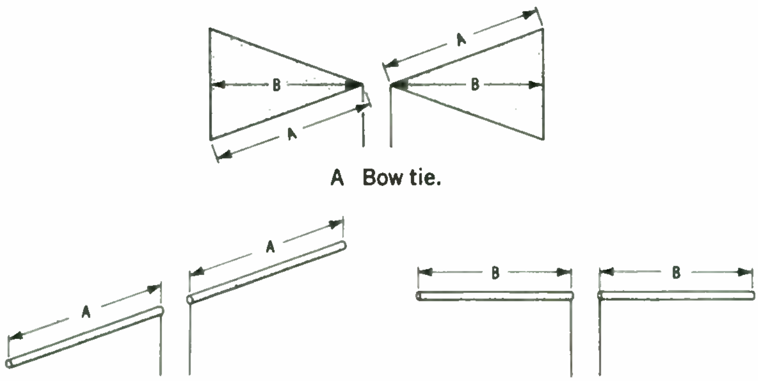


VHF/UHF/FM COLOR VECTOR		
MODEL	DESCRIPTION	LENGTH
1211	Deepest Fringe	163"
1221	Deep Fringe	138"
1231	Fringe Power VHF, Deep Fringe UHF	114"
1251	Outer Sub. VHF, Deep Fringe Power UHF	100"
1252	Outer Suburban VHF, Fringe Power UHF	62"
1262	Inner Suburban VHF, Fringe Power UHF	46"
1272	Metropolitan VHF, Fringe Power UHF	36"

Figure 9 — A series of antennas of the same general design, but constructed of an increasing number of elements for a wide range of distances from the TV transmitters. (Courtesy of Channel Master Corp.)

vide maximum bandwidth. Since the frequency of an antenna is determined by its length, the bow tie is, in effect, several dipoles cut to various lengths. Length A Figure 10A is equivalent to the dipole in Figure 10B, and length B is equivalent to the one in Figure 10C. The bow-tie antenna combines the dipoles of every length between A and B. The dipole at length A is resonant near the low end of the band, while the B length covers the high end of the band. The bow tie offers somewhat more gain at the high end of the band than does a simple dipole. However, the principal use of the bow tie is to give broad-band coverage.

Like other simple dipoles, the horizontal directivity pattern of a bow tie is essentially a figure eight (Fig. 11). As the frequency increases toward the high end of the band, the second harmonic of the low end is approached, since the UHF band is almost 2 to 1 (470 to 890 MHz).

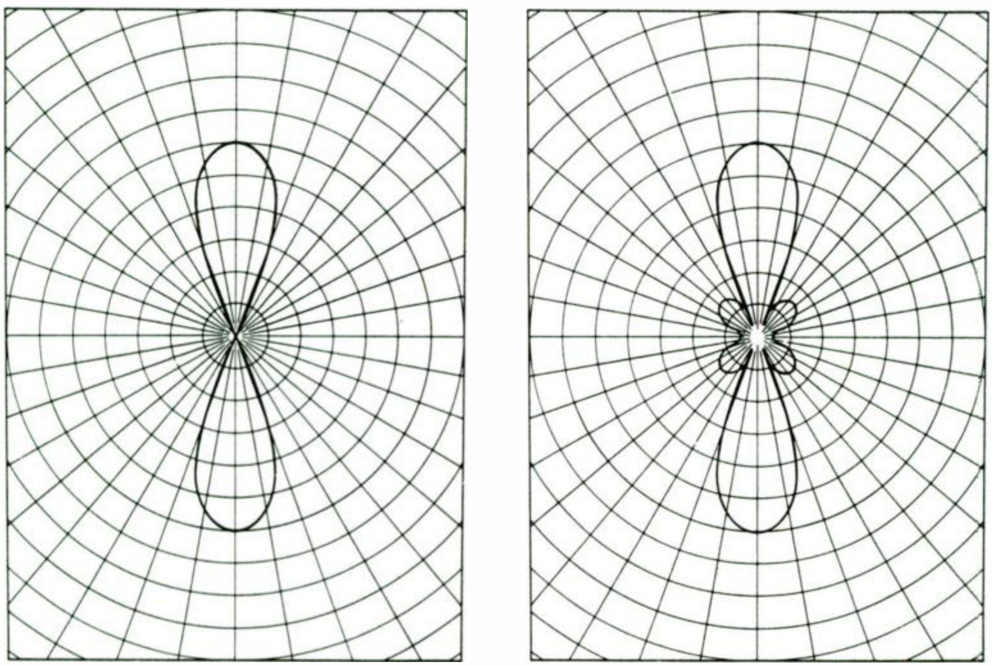


A Bow tie.

B Longest equivalent dipole.

C Shortest equivalent dipole.

Figure 10 — Basic bow-tie antenna.



A Low end of band.

B High end of band.

Figure 11 — Directivity pattern for a dipole antenna.

Under these conditions, additional side lobes appear as shown in Figure 11B. Additional gain will result from stacking bow-tie antennas, either vertically, horizontally, or both. The effect of such stacking is shown in Figure 12. When bow-tie antennas are stacked, their feed points are tied together with bars or rods to a common 300-ohm impedance point. Bow-tie antennas can be made directive, at least to the

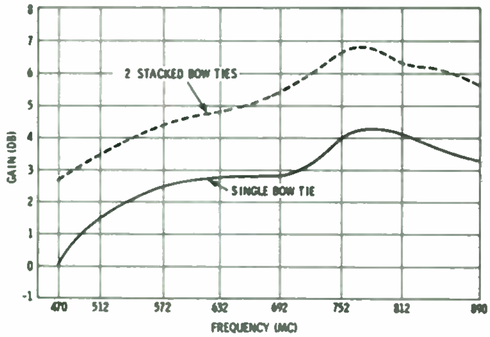


Figure 12 — Gain for single and stacked bow-tie antennas.

point of eliminating the rear lobe, by means of a reflector. The outdoor bow tie in Figure 13 is an 8-bay, stacked array. All of these use screen reflectors behind the bow ties to eliminate the back lobe of the directivity pattern.

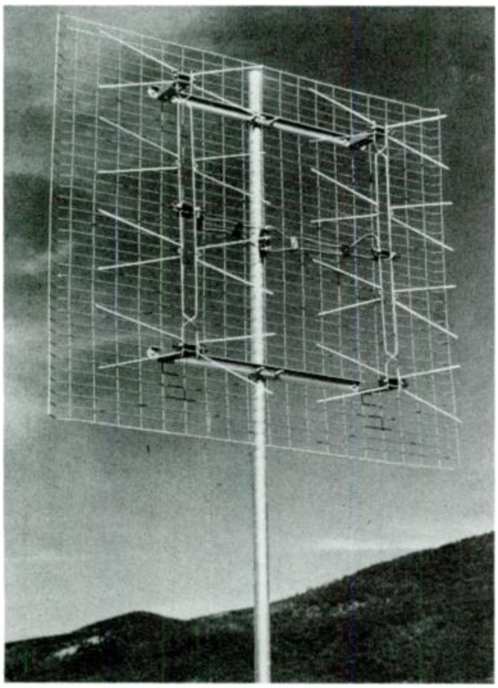


Figure 13 — Outdoor multi-band stacked bow-tie antenna. (Courtesy of Channel Master Corp.)

Corner Reflectors

The corner reflector is basically a bow-tie antenna with a triangular reflector. The effect is to concentrate the signals onto the dipole, since the top part of the reflector deflects the signals down to the dipole, while the bottom part deflects the signals up to the dipole. This provides additional gain over stacked bow ties, as shown in Figure 14. However, the principal reason for the corner reflector is to provide greater directivity than with stacked bow ties. This is desirable where ghosts from multiple reflections make a bow-tie antenna unsatisfactory. As shown in Figure 15, the rear lobes are almost eliminated with a corner reflector. Figures 16 and 17 show two typical corner reflector antennas, one with 12 reflectors and the other with 22.

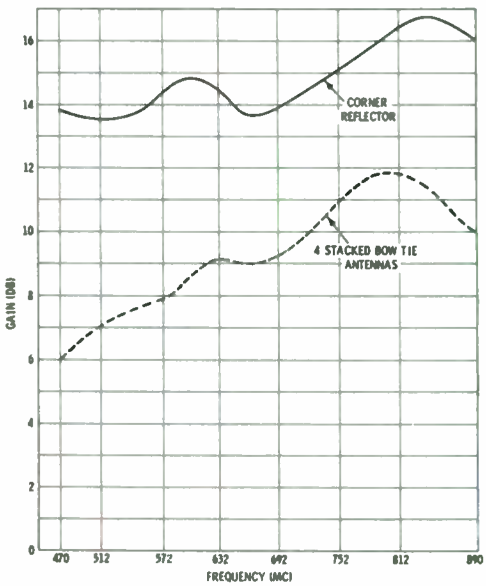


Figure 14 — Gain for bow-tie and corner reflector antennas.

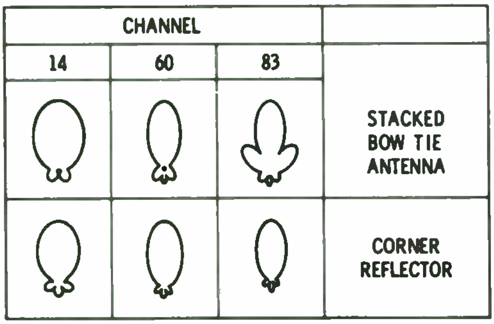


Figure 15 — Directivity patterns for bow-tie and corner reflector antennas.

Parabolic Reflectors

The major function of a parabolic reflector is the same as a corner reflector—to make the antenna more directive than it would be with a flat reflector. Also, the concentration of signals from the curved surface on to the driven element provides more gain than would be possible with a flat reflector. However, this does not necessarily mean that a parabolic reflector with a single driven element will provide more gain than several stacked elements and a flat reflector.

The main advantage of parabolic reflectors is their ability to bring in signals from hot spots. When you are installing UHF antennas, it is often necessary to probe at various heights because of the alternating hot and dead spots, as shown in Figure 18. Such variations in strength are caused by the interaction of signals direct from the transmitter with signals reflected from other antennas, metal gutters, vehicles in the street, etc. However, even though you probe and find a "hot" spot, there is no guarantee that it will remain hot, because

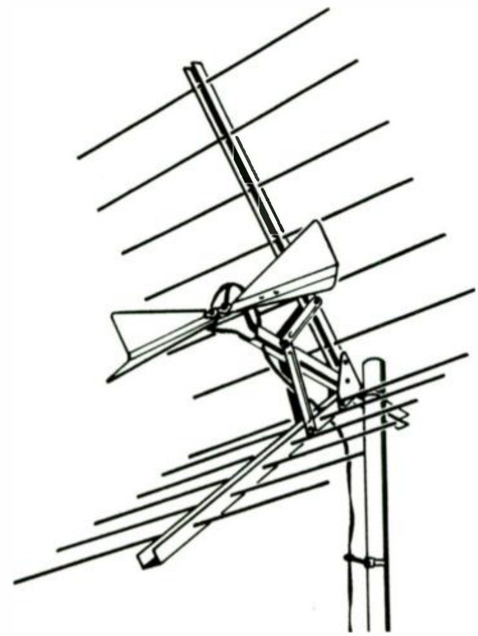


Figure 16 — Corner reflector antenna. (Courtesy of Channel Master Corp.)

Figure 17 — Corner reflector antenna. (Courtesy The Finney Co.)

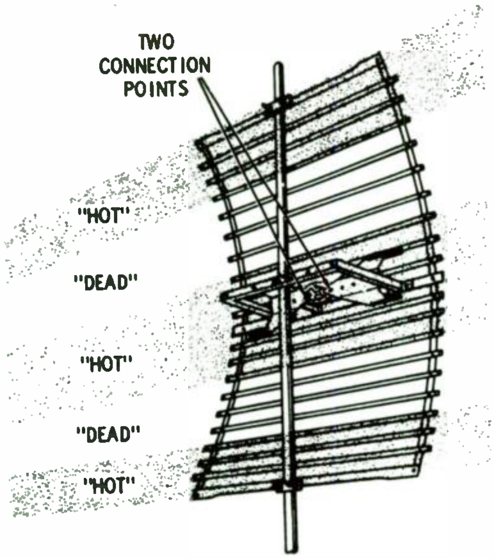


Figure 18 — A parabolic reflector intercepting hot and dead signal areas.

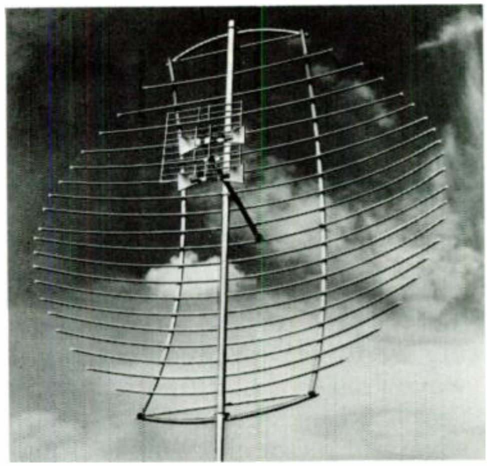


Figure 19 — Parabolic reflector antenna. (Courtesy of Channel Master Corp.)

these good signal spots tend to shift significantly. An antenna that has a small vertical interception area is most vulnerable to these shifts so that UHF antennas such as Yagis, corner reflectors, log periodics, etc., may end up in a dead spot. It should be noted, however, that vertically stacked arrays share this same advantage to some degree as at least one of the driven elements will remain in a hot spot.

Figure 18 shows a parabolic reflector antenna with a special driven element which was designed to give better directivity over a wider range of frequencies. The antenna in Figure 19 has two bow-tie driven elements to provide extra gain. The reflector shown in Figure 20 is not a true parabola. Instead, the reflective elements are adjusted to precise angles so as to give maximum gain. This antenna uses a folded dipole as the driven element.

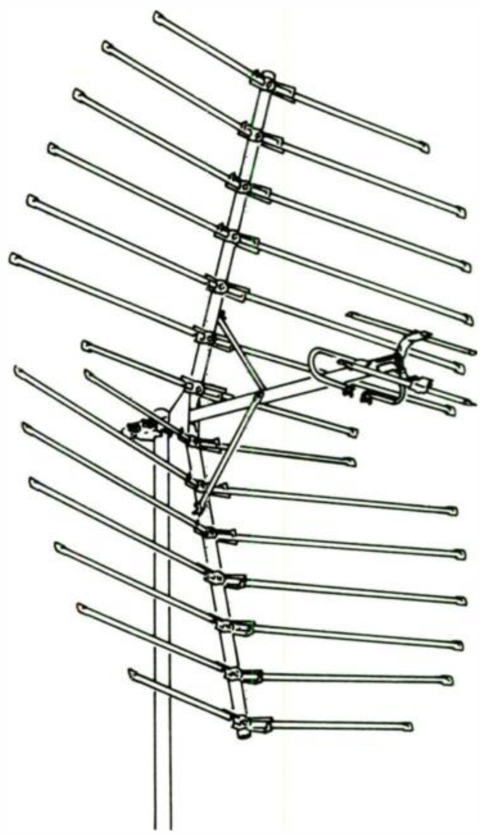


Figure 20 — Parabolic reflector antenna. (Courtesy Winegard Co.)

It should be noted that all three antennas have a screen or shield in front of the driven element. This is to prevent direct signal pickup, which would arrive out of phase with the reflected signal.

Yagi Antennas

The Yagi antenna, in its various forms, is a popular narrowband, highly directive version of the half-wave dipole. The high directivity of the Yagi is obtained by placing several director elements in front of the dipole. These elements are cut shorter than the dipole, but they are all of the same length. Therefore all of the elements resonate at the same frequency, or over a very narrow band, providing high gain at that frequency. Signals coming from directly in front of the elements will have maximum gain since they receive the benefit of all director elements, while signals from either side will have less gain since they receive the benefit of only a few director elements. This accounts for the high directivity. Usually only one reflector is placed behind the dipole to eliminate the rear lobes. Any number of director elements may be used; more elements provide higher directivity and gain.

The narrow frequency response of the Yagi antenna has advantages and disadvantages. Its selectivity and gain are very useful in single-channel areas where reflections produce ghosts that cannot be easily eliminated. If several channels are available, however, a simple Yagi may not be able to receive all of them. Various manufacturers have devised methods to eliminate this problem. The Yagi antenna shown in Figure 21 covers a wider band than usual. This is accomplished by a special dipole which is actually two dipoles of different lengths, capacitively coupled. One set of director elements is cut for the short dipole, while the other set is cut for the longer dipole. This provides two resonant points across the UHF band, thus increasing the overall frequency response.

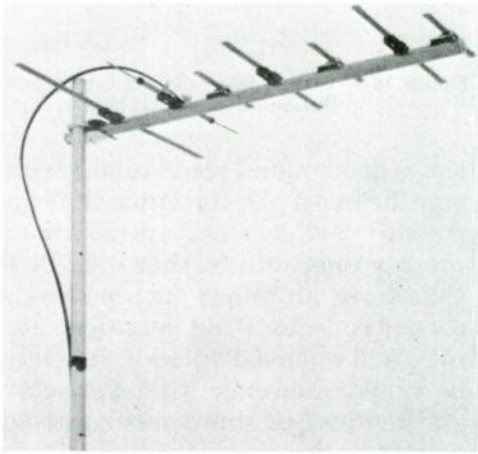


Figure 21 — Broad-band Yagi antenna. (Courtesy Antennacraft Co.)

Another problem with Yagis is that the impedance is lowered as directive elements are added. This condition is compensated by using a high-impedance dipole. The antenna shown in Figure 22 uses a special folded dipole (cut from one piece of aluminum) to increase the impedance. This offsets the lowered impedance caused by the 14 director elements.

Figure 22 — Narrow-band Yagi antenna. (Courtesy Channel Master Corp.).

Most Yagi antennas are vulnerable to the variation in signal strength at different heights as previously mentioned. The antenna shown in Figure 23 is provided with a corner reflector, instead of the usual single reflector element. The corner reflector provides additional vertical interception.

The antenna shown in Figure 24 also uses a vertical reflector to provide additional vertical interception. However, the unique feature of this antenna is its ability to be adjusted to cover any particular

Figure 23 — Yagi antenna with corner reflector. (Courtesy Finney Co.)

channel, or to cover any particular portion of the UHF band. The adjustment is accomplished by manually setting the length of the elements to the desired frequency before installation. The antenna can be re-adjusted to another frequency at some later time if desired. However, the antenna will cover only one frequency, or a narrow band of frequencies, at a time.

LOG PERIODIC ANTENNAS

Log periodic antennas provide high directivity with broad-band coverage. The high directivity is obtained by placing several swept-forward reflector elements behind the dipole. These elements are all cut longer than the dipole, but each is progressively or periodically longer than the next, increasing in a logarithmic progression. Signals directly in line with the dipole will have maximum gain since they receive the benefit of at least one reflector element. This provides the increased directivity. The broad-band coverage occurs since at least one of the reflectors is resonant at any point across the UHF band.

Log periodic antennas are also vulnerable to the vertical interception problem previously described. This can be partially overcome by stacking the antennas as shown in Figure 25. Another solution is shown in Figures 26 and 27. These log periodic antennas are flattened out versions of helical antennas and provide an almost constant frequency response over the entire band. The stacked antenna (Fig. 27) has considerably more gain and consequently will

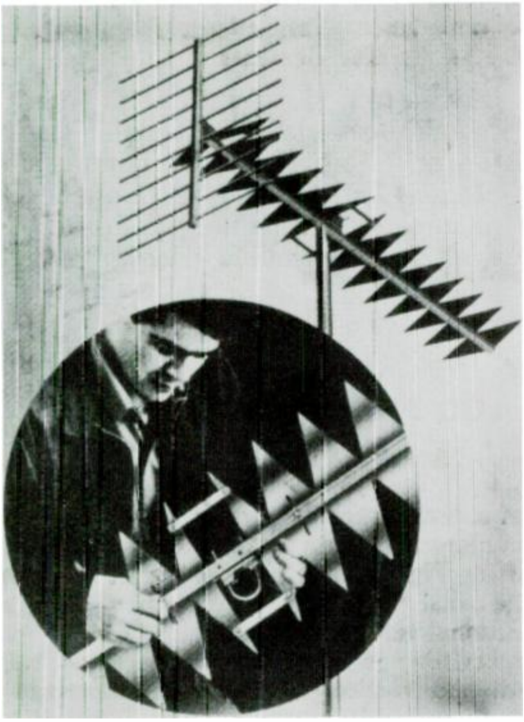


Figure 24 — Adjustable Yagi antenna. (Courtesy Channel Master Corp.)

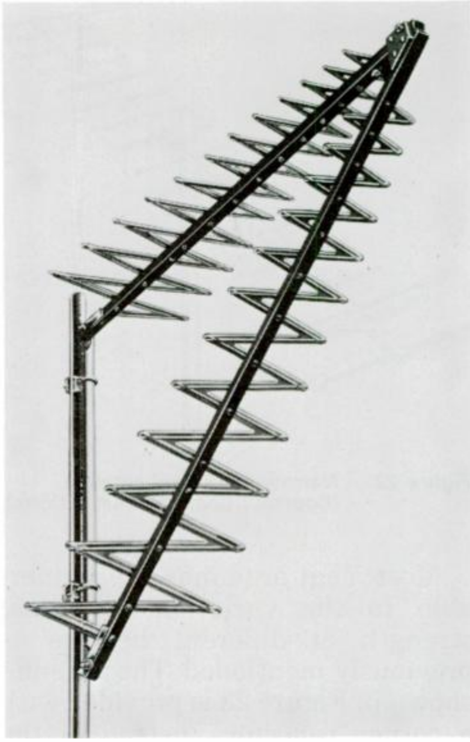


Figure 26 — Planar helical log periodic antenna. (Courtesy J F D Electronics Corporation)

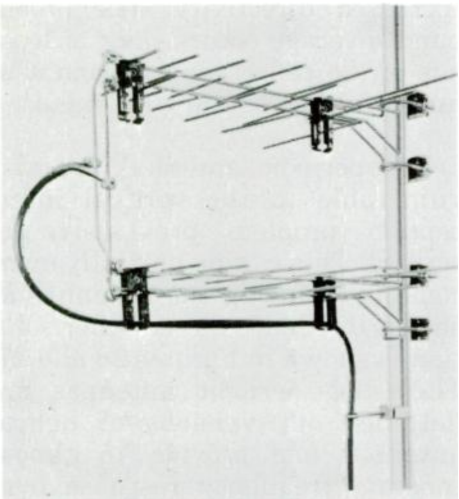


Figure 25 — Stacked log periodic antenna. (Courtesy Blonder-Tongue Labs., Inc.)

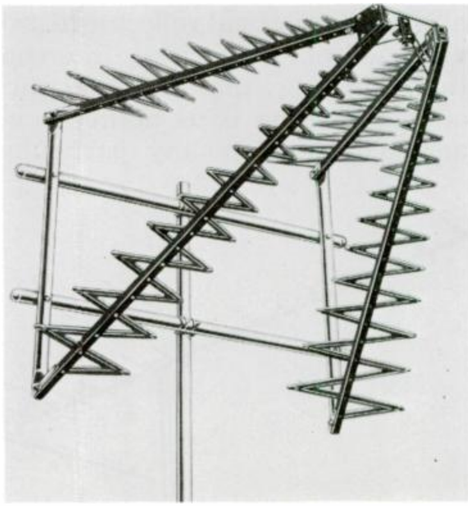


Figure 27 — Stacked planar helical log periodic antenna. (Courtesy J F D Electronics Corporation)

pull in more distant stations. Figures 28 and 29 show conventional log periodic antennas for outdoor installation. Again, the more elaborate antenna is able to obtain a better picture in weaker signal areas.

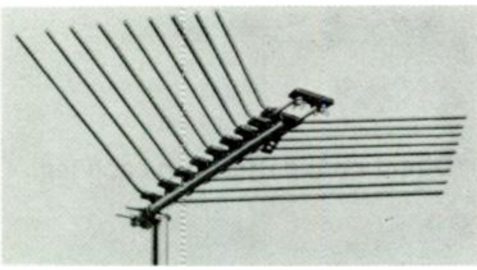


Figure 28 — Log periodic antenna with 9 cells. (Courtesy J F D Electronics Corporation)

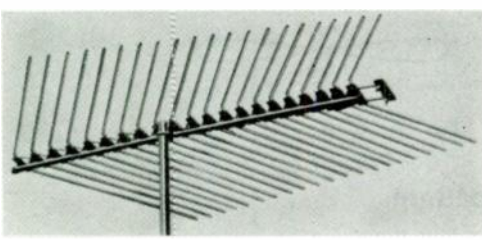


Figure 29 — Log periodic antenna with 21 cells. (Courtesy J F D Electronics Corporation)

LONG WIRE ANTENNAS

Long wire antennas, such as the "V" (Fig. 30A) and the rhombic (Fig. 30B) make use of the fact that the directional pattern of an antenna changes from a figure eight to a four-lobe pattern (Fig. 30C) when the antenna is made more than one wavelength long. Also, the four-lobe patterns can be added to provide high gain, when the full wavelengths are connected together to form a "V" or rhombic antenna. This results in a high-gain two-lobe pattern (Fig. 30D) and provides broad-band coverage. When such long wire antennas are combined with a reflector, one of the lobes is removed, resulting in a fairly directional antenna.

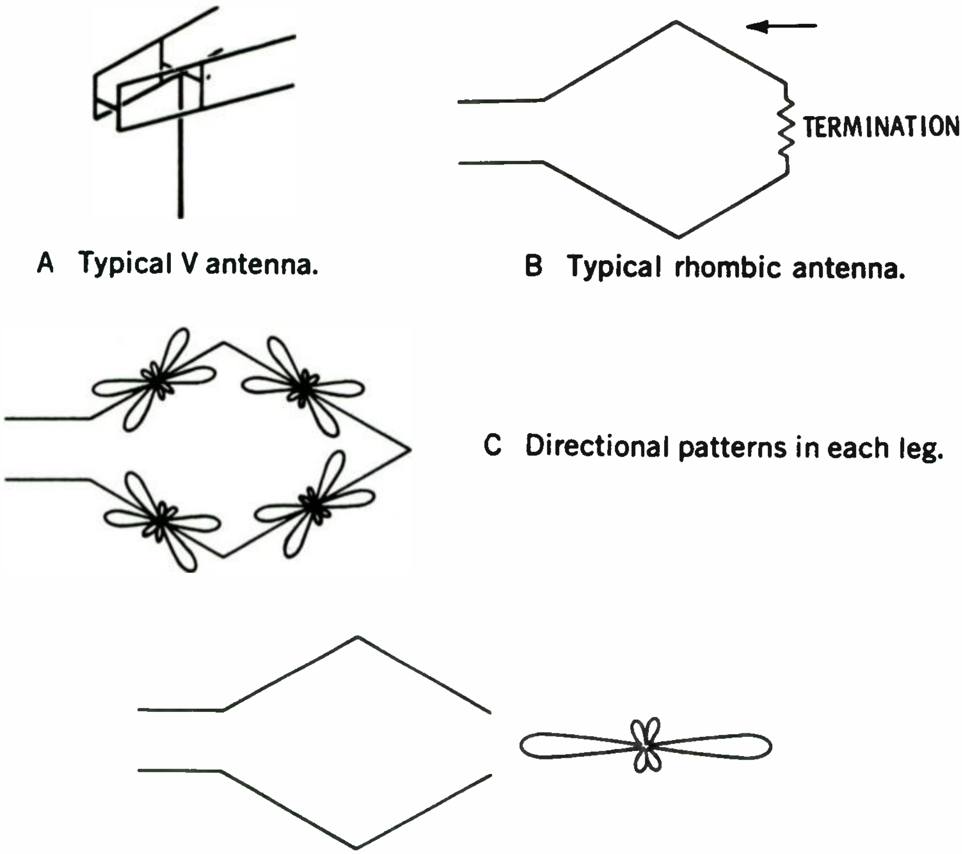
Two versions of a long wire antenna are shown in Figure 31. These antennas use a single continuous wire on each side for the driven elements (instead of a dipole), backed by a multi-resonant reflector element for each section. The gain is high because of the vertical length of the array. This also minimizes the vertical interception problem. Continuous wire is used for the driven elements to eliminate the possibility of failure due to the interconnections of separately connected elements.

INTERMIXED ANTENNAS

As the use of UHF increases, the number of intermixed antennas that will cover VHF, UHF, and FM, is also increasing. These intermixed antennas may be in any of the usual forms. Figures 32 and 33 show two typical intermixed antennas.

TRANSMISSION LINES

To a TV serviceman accustomed to working with VHF, transmission line, or lead-in, is simply the 300-ohm twin-lead. Unless he has encountered unusual service problems, there has been no occasion to use anything else. For UHF the basic lead-in remains 300-ohm line. However, the unusual situations occur more frequently, especially in



A Typical V antenna.

B Typical rhombic antenna.

C Directional patterns in each leg.

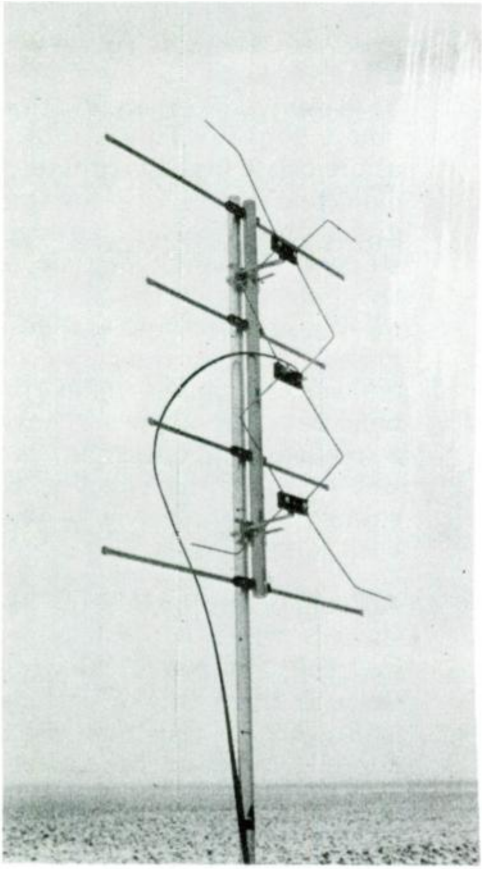
D Resultant pattern.

Figure 30 — Rhombic and V antennas.

weak signal areas, making it desirable for the serviceman to be familiar with all possible types of transmission lines and their distinctive features.

Transmission Line (Lead-in)

A transmission line (lead-in) is any device that will conduct electrical energy from a source to a load. The term lead-in is usually applied to a conductor between the antenna and a receiver, while transmission line usually means the line between a transmitter and antenna. Since the same types of wire are used in both applications, the terms are actually interchangeable. In UHF TV, two wires are required since the antennas are dipoles. Two basic types of lead-in are parallel-wire lines and coaxial lines. To break it down further, parallel-wire lines can be of the open-wire type where there is no material between the conductors except widely separated spacers.



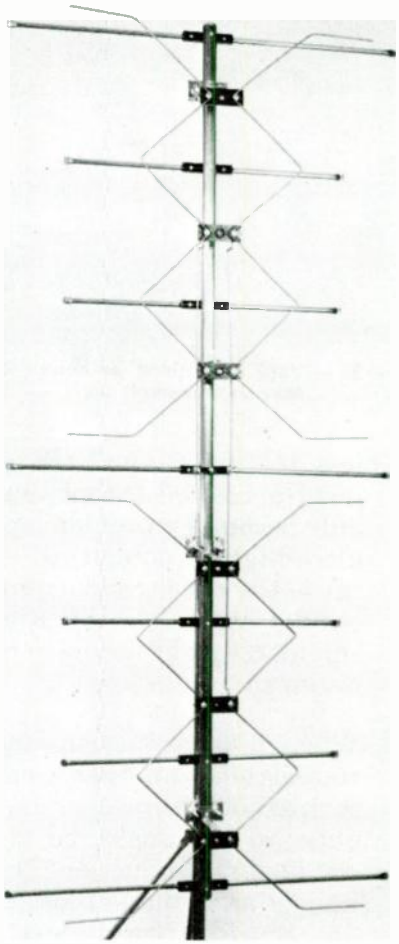


Figure 31 — Long-wire antennas. (Courtesy Antennacraft Co.)

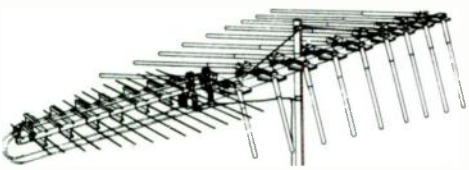


Figure 32 — Log periodic intermixed antenna. (Courtesy The Finney Company)

More likely it will be flat ribbon (twin-lead) or possibly tubular line. Coaxial lines are those where a center conductor is completely surrounded by the outer conductor, which also serves as a shield.

Line Losses

All transmission lines have some losses. That is, part of the energy or signal will be lost in the transfer from the source to the load. There are four basic reasons for such losses.

1. Since a transmission line is carrying an RF signal, a portion of that signal is radiated outward from the line (Fig. 34). This is known as radiation

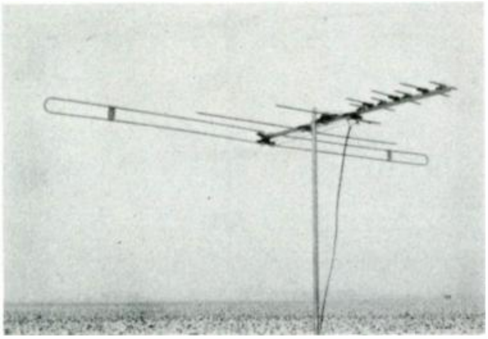


Figure 33 — Yagi intermixed antenna. (Courtesy Antennacraft Co.)

loss. It is present on VHF lead-in to a limited extent, but it only becomes a problem at the ultra-high frequencies. Because the outer conductor of a coaxial line also serves as a shield, coaxial lines have minimum radiation loss.

2. When a transmission line is routed near another conductor, part of the energy radiated outward is transferred to the conductor by induction. This is known as induction loss (Fig. 35). Since induction loss is a result of radiation, it will be at a minimum when coaxial lines are used.

3. The insulating material between the two transmission wires forms a dielectric which acts as a high resistance shunt. A portion of the energy or signal is lost across this shunt (Fig. 36). This is known as dielectric loss. Fortunately, dielectric losses are not too great under normal circumstances. Although dry air is the dielectric which offers the most resistance (and the least losses), moist air is a very poor dielectric. Likewise, flat-ribbon lines normally would have a low loss, but when they are wet or dirty the effect is to change the dielectric to one with higher losses.

4. All conductors have some resistance which will cause loss in the currents flowing through them (Fig. 37). This is known as resistance loss. For UHF lead-in, the DC resistance loss is very small. However, because of skin effect, the RF resistance losses can be quite large. Skin effect results from the fact that RF currents tend to travel on the

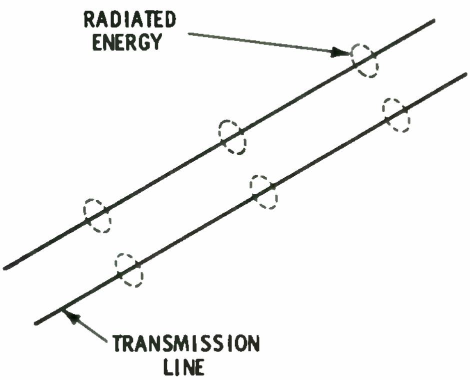


Figure 34 — Radiation loss in transmission lines.

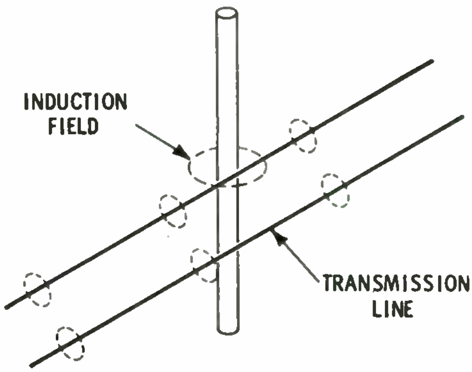


Figure 35 — Induction loss in transmission lines.

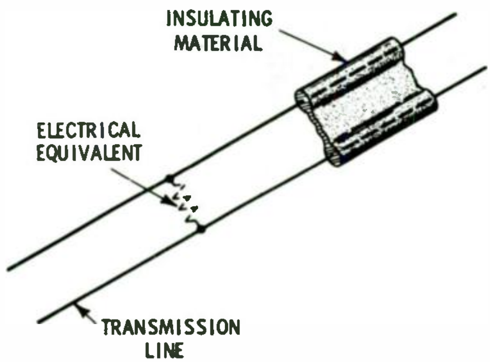


Figure 36 — Dielectric loss in transmission lines.

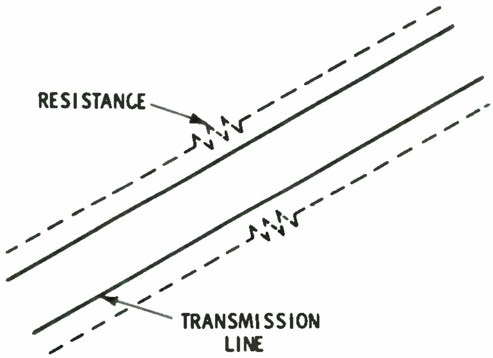


Figure 37 — Resistance loss in transmission lines.

surface of conductors rather than through the entire conductor. Since resistance is dependent on the cross-sectional area through which the current passes (smaller area, higher resistance), the RF resistance of a given conductor can be considerably higher than the DC resistance. As the frequency of the RF currents increases, the skin effect becomes more pronounced. Actually, the resistance of a hollow tube and a solid conductor, both of the same diameter, is about the same at high radio frequencies. Hollow tubes are used for many UHF circuit applications, but they are not practical for lead-ins. Because of skin effect, many UHF circuits are silver-plated. RF currents traveling on the outer surface meet less resistance since silver is a much better conductor than copper. Skin effect is measured in terms of skin depth or penetration depth, which is the thickness of the material that is actually carrying RF currents. As the frequency increases, depth decreases, and resistance increases. RF resistance varies directly with the square root of frequency. Thus, the RF resistance will double when the lead-in used for VHF at 200 MHz is used for UHF at 800 MHz.

Line Attenuation

The combination of the four types of line losses results in a net attenuation of the signal. This is usually expressed in db per 100 feet or in percentage of efficiency. Figure 38 shows the relationship between attenuation in decibels and efficiency in percent. Obviously, attenuation increases with length. To be of real value, however, the attenuation factor of a lead-in should be related to the entire frequency range used, as well as the surrounding conditions. For example, a lead-in may be advertised as having a 1db loss per 100 feet. This should mean that the loss will not exceed 1 db per 100 feet over the entire UHF range, under the worst possible conditions —wet, iced over, etc. Be sure to read the fine print to see if it really does.

Efficiency (percent)	Attenuation	Efficiency (percent)	Attenuation	Efficiency (percent)	Attenuation
93	0.1	78	0.8	22	6.0
90	0.2	76	0.9	18	7.0
89	0.3	74	1.0	15	8.0
87	0.4	60	2.0	12	9.0
85	0.5	47	3.0	9	10.0
83	0.6	35	4.0	1	20.0
80	0.7	30	5.0		

Figure 38 — Line attenuation versus efficiency

Line Impedance

5 Since a transmission line has inductance (in each lead), capacitance (between the leads), and resistance (in each lead and across the dielectric), it has a characteristic impedance which takes into account all of these (Fig. 39). This impedance is dependent on a number of factors the most important of which are: spacing between conductors, diameter of conductors, and type of dielectric. This impedance is present in a transmission line, with or without a load. In practical terms, the impedance of most flat-ribbon lines is 300 ohms, while the impedance of most TV coaxial lines is 75 ohms. The open wire line used in the early days of UHF had an impedance of about 450 ohms, but now it is manufactured with an impedance near 300 ohms. The actual impedance of a line is not as important as the impedance match with the antenna and the receiver input. Most antennas and receivers are now designed to be used with 300-ohm transmission lines. However, other values are sometimes used that may require matching transformers or baluns, which are discussed later.

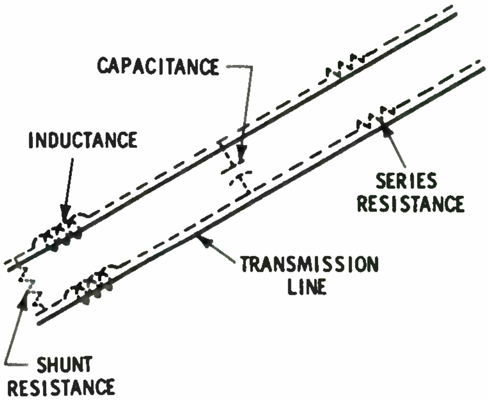


Figure 39 — Factors in transmission-line impedance.

Line Velocity

Radio waves traveling through a transmission line are slowed down by the line. The ratio of radio-wave velocity through a transmission line to the velocity through open air is the velocity constant. This is usually expressed as a percentage of the free-space velocity. As shown in Figure 40, the velocity constant varies with the type of transmission line. Since velocity is affected by transmission lines, wavelength is also affected. For example, if the velocity constant is .70 (70%), the wavelength of any given frequency

Type of Line	Velocity Constant	Type of Line	Velocity Constant
Open Wire Line	.975	Twin-Lead, 300 ohm	.85
RG-58/U	.66	Twin-Lead, 150 ohm	.77
RG-59/U	.66	Twin-Lead, 75 ohm	.68

Figure 40 — Transmission-line characteristics.

on such a transmission line is 70% of the free-space wavelength. This is why *resonant* transmission lines and antennas are usually cut shorter in length than the free-space wavelength.

TYPES OF TRANSMISSION LINES

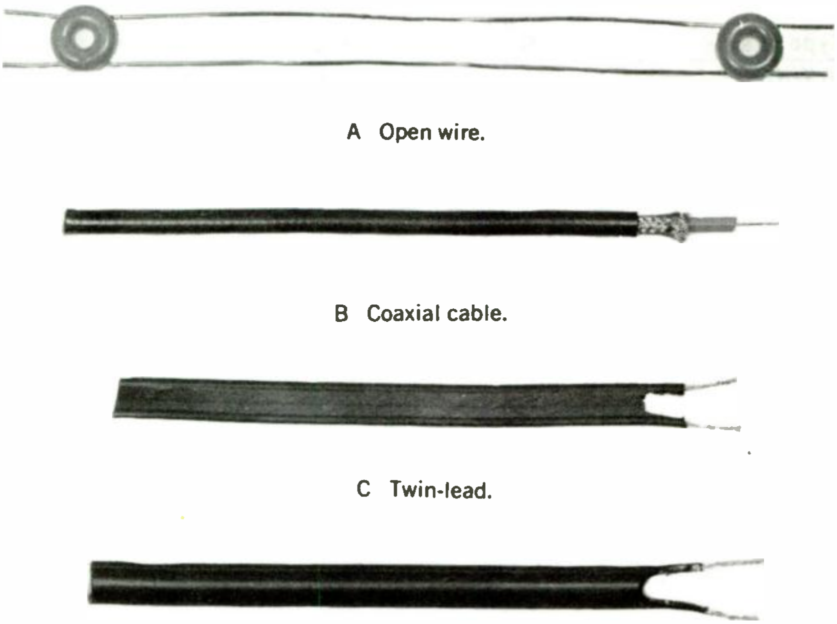
There are four basic types of transmission lines (or lead-ins) available for TV use, each with its own particular advantages and disadvantages. The following information is included to help the technician in making his selection. Before you become alarmed with the idea that you must make a detailed analysis of transmission lines before you can install a UHF antenna, it will be reassuring to know that the great majority of UHF antennas currently use the same basic 300 - ohm flat ribbon used in VHF installation!

Open Wire Line

The open-wire line (Fig. 41A) has the least loss, because air is used as the dielectric. The two conductors are separated at intervals by polyethylene spacers that vary in shape between manufacturers. There is little chance for dirt or moisture to build up across the open leads, so an open-wire line is a good choice for very long runs where losses must be kept to a minimum. However, open wire is difficult to install, and it deteriorates from exposure to the elements faster than other types of line. It is available with a nominal impedance of 300 ohms (½″ spacing between conductors) or 450 ohms (1″ spacing).

Coaxial Line

Because of its shielding, coaxial line (Fig. 41B) is the best bet where there are radiation problems, or where exposure to the elements is a problem. This cable consists of an inner conductor embedded in polyethylene which serves as the dielectric. This is enclosed in a copper braided shield and a vinyl jacket for weather and abrasion protection. Coaxial line is virtually unaffected by moisture and dirt outside the line. Also, nearby conductors will not absorb energy from the line, nor will interference signals enter the line. Coaxial line is fairly simple to install, but it does require a hole at the feed-through point. (Flat ribbon line can usually be slipped under a window.) Coaxial-line impedances are 50 or 75 ohms, which does not match the normal antenna impedance of 300 ohms,



A Open wire.

B Coaxial cable.

C Twin-lead.

D Tubular.

Figure 41 — Types of transmission line.

so a matching transformer is required. A matching transformer is also needed when you are connecting a 75-ohm line to a 300-ohm input on the TV set.

Flat Ribbon Line

As in the case of VHF, the flat ribbon line or twin-lead (Fig. 41C) is the most popular lead-in. One of the reasons for this is that it can usually be routed into the house without drilling holes. Its impedance is normally 300 ohms so it will match most antennas. Also available is a narrower 72-ohm twin lead. In addition to the conventional flat ribbon, twin-lead is available in a punched or slotted ribbon where a large percentage of the insulating material between the leads has been removed. This reduces losses, as long as the line is kept dry and clean. Dirt or moisture can accumulate in the slots or holes, however, making the losses almost as bad as with conventional ribbon line. In another version of the ribbon line a polyethylene covering or sheath is placed over the line. This keeps the line protected from the elements, so it shows considerably lower losses than other twin-lead when the lines are wet. No matter which type of flat ribbon line is used, it should be twisted a full turn every 3 to 4 feet. The voltages from any unwanted interfering signals (like auto ignition signals), will be induced in equal amounts in both conductors, and will be balanced out.

Tubular Line

One of the best all-weather lead-ins is the tubular line (Fig. 41D) which was designed to keep losses down when the lead-in is wet, or covered with dirt and snow. As shown in Figure 42, the energy fields between the two conductors of a transmission line are essentially circular. These energy fields are outside the insulation with conventional flat line. When moisture is present, it acts as a high-resistance shunt between the conductors causing additional losses. On tubular line, the moisture remains outside the field of energy. The exposed end of tubular line must be sealed against moisture when it is installed. This is accomplished by heating the end of the line and pinching the tubular sides together with pliers. If desired, the line can be sealed with a plug. Usually the manufacturers recommend that a small hole be punched at the bottom of the drip loop to remove moisture that may accumulate inside the hollow tubular line. Tubular line has a drawback as a fairly large hole must be drilled at the feed-through point into the house. Except for this one point, tubular lines are probably the most satisfactory for general TV use.

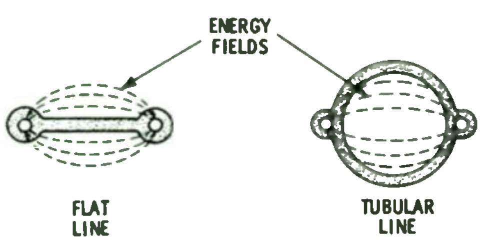


Figure 42 — Cross sections of flat and tubular line.

Line Loss Comparisons

Figure 43 shows a comparison of wet and dry line losses for various types of lead-in operating at a fixed frequency near the center of the UHF range. Note how much higher the losses are for the flat line when it is wet. In some areas this may not matter at all, but in others it can make the difference between a picture and no picture in bad weather (when watching TV is likely to be most popular).

INSTALLATION

When working with VHF the service man does not normally have to be concerned with losses of signal strength in the lead-ins. If there is an adequate signal at the antenna, reasonable care when installing the lead-in will get that signal to the set.

At ultrahigh frequencies the situation becomes more critical. It is as though the UHF signal tries to be elusive, taking every opportunity to get lost. Therefore, much more care has to be taken to eliminate or reduce all possible sources of loss. This starts at the antenna itself. The nominal impedance of the antenna and the transmission line must be the same, or a matching transformer must be used. This should not be a problem since most antennas are designed for 300-ohm line which most servicemen favor. However, if open wire or coaxial cable is used for lead-in due to special circumstances, impedance matching at the antenna and the set will not be automatic—it will have to be planned. Antennas are

Type of Line	Loss (db) Dry	Wet	Type of Line	Loss (db) Dry	Wet
Flat (not punched or slotted)	3.5	20	Flat (Sheathed)	3	6
Open Wire	2	4	Coaxial (RG-11/U)	5	5
Flat (Slotted)	3	10	Tubular	3	7

Figure 43 — Transmission-line losses.

available to match 75-ohm coaxial line, and using one of these may be advantageous.

Special care must be taken in routing the lead-in. This wire should be as short as possible and in a single piece. Avoid sharp bends in the lead-in and stay away from metal objects. Standoff insulators should be installed carefully to guide the lead-in over gutters and to maintain a uniform distance from the side of the house. If the standoffs have a metal ring that circles the lead-in, don't squeeze the ring all the way shut. A closed ring would look like a transformer with a shorted secondary, to the UHF signals, and losses would go up rapidly. Use as few standoff insulators as possible. Figure 44 summarizes the correct techniques.

RECEPTION AIDS

There are a number of accessories and reception aids available for television reception. These include amplifiers (or boosters), antenna couplers, splitters, matching transformers, and antenna rotators.

These units are designed for long life, and they require a minimum of service. However, it is essential that anyone going into the TV service field has a working knowledge of where and how such units are used. Servicemen are in a very favorable position to recommend reception aids to their customers. To take full advantage of this position, they need to be well informed. Reception aids can be divided into two major classifications: passive accessories, which include couplers, splitters, and matching transfomers; and active accessories, which include amplifiers, boosters, and combination couplers and amplifiers. Each of these will be discussed in turn.

Couplers and Splitters

The terms coupler and splitter are used interchangeably, although technically a coupler is used to join two or more sets to one antenna, while a splitter is used to combine the signals from two or more antennas so that they can use a single lead-in. The term coupler usually means joining two units of the same type or frequency, while splitter implies separation of two different frequencies, or bands.

Splitters are usually a combination of a low-pass filter and a high-pass filter contained in a single unit. For example, assume that a VHF antenna and a UHF antenna must be mounted together or near each other, and there is no room for

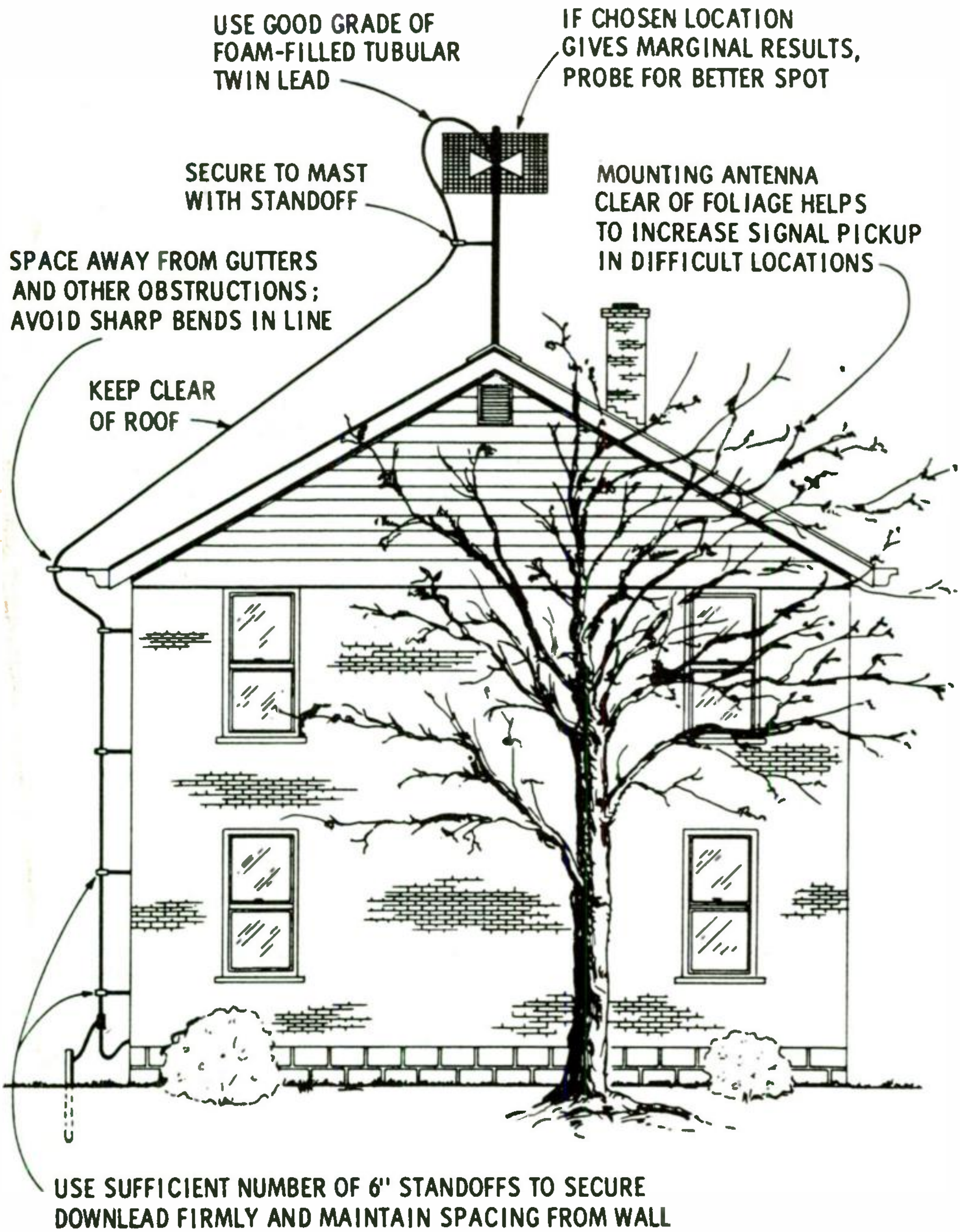


Figure 44 — Installation of a UHF antenna.

separate lead-ins. A splitter can be connected to the two antennas and to the lead-in. A second splitter can be connected between the lead-in and the UHF/VHF terminals. Such a splitter is shown in Figure 45 and a typical schematic is shown in Figure 46. With such an arrangement, high-pass filters are connected to the UHF antenna and to the UHF terminals on the set, while low-pass filters are connected to the VHF antenna and the terminals. UHF signals go through the high-pass filters to the lead-in from the UHF antenna and from the lead-in to the UHF terminals, but they are blocked from the VHF antenna and antenna terminals by the low-pass filters. VHF signals are passed by the low-pass filters, but they are blocked by the high-pass filters.

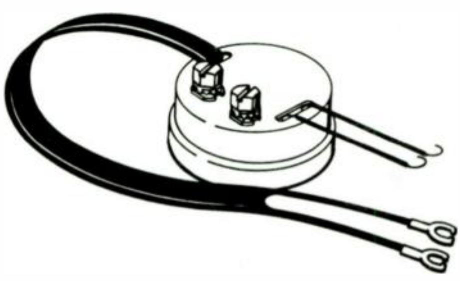


Figure 45 — A coupler or splitter. (Courtesy Winegard Co.)

Instead of being designed to pass (or reject) an entire band of frequencies, some splitters pass one specific frequency or channel through one set of terminals and all other channels through another set of terminals. In this case, a separate splitter must be used for each specific channel. Such splitters

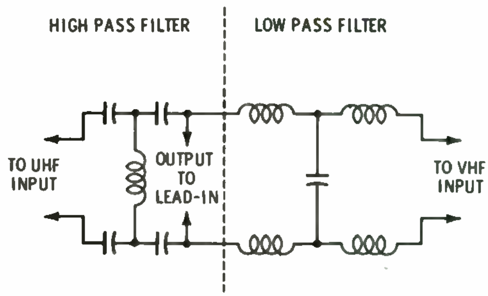


Figure 46 — Typical UHF/VHF splitter schematic

consist of a passband filter and a channel trap (sometimes known as a stopband filter). The channel trap permits the specific channel to pass, while rejecting all other channels. The passband filter permits a wide range of frequencies to pass. Some specific examples of how such a coupling system can be used to solve specific UHF antenna installation problems follow.

In Figure 47 two single-channel antennas (21 and 32) are coupled to a single transmission line by a channel 21 splitter. The channel 21 antenna is connected to a channel 21 trap in the splitter that allows only the one channel to pass through to the TV set. The channel 32 antenna is connected to a passband filter in the splitter. This type of splitter requires that the two TV stations be at least five channels apart.

A single-channel antenna (channel 34) and a broad-band UHF antenna are shown in Figure 48, coupled to a single lead-in. In this case, satisfactory reception using a single broad-band antenna was possible from all stations but one available in the area. For that one

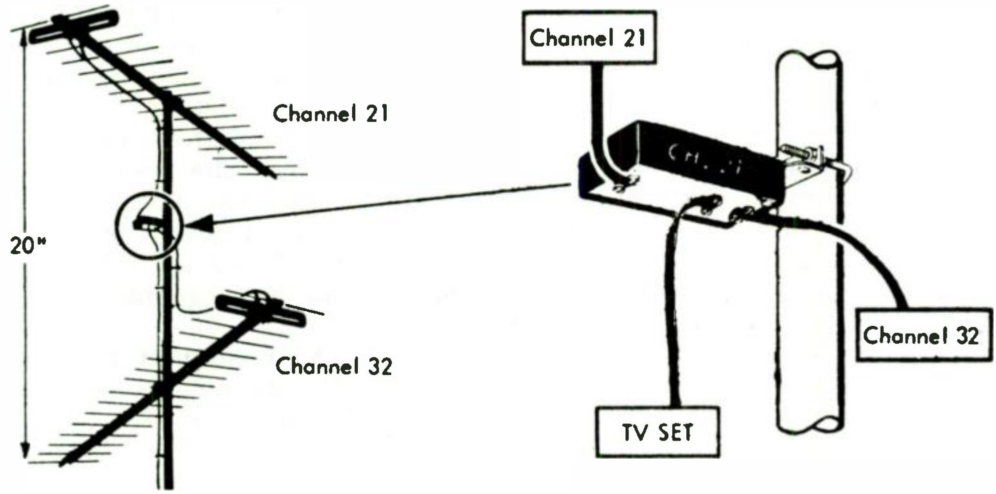


Figure 47 — Coupling two single-channel antennas. (Courtesy Channel Master Corp.)

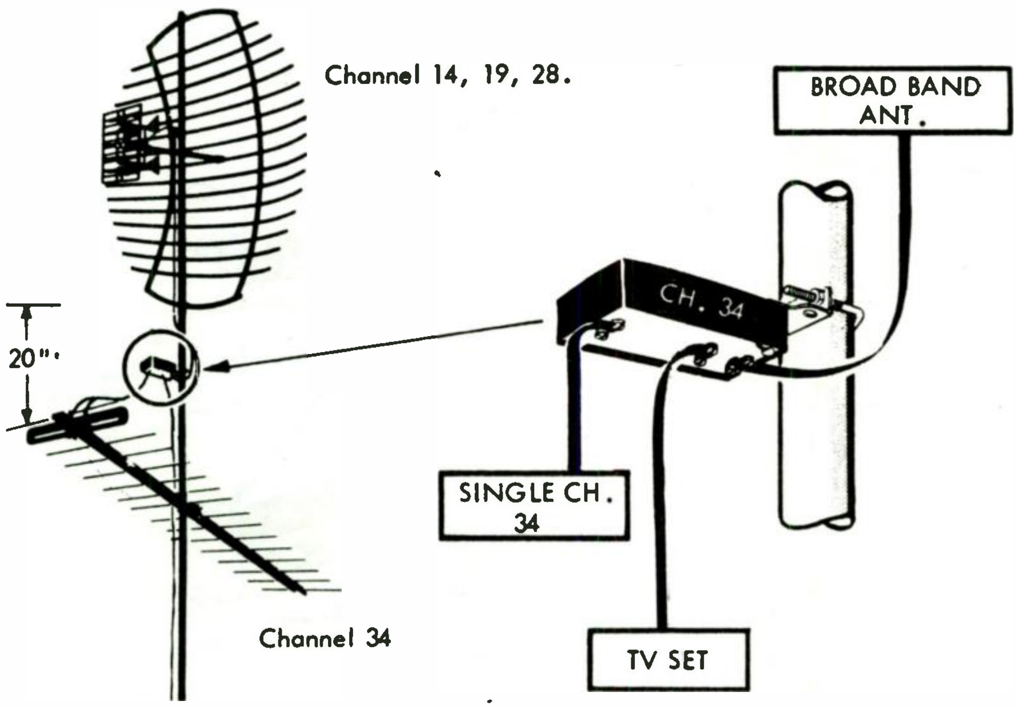


Figure 48 — Coupling broadband and single-channel antennas. (Courtesy Channel Master Corp.)

station a high-gain Yagi antenna is used. A splitter is incorporated so that a single lead-in would give a good performance.

Three single-channel antennas are required in the situation represented by Figure 49. In this case two channel-selective splitters are necessary to prevent interaction between the three antennas.

Notice how the directional nature of the antennas enters into the arrangement shown in Figure 50. A broad-band antenna pointed in one direction is able to pick up a majority of stations available in that area. In order to receive the other two channels, however, high-gain antennas cut to the specific channels are required. Each splitter has a wave trap tuned to a specific channel and a passband filter.

In Figure 51 a two-bay antenna and a single-channel antenna are coupled to a single lead-in by using a splitter. The relative strength of the signals from the antennas is not important. The splitter effectively isolates the antennas and prevents signal loss that might have been caused by interaction between the two antennas.

When a VHF antenna is included with UHF antennas, as in Figure 52, a different type of splitter is required. A channel 19 splitter connects the two UHF antennas, and then a UHF/VHF splitter adds the VHF antenna to the system. Some means of dividing the signals at the TV set may be necessary since they will go to separate tuners.

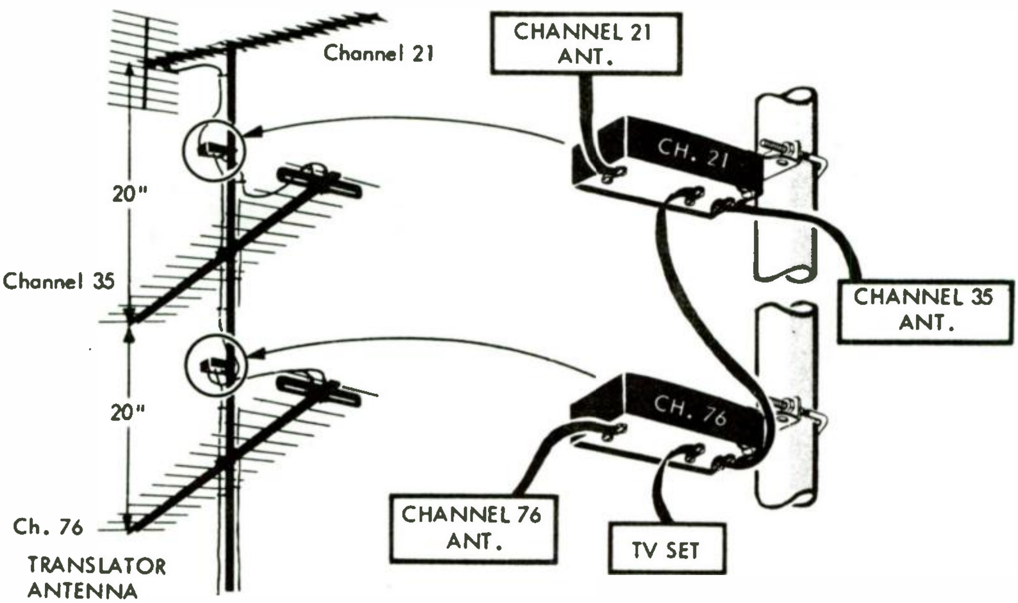


Figure 49 — Coupling three single-band antennas. (Courtesy Channel Master Corp.)

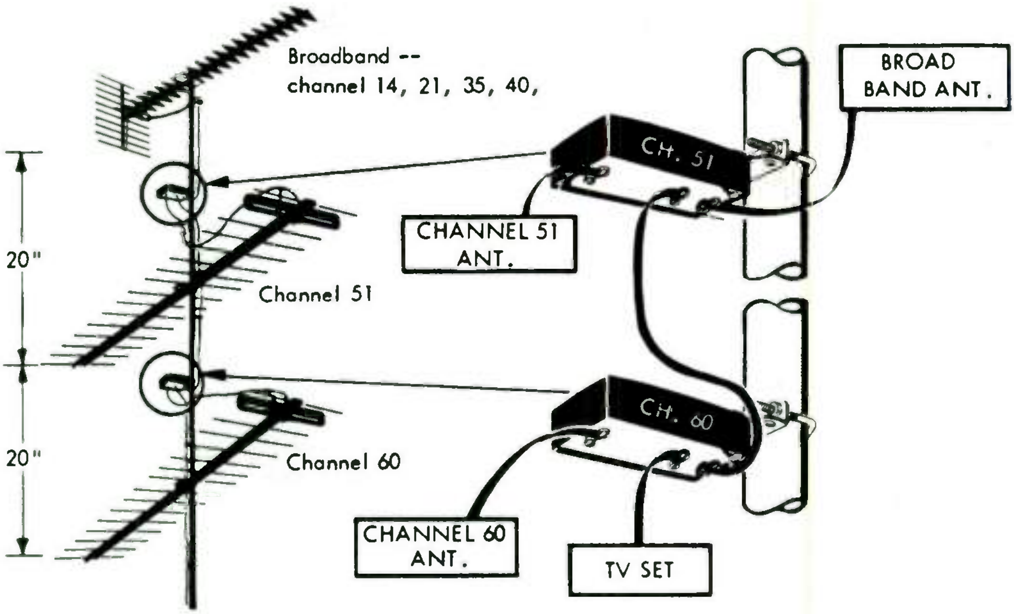


Figure 50 — Coupling one broadband and two single-channel antennas. (Courtesy Channel Master Corp.)

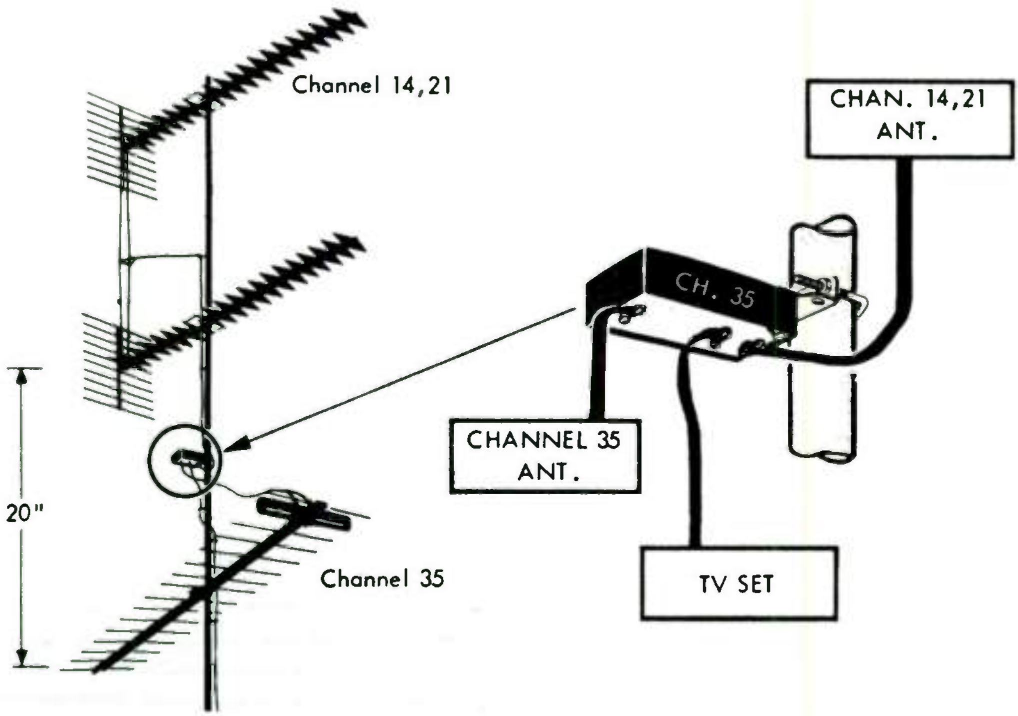


Figure 51 — Coupling stacked and single-channel antennas. (Courtesy Channel Master Corp.)

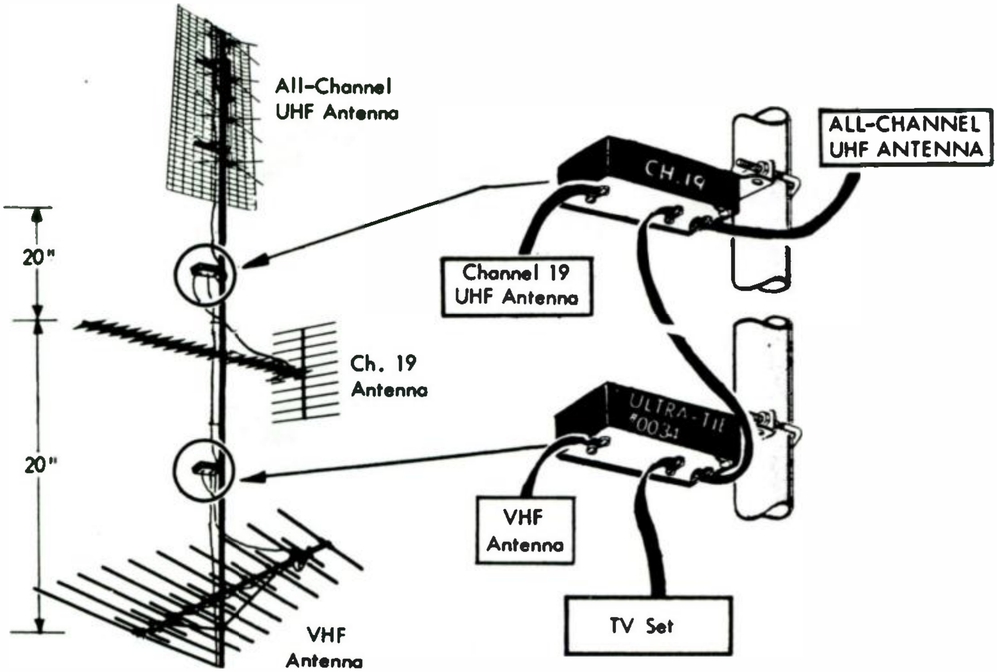


Figure 52 — Coupling UHF and VHF antennas. (Courtesy Channel Master Corp.)

Matching Transformers

In UHF work, a matching transformer is used between a 300-ohm antenna and a 75-ohm coaxial lead-in. Most antennas are designed for 300-ohm impedance. However, in many cases it is an advantage to use coaxial cable for the lead-in—where it is exposed to extreme element of weather, where it must pass near metal elements that could cause induction losses, or where the lead-in must pass near interference sources. When coaxial cable is used, the 300-ohm antenna can be matched to the 75-ohm coaxial cable with one matching transformer at the antenna end. Then, the coaxial lead-in can be matched to the 300-ohm input of the set with another matching transformer at the set end. Some antennas are designed for 75-ohm impedance, so the matching transformer is required at the set end only when coaxial lead-in is used.

Amplifiers and Boosters

The terms amplifier and booster are interchangable. These units amplify weak antenna signals before they arrive at the set or converter. There are two basic designs. The indoor amplifier is a single unit mounted on or near the set. The antenna lead-in is routed to the amplifier input, and the amplifier output is connected to the UHF input terminals of the set or converter. The amplifier is also connected to an AC outlet. Once placed in operation, the amplifier performs its function automatically; there are no operating controls or service adjustments. In fact, because of their low power drain (usually 2 or 3 watts), these amplifiers normally remain turned on at all times.

The outdoor amplifier is divided into two units: an amplifier mounted on the antenna mast and a power supply mounted on or near the set. The antenna is connected to the input on the amplifier. The amplifier output is connected to its power supply through the lead-in, and the power-supply output is connected to the UHF terminals of the set or converter. The power supply requires 115-volts AC and provides the mast amplifier with reduced-voltage AC (15–30 volts) through the lead-in. The outdoor amplifier functions automatically, without operating or adjustment controls. The power supply remains turned on all the time.

In general, outdoor amplifiers provide more gain and have less of a noise problem than the indoor type. With either one, any noise or interference picked up before amplification will increase along with the desired channel signals. However, since the lead to the outdoor amplifier is much shorter, the chance of noise being amplified is lessened.

Some amplifiers serve the dual purpose of amplifier and splitter, or amplifier and coupler. There are many areas where the signal strength is sufficient to drive a single set from an antenna, but not two sets. An amplifier-coupler combination will work nicely. Another condition is where VHF and UHF signals both require amplification. Here the signals can be split in the amplifier instead of using separate circuitry.

Amplifiers are rated as to power consumption, gain, frequency range, noise level, input and output impedances, recommended input level, and possibly flatness of response. Power consumption for most UHF boosters is fairly standard. Usually it is small enough so that once in operation the amplifier is left on indefinitely. It is obvious that the frequency range must cover the entire UHF band from 470 to 890 MHz (plus the VHF band if a combined antenna system is to be used), and the input/output impedances must match the antennas and the sets.

Gain is a good way to compare amplifiers, but it is not the only factor. Usually, an increase in gain means increased noise. Therefore signal-to-noise ratio is of equal importance to gain. Another point to check is how the gain is expressed: flat, average, or minimum. A minimum gain of 3 db means that the gain will be at least 3 db on all channels. This is a more meaningful figure than average gain or "gain up to" some specified figure minimum on the channel to be used by your installation. Flatness of gain or response is a measure of gain across some given bandwidth. If an amplifier is said to be flat within 3 db across a 100 MHz width, this means that the gain would be constant within 3 db across each one-fourth of the UHF band, but it does not necessarily mean that the gain would be constant over the *entire* UHF band.

One final factor of special importance is the maximum recommended input. This reference to the signal level at the antenna is usually expressed in microvolts. If this maximum recommended input is exceeded, it is possible for the amplifier to be overloaded, resulting in signal distortion. The only sure way to determine the signal strength for a given installation is with a field-strength meter, but most shops are not equipped with field-strength meters.

If you do not use field-strength meters for antenna installations, there is one logical way of determining the input limits of an amplifier. Try to solve a weak signal problem with the best possible antenna. If this does not cure the trouble, you can be reasonably sure that an amplifier will not be overloaded.

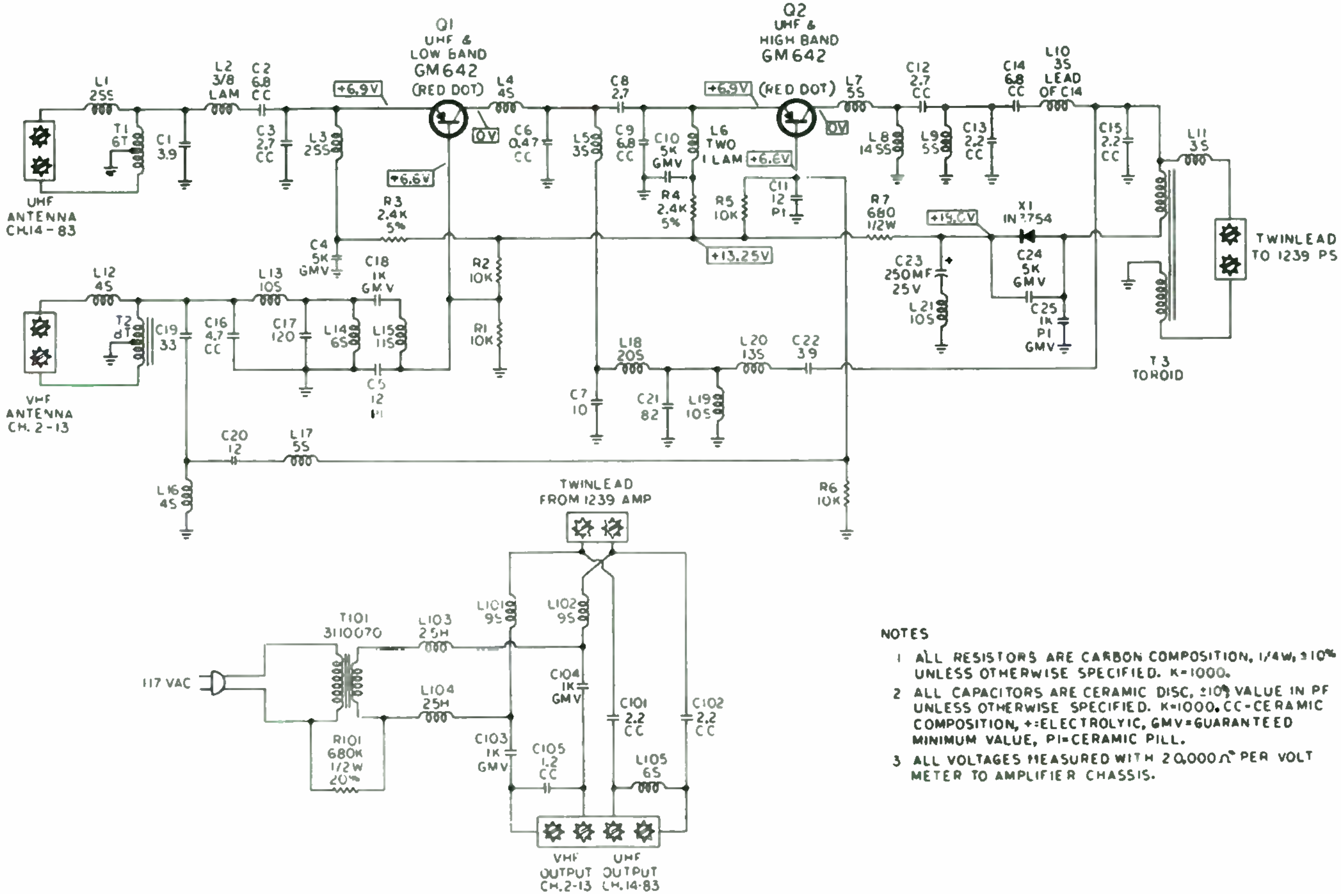
It is not recommended that you try to compensate for a poor antenna or a bad set with an amplifier; however, there are exceptions. Many set owners are limited as to their antenna. They may be apartment-house dwellers who are provided with a built-in antenna, but are not permitted any other. If it does not have sufficient gain, an amplifier may do the trick.

Outdoor Amplifier Circuits

The outdoor amplifier pictured in Figure 53 (schematic in Figure 54) can be used with both UHF and VHF antennas simultaneously. It amplifies the antenna signals, passes them down a single lead-in, and separates the signals at the set for connection to separate UHF and VHF terminals. This amplifier can also be used with a single, combined UHF/VHF antenna, provided some form of splitter is used between the antenna and the amplifier input terminals.

Figure 53 — VHF/UHF outdoor amplifier. (Courtesy Blonder-Tongue Labs., Inc.)

The antennas are connected to their respective inputs on the amplifier. Each input is provided with the necessary bandpass filters to reject all but the desired frequencies. The UHF input is applied to the emitter of transistor Q1 where it is amplified and coupled to transistor Q2. The VHF input is applied to the bases of transistors Q1 and



NOTES

1 ALL RESISTORS ARE CARBON COMPOSITION, 1/4W, ±10% UNLESS OTHERWISE SPECIFIED. K=1000.

2 ALL CAPACITORS ARE CERAMIC DISC, ±10% VALUE IN PF UNLESS OTHERWISE SPECIFIED. K=1000. CC-CERAMIC COMPOSITION, +=ELECTROLYTIC, GMV=GUARANTEED MINIMUM VALUE, PI=CERAMIC PILL.

3 ALL VOLTAGES MEASURED WITH 20,000Ω PER VOLT METER TO AMPLIFIER CHASSIS.

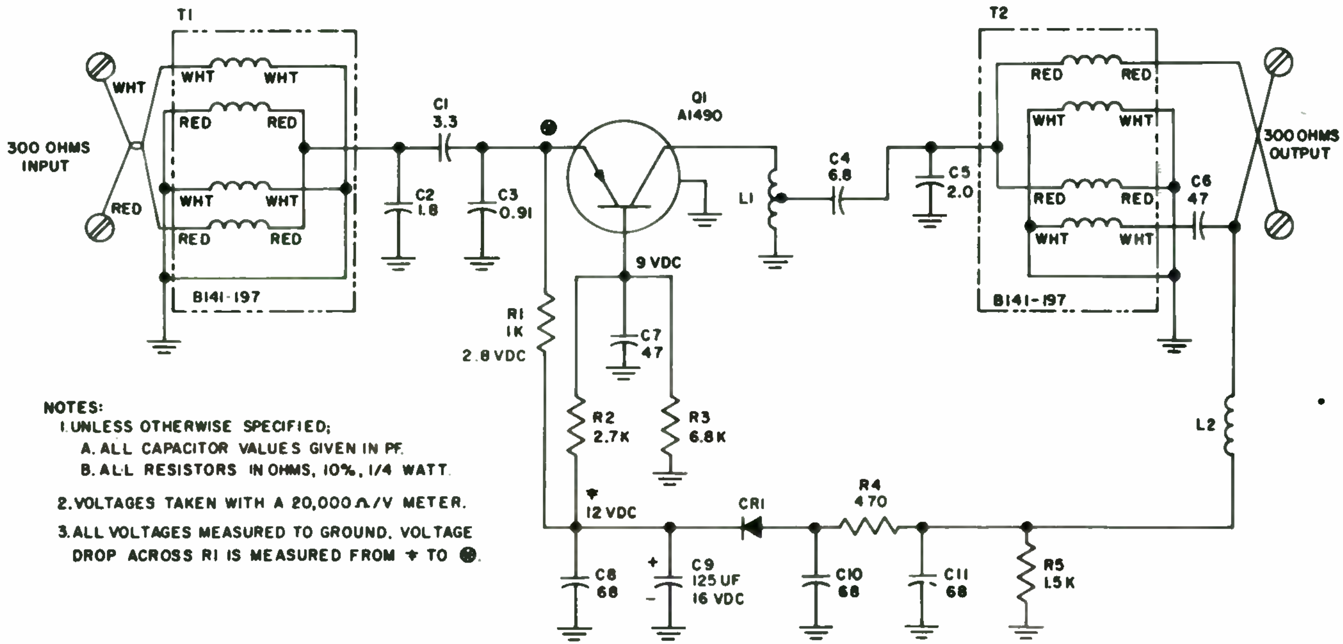
Figure 54 — Schematic for Figure 53. (Courtesy Blonder-Tongue Labs., Inc.)

Q2; the low-band signals are amplified chiefly by Q1, and the high-band signals by Q2. The amplified output from Q2 is applied through matching transformer T_3, and the lead-in, to the power supply unit at the set. The power supply serves the dual purpose of providing for output terminations to the set and supplying power to the mast-mounted amplifier. The 117-volt AC power is reduced to approximately 30 volts by transformer T101. This voltage is applied through the lead-in to rectifier X1 in the amplifier. The rectified output of +18 volts from X1 is used to supply power to transistors Q1 and Q2. The UHF and VHF signals are separated at the power supply by high-pass and low-pass filters into UHF and VHF outputs.

The unit shown in Figure 55 (amplifier schematic is in Figure 56, and the power-supply schematic is in 57) is used to amplify the signals from one UHF antenna and feed them to one UHF receiver or converter. The antenna is connected to the amplifier input. The UHF signals are applied to the input of transistor Q1 through a matching transformer and filter network. The amplified output from transistor Q1 is applied through matching transformer T_2 and the lead-in to the power-supply unit at the set (Fig. 57). The power supply serves the dual purpose of providing the output terminations to the set and supplying power to the mast-mounted amplifier. The 117-volt AC power is reduced to approximately 20 volts AC by power-supply transformer T_1. This voltage is applied through the lead-in to rectifier CR1 in the amplifier. The rectified output of +12 volts from CR1 is used to power transistor Q1.

Figure 55 — UHF outdoor amplifier. (Courtesy Jerrold Electronics Corp.)

The outdoor amplifier in Figure 58 and its schematic in Figure 59 uses a two-transistor amplifier to boost signals from a UHF antenna in order to have ample signal for a UHF receiver or converter. The antenna is connected to the amplifier input. The UHF signals are applied to the input of transistor Q1 through a matching transformer and filter network. The amplified output from transistor Q1 is direct-coupled to transistor Q2. The output from Q2 is applied through a matching transformer and the lead-in to the power-supply unit at the set. The 117-volt AC power is reduced to approximately 30 volts AC and is applied to rectifier X1 to supply the required B+ power for the amplifier.



NOTES:
1. UNLESS OTHERWISE SPECIFIED;
   A. ALL CAPACITOR VALUES GIVEN IN PF.
   B. ALL RESISTORS IN OHMS, 10%, 1/4 WATT.
2. VOLTAGES TAKEN WITH A 20,000 Ω/V METER.
3. ALL VOLTAGES MEASURED TO GROUND. VOLTAGE DROP ACROSS R1 IS MEASURED FROM ✱ TO ●.

Figure 56 — Amplifier schematic for Figure 55. (Courtesy Jerrold Electronics Corp.)

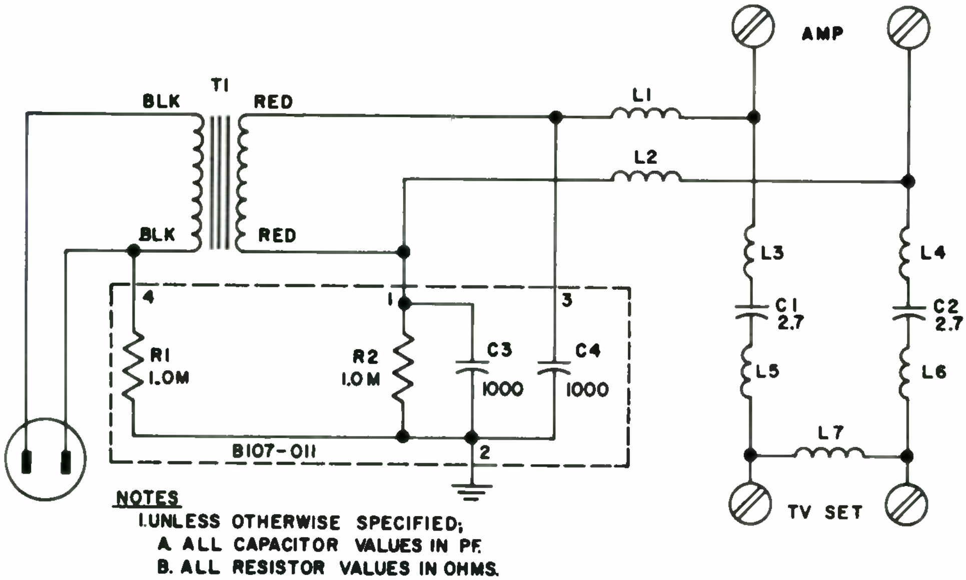


Figure 57 — Power supply schematic. (Courtesy Jerrold Electronics Corp.)

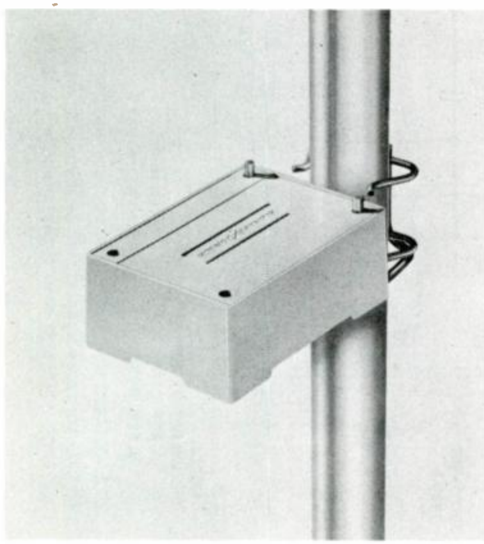
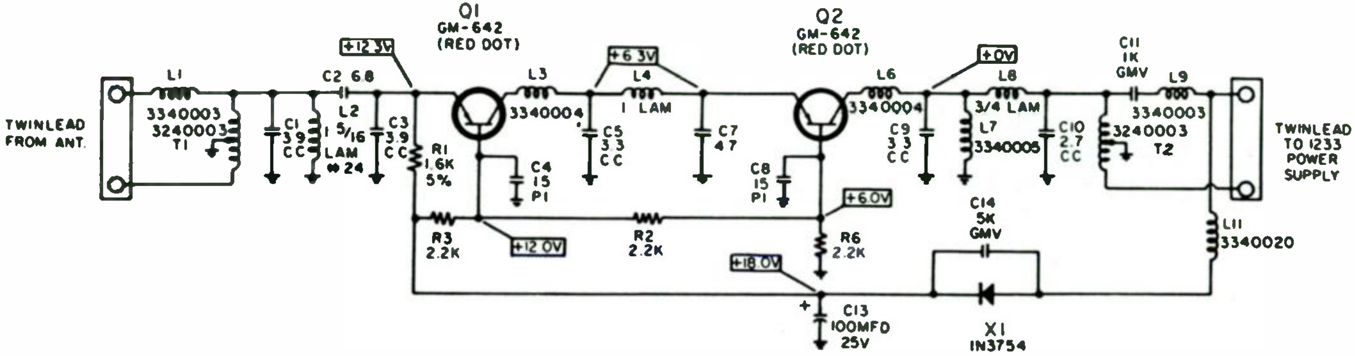
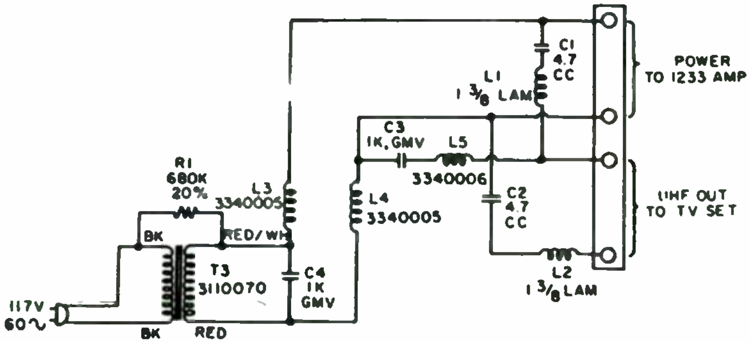


Figure 58 — UHF outdoor amplifier. (Courtesy Blonder-Tongue Labs., Inc.)





NOTE:

1. ALL RESISTORS ARE 1/4 WATT, 10% UNLESS OTHERWISE SPECIFIED, K = 1,000, M = 1,000,000
2. ALL CAPACITORS ARE CERAMIC DISC, VALUES IN MMF, ± 10% UNLESS OTHERWISE SPECIFIED BY THE FOLLOWING CODE:
   - + : ELECTROLYTIC
   - CC : CERAMIC COMPOSITION
   - GMV : GUARANTEED MIN. VALUE
3. SEVEN DIGIT NUMBERS ARE B-T PART NUMBERS
4. ALL VOLTAGES MEASURED WITH A 20,000 OHMS PER VOLT METER TO GROUND.

Figure 59 — Schematic for Figure 58. (Courtesy Blonder-Tongue Labs., Inc.)

Indoor Amplifier Circuits

The indoor amplifier shown in Figures 60 and 61 is used to amplify the signals from one UHF antenna and supply signals to two UHF receivers or converters. The antenna is connected through a 300-ohm lead-in to the amplifier input. The UHF signals are applied to the input of transistor Q1 through a matching transformer and filter network. The amplified signal from transistor Q1 is fed through two matching transformers to two balanced 300-ohm inputs. The outputs are isolated from each other so there will be no interference between TV sets if they are tuned to different channels. The 117-volt AC power source is reduced to approximately 18 volts AC by transformer T_5, is rectified by CR1, and is used to power transistor Q1.

Figure 60 — UHF indoor amplifier and coupler. (Courtesy Jerrold Electronics Corp.)

Fig. 62 shows a UHF/VHF booster designed to amplify the signals from a combined UHF/VHF antenna and to separate the signals for connection to separate UHF and VHF terminals. The schematic is shown in Figure 63. The unit can also be used with separate UHF and VHF antennas, if some form of splitter is provided between the antennas and the amplifier input terminals. Such a splitter would have to take the inputs from two antennas and combine them into a single lead-in. The combined UHF/VHF antenna is connected to the amplifier input through a lead-in. UHF and VHF signals are amplified by transistor Q1 and Q2, working in a grounded base configuration. The amplified output from transistor Q2 is divided by matching transformers and filter networks into balanced 300-ohm outputs. The 117-volt AC power source is rectified by X1, reduced to approximately 20 volts, and used to power transistors Q1 and Q2.

Antenna Rotators

Although an antenna rotator is not limited to UHF antennas, its value is greater now that the number of UHF stations is increasing. As additional UHF stations are placed in operation, there is no guarantee that their transmitting antennas will be near the same locations. This will require a multiple UHF antenna installation, with two or more antennas oriented in different directions. The same is true of VHF. However, orientation of UHF antennas is usually more

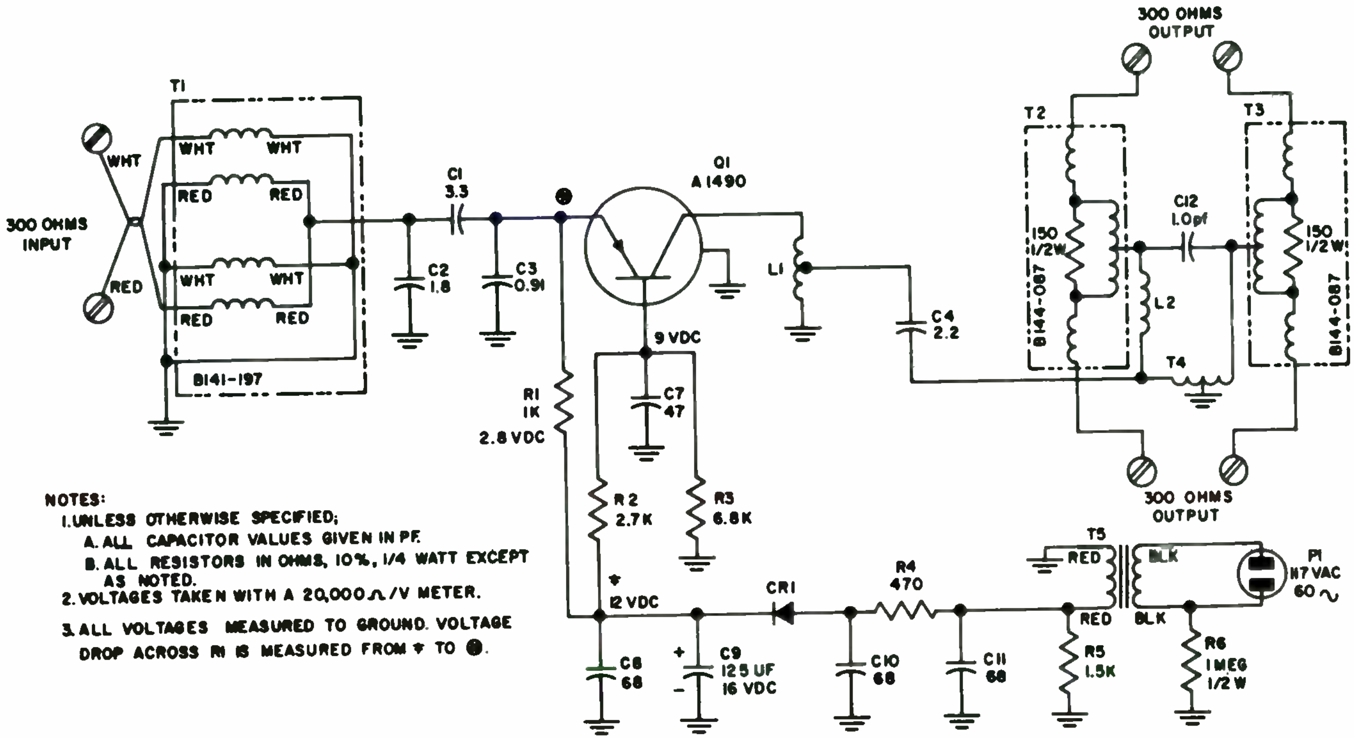


Figure 61 — Schematic for Figure 60. (Courtesy Jerrold Electronics Corp.)

Figure 62 — UHF/VHF amplifier and coupler. (Courtesy Blonder-Tongue Labs., Inc.)

critical than with VHF. One practical solution to the problem is to use an antenna rotator in conjunction with a highly directive VHF or UHF antenna. Antenna rotators for UHF are identical to VHF rotators. In fact, the same units are used. About the only possible difference is that UHF antennas are generally smaller and lighter than VHF antennas, so it is possible that an antenna rotator designed for light-weight duty might be used if available.

There are two basic designs for antenna rotators: compass indicating and automatic. The compass-indicating type of rotator shown in Figure 64 is operated by a push bar at the indicator-control unit. The schematic for both control and drive units is shown in Figure 65. When the switch is closed by depressing one end or the other of the bar, power is applied to the antenna drive motor (57) in the drive unit. The drive motor will continue to turn the antenna so long as the switch is held closed. As the antenna and drive motor turn, the wiper arm of a follow-up potentiometer (61) also moves. This produces a current through the potentiometer that is in direct relationship to the antenna position. The current is measured by a meter calibrated in compass headings, so the compass-indicator movement shows the position of the antenna. Direction of antenna rotation can be changed by depressing the appropriate end of the push bar.

The automatic type of rotator shown in Figure 66 (schematic is shown in Figure 67) is operated by a ring knob around the center pointer on the indicator-control unit. As long as the index on the outer ring and the center pointer both indicate the same direction, the power switch is open. When the outer ring is turned so that the index points toward the desired TV station, power is applied to the transformer primary, to a motor in the indicator-control unit, and to a motor in the antenna-drive unit. The latter turns the antenna, while the former turns the center pointer at the same angular velocity (1 rpm) and in the same direction. When the pointer matches the index on the outer ring, the power switch opens, and both motors stop. Since the movement of the pointer and the rotation of the antenna are synchronized, the antenna will then point in the desired direction.

MASTER ANTENNA TELEVISION SYSTEMS

With the increase in the number of multi-dwelling units such as high rise apartments the need for an antenna system to supply each apartment led to the development

NOTES:

1. ALL RESISTORS ARE CARBON COMPOSITION, 1/4W, 10% UNLESS OTHERWISE SPECIFIED. K=1000, M=1,000,000.
2. ALL CAPACITOR ARE CERAMIC DISC, ±10%, VALUES IN PF, UNLESS OTHERWISE SPECIFIED K=1000, CC=CERAMIC COMPOSITION, +=ELECTROLYTIC, PI=CERAMIC PILL, GMV=GUARANTEED MINIMUM VALUE.
3. ALL DC VOLTAGES MEASURED WITH 20,000Ω/VOLT METER TO NEGATIVE SIDE OF C24.

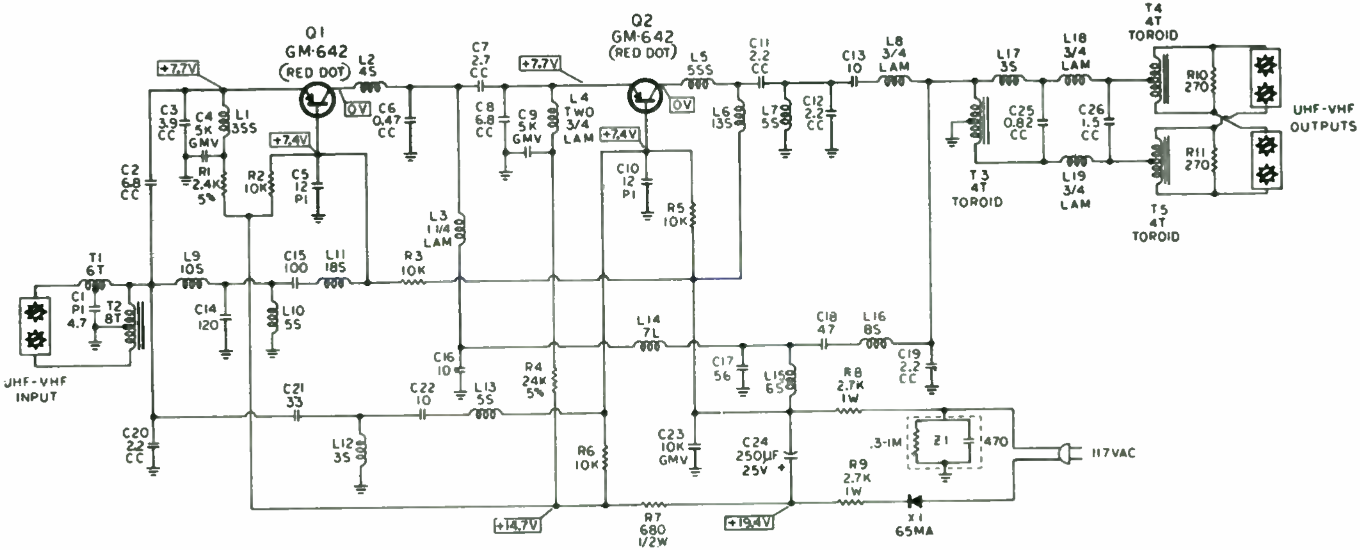


Figure 63 — Schematic for Figure 62. (Courtesy Blonder-Tongue Labs., Inc.)

Figure 64 — Compass-indicating rotator. (Courtesy Channel Master Corp.)

of master antenna television systems. The use of these systems, abbreviated to MATV, spread to many other housing projects, such as condominiums, townhouse dwellings, and apartment complexes.

A properly designed MATV system provides:

1. a separate antenna for each TV channel and FM station for maximum directivity and the elimination of undesired signal.
2. individual amplifiers on each channel, to insure an adequate signal level supplied to the distribution trunk line.
3. a tapoff at each dwelling or apartment for the TVs and the FM receivers.
4. the additional amplifiers along the trunkline to bring the signal(s) up to the required levels.

A system such as this takes time to analyze and design, and requires a knowledge of the many types of additional equipment required. Many of these systems must be designed for future expansion of both additional TV channels and the extension of the system to additional dwellings. It should also provide for the addition of music channels and any closed circuit TV (CCTV) in the present design or in the future.

The equipment used in these systems after the antenna, is usually solid state. It employs conventional electronic parts and circuits, but as each device is used for a specific function, they carry more-or-less descriptive names. There are UHF and VHF preamplifiers, single channel head-end amplifiers, traps

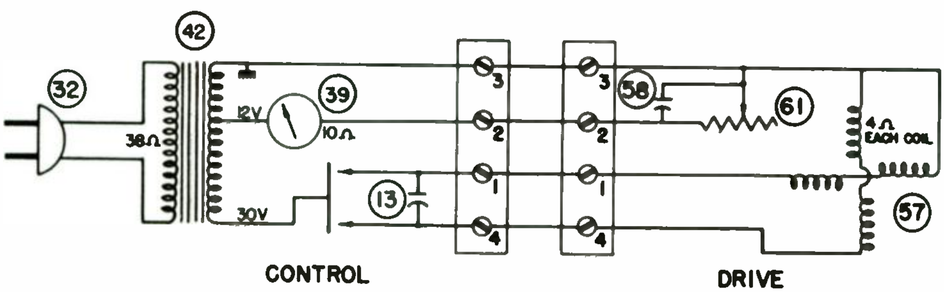


Figure 65 — Schematic for Figure 64. (Courtesy Channel Master Corp.)

Figure 66 — Automatic rotator. (Courtesy Channel Master Corp.)

to suppress any interfering signals, splitters to supply signals to a number of trunklines, bandpass filters, tap-offs, etc. The application of each piece of equipment is described by the manufacturer making it possible for a competent service organization to analyze, design, install, and service a system of this type (Fig. 68).

Systems of this type are not limited to large multi-dwelling complexes. It is possible to design and install amplifiers and distribution systems in larger homes to improve reception and to eliminate inter-channel interference (Fig. 69). Showrooms that have a large number of TVs in operation also use MATV installations and the associated amplifiers and distribution systems.

ANTENNA MOUNTING HARDWARE

Television antennas are generally mounted as high above a roof as possible in order to place the antenna above other neighboring structures. When an antenna is located some distance above nearby buildings and above its own supporting roof, it is much more subject to the force of strong winds. Even though the antenna presents the appearance of a few round pieces of metal, the total area of all of the surfaces combined is considerable. Some manufacturers list the equivalent surface area of the antenna in square feet, thus giving the installers an idea of how well the

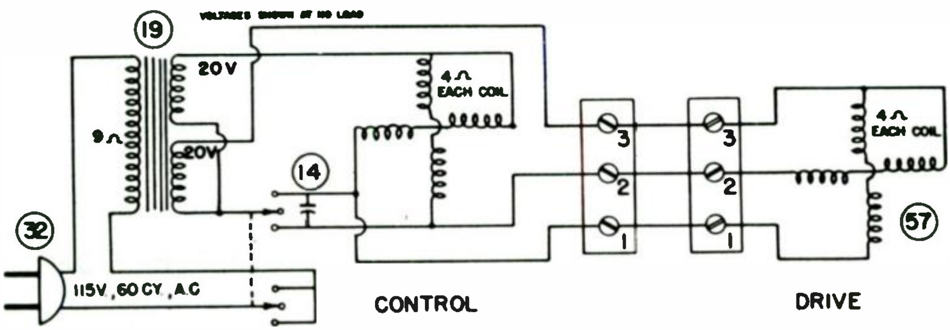


Figure 67 — Schematic for Figure 66. (Courtesy Channel Master Corp.)

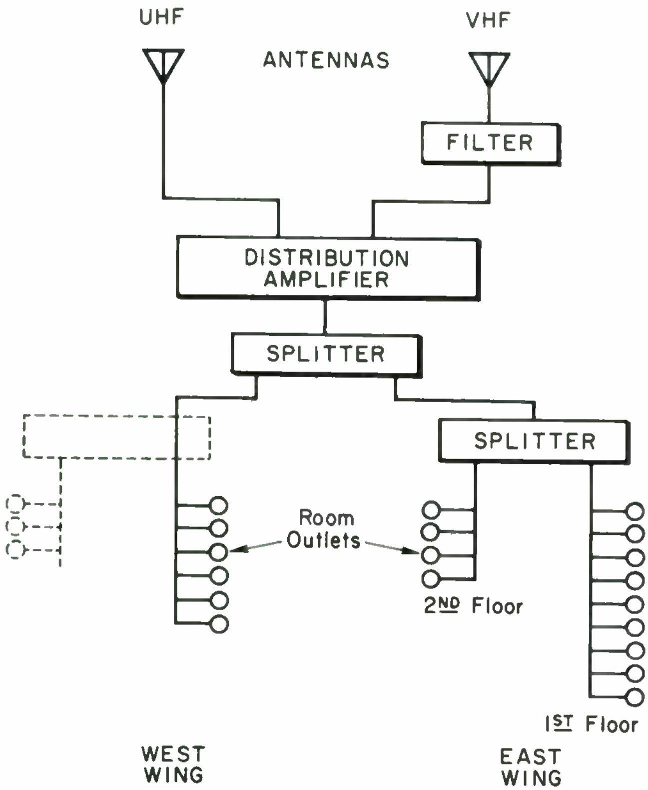


Figure 68 — An example of a signal distribution system designed for present and future use.

supporting mast should be guyed. A few guy wires will act to reduce the amount of motion of the antenna in a strong wind, thus preventing vibration of the elements of the antenna. Evidence that this vibration does take place can be observed on the antennas that usually have one half of the reflector broken off.

Most of the mounting hardware has become standardized in size and shape. Only the items from a reputable manufacturer should be used to be certain that they are properly designed. An important consideration is the amount of protective coating, which consists in most instances of a cadmium plate or the recent vinyl acrylic finish. Illustrations of the various types of mounting hardware are shown in Figures 70, 71, 72. The description and size of the different types of clamps, tripods, masts, and accessories are included on these figures.

LIGHTNING PROTECTION

Any metallic object that projects skyward and is above surrounding surfaces like rooftops, is susceptible

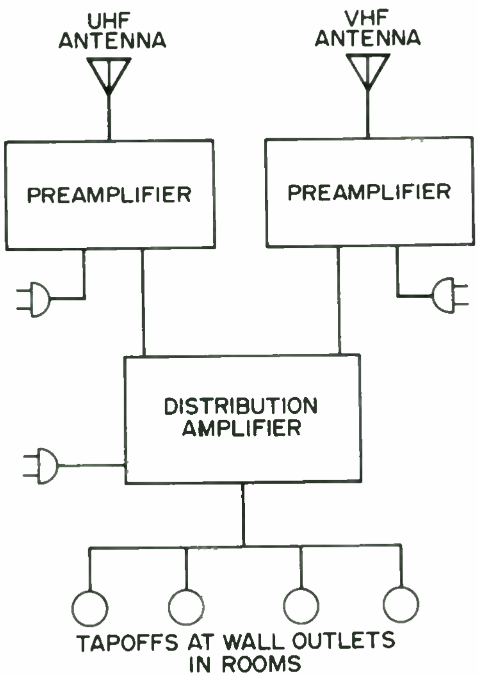


Figure 69 — Amplifiers used to improve the signal level and distribute it throughout the house.

to being struck by lightning. As antennas and their supporting masts are usually placed as high as possible, they not only are prone to being struck by lightning, but when they are properly grounded they serve to protect the buildings beneath them.

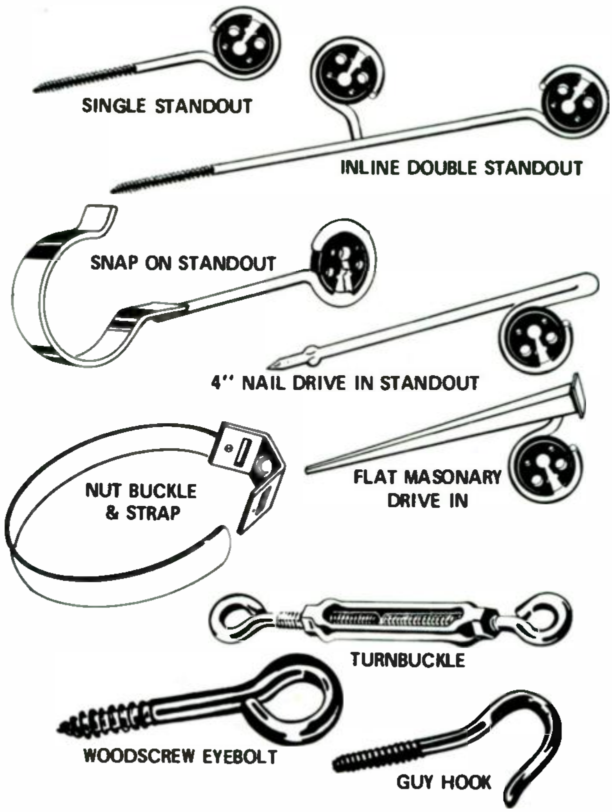
When the supporting mast of the antenna and the lead-in to the TV set are both grounded, they serve the same purpose as lightning rods do. Farm buildings located in the middle of open farm land are generally the highest structures around and must be protected by lightning rods. These lightning rods with their pointed ends act as conductors to draw off electrical charges that accumulate in the air and the clouds above the buildings. The illustration in Figure 73 shows how the lightning protector and the grounding wires should be installed. The ground rod should extend far enough below the surface to be certain that it comes into contact with the moist earth.

SUMMARY

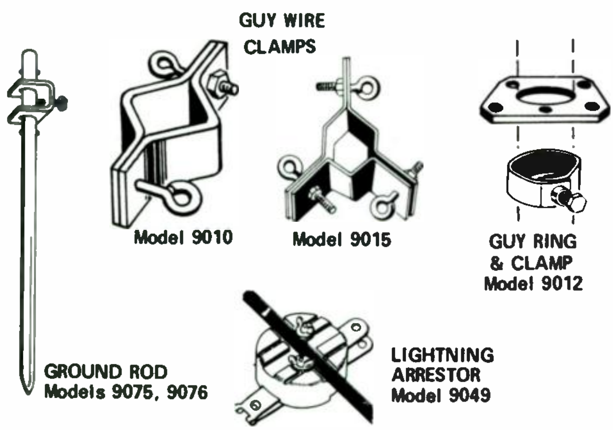
All TV antennas use the half-wave dipole as the basic element of the antenna. The other elements of the antenna are located in front of the dipole and act as directors, while the remaining elements located back of the dipole act as reflectors. The shape and length of the dipole vary in size depending upon the frequency to be received. Even the shape and size of the reflectors vary with the frequency range to be covered.

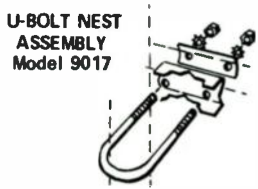
After a signal has been received, it must be delivered to the receiver. This action is performed by the transmission line and selection of the proper one, and the method of mounting and securing this lead-in is important for satisfactory TV reception. There are many accessories that may be employed to insure satisfactory reception. Multiple antennas are employed in apartment complexes. Each antenna is generally sized for a particular channel, and each TV signal is amplified and distributed throughout the building by coaxial cable.

MODEL	DESCRIPTION
	STANDOUTS AND GROMMETS
9602-V	3½" Single
9632-U	3½" Single
9603-V	5½" Single
9633-U	5½" Single
9604-V	7½" Single
9634-U	7½" Single
9610-V	7½" in Line Double
9640-U	7½" in Line Double
9615-V	Snap on Standout...for 1¼" Masting
9645-U	Snap on Standout...for 1¼" Masting
9617-V	4" Nail Drive in Standout
9621-V	Flat Masonry Drive-in Standout
9651-U	Flat Masonry Drive-in Standout
	STRAP FOR STANDOUTS
9660	Galvanized Steel Strap
9662	Stainless Steel Strap
	TURNBUCKLES
9667	4½" closed...6-3/8" open (7/32)
9668	5½" closed...7-5/8" open (¼")
9669	6¾" closed...9" open (5/16)
	WOOD SCREW EYEBOLTS
9672	3" x ¼"
9673	5" x ¼"
9674	5" x 5/16"
	GUY HOOKS
9676	4" x ¼"
9677	5" x ¼"



ACCESSORIES

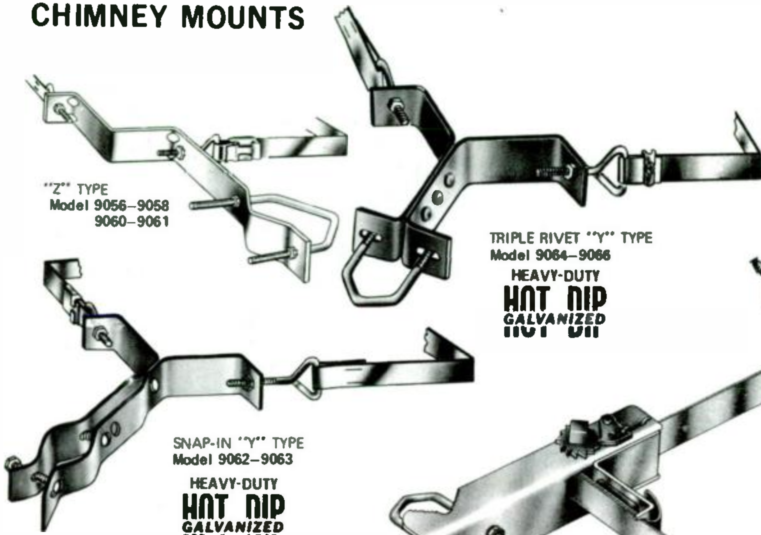


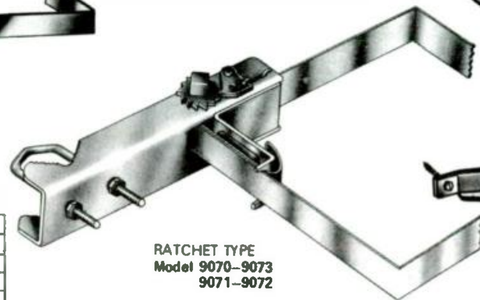


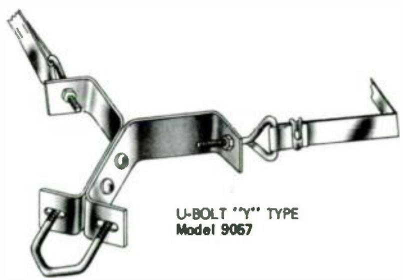
MODEL	DESCRIPTION
9010	GUY WIRE CLAMP/with 2 eyebolts...takes up to 1¾" masts
9015	TRIPLE GUY WIRE CLAMP with 3 eyebolts...takes up to 2" mast
9012	1¼" GUY RING AND CLAMP
9017	U-BOLT and NEST ASSEMBLY
9049	LIGHTNING ARRESTOR
9075	4' x 3/8" GROUND RODS steel rod, copper coated with captive clamp
9076	6' x 3/8"

Figure 70 — Transmission line, guy wire hardware, and accessories. (Courtesy Channel Master Corp.)

CHIMNEY MOUNTS

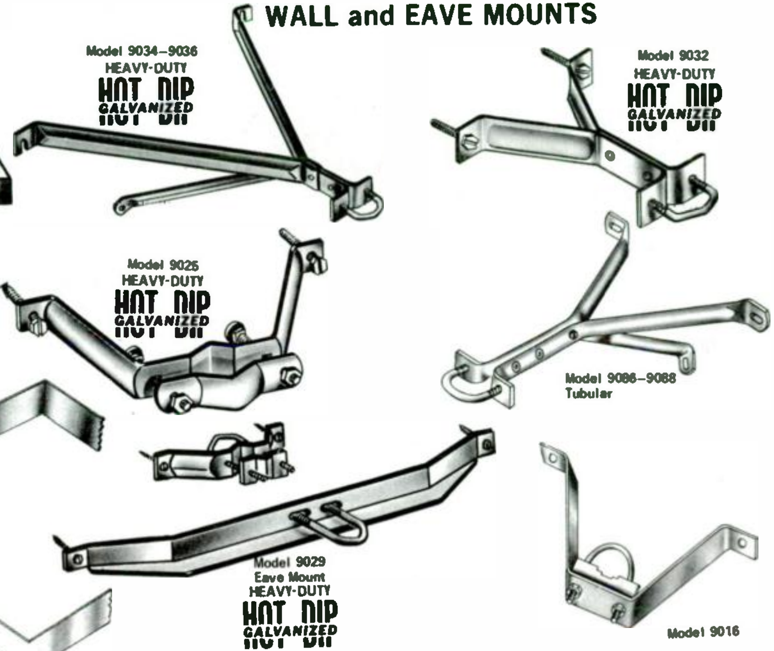


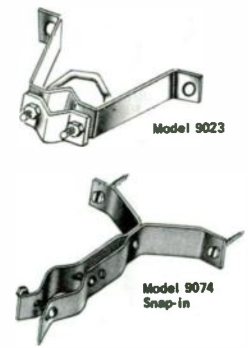




MODEL	DESCRIPTION
	Z TYPE CHIMNEY MOUNTS
9056	10' Galvanized Straps
9058	10' Stainless Steel Straps
9060	12' Galvanized Straps
9061	12' Stainless Steel Straps
	SNAP-IN-"Y"-TYPE CHIMNEY MOUNTS
	Hot Dipped Galvanized
9062	12' Galvanized Steel Straps
9063	12' Stainless Straps
	U-BOLT "Y" TYPE CHIMNEY MOUNTS
9057	10' Stainless Steel Straps
	Hot Dipped Galvanized
9064	12' Stainless Steel Straps Triple Rivet
9066	18' Stainless Steel Straps Triple Rivet
	RATCHET TYPE CHIMNEY MOUNTS
9070	3/4" x 12' Galv. Steel Straps
9071	3/4" x 18' Galv. Steel Straps
9072	3/4" x 12' Stainless Straps
9073	3/4" x 18' Stainless Straps

WALL and EAVE MOUNTS





MODEL	DESCRIPTION
	WALL MOUNTS
9023	4" Takes Masts up to 1½" (Lag Bolts Included)
9032	6" Hot Dipped Galvanized (Lag Bolts Included)
9034	12" Hot Dipped Galvanized (Lag Bolts Included)
9036	18" Hot Dipped Galvanized (Lag Bolts Included)
	TUBULAR WALL MOUNTS
9086	12" Up to 1½" Mast (Lag Bolts Included)
9088	18" Up to 1½" Mast (Lag Bolts Included)
	ADJUSTABLE WALL MOUNTS
9016	4" Heavy Duty up to 1½" Mast
9074	8" Snap-in up to 1½" Mast
9025	3" Hot Dipped Galvanized up to 2½" Mast
	EAVE MOUNT
9029	48" Hot Dipped Galvanized up to 1½" Mast

Figure 71 — Mounting hardware for TV antennas. (Courtesy Channel Master Corp.)

TRIPOD MOUNTS

UP TO 1¾" MAST
HEAVY DUTY TRIPOD MOUNT
Models 9003–9004

UNIVERSAL TRIPOD MOUNTS
Models 9009–9019
INCLUDES MOUNTING HARDWARE

TRIPOD MOUNTS with NEW ADJUSTABLE LEG
Model 9137–9138
Model 9137 with all weather gold finish, pitch pads, lag bolts.

BASE MOUNTS

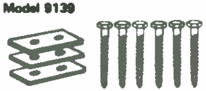
Model 9014 **Model 9013** **Model 9006**
UNIVERSAL SWIVEL BASE MOUNTS

PEAK MOUNT
Model 9005

UNIVERSAL STEEL
Model 9039–9040–9041

VENT MOUNT
Model 9001

PITCH PAD & LAG BOLT KIT
Model 9139



3–Pitch Pads
6–¼" LAG BOLTS

MODEL	DESCRIPTION
	TRIPOD MOUNT
9003	3'...1¼" Dia. Legs...Heavy Duty Galv. Steel Mount Preassembled...up to 1¾" mast
9004	5'...1¼" Dia. Legs...Heavy Duty Galv. Steel Mount Preassembled..up to 1¾" Mast
9019	5'...Heavy Duty Gold Duratube Mount...1¼" Dia. Mast
9009	4'...Aluminum Tripod Mount...1" Dia. Mast, Spun Ends
9137	3'...Gold Duratube Tripod Mount...1¼" Dia. Legs 1 per box
9138	3'...Galvanized...1¼" Dia. Legs...packed 3 per bundle
9139	Pitch Pad & Lag Bolt Kit
	UNIVERSAL SWIVEL BASE MOUNTS
9014	Up to 1½" Mast
9013	1¼" to 1½" Mast
9006	Up to 2¼" Mast
	UNIVERSAL STEEL MOUNTS
9039	1¼" to 1½" Mast
9040	1½" to 1¾" Mast
9041	2" to 2¼" Mast
	PEAK MOUNT
9005	Up to 1½" Mast
	VENT MOUNT
9001	Up to 6" Vent, Up to 1½" Mast

DURATUBE

SPECIAL PROCESS STEEL STRAIGHT LENGTH
Red Oxide Primer with Gold Vinyl Acrylic Finish
STRONGEST MASTING MADE

Channel Master DURATUBE Super Alloy Steel Masting with the double overcoat for lasting beauty and protection!

Channel Master starts with the finest quality high tensile steel tubing, coats it with high adhesive red oxide primer...inside and out...then gives it an overcoat of gleaming gold acrylic vinyl. The result is a super tough mast that stays clean...inside in stock...and outside on the job!

Duratube is 50% stronger than high carbon steel of the same diameter.

SUPER MAST TELESCOPING MAST
High Carbon Steel
Hot Dip Galv.
Inside & Outside

STRAIGHT LENGTH
High Carbon Steel
Hot Dip Galv.
Inside & Outside

Now "Safety-Packed" in closed cartons. Heavy duty corrugated-board covering insures full protection against scrapes and nicks. 10-unit bundles come clean on arrival.

MODEL	DESCRIPTION
	DURATUBE
1607	5 ft. 1¼" x 16 Ga.
1612	10 ft. 1¼" x 16 Ga.
1807	5 ft. 1¼" x 18 Ga.
1812	10 ft. 1¼" x 18 Ga.
2007	5 ft. 1¼" x 20 Ga.
2012	10 ft. 1¼" x 20 Ga.
	SUPER MAST TELESCOPING MAST
1620-C	20 ft. 16, 16 Ga.
1630-C	30 ft. 16, 16, 18 Ga.
1640-C	40 ft. 16, 16, 18, 18 Ga.
1650-C	50 ft. 16, 16, 18, 18, 18 Ga.
1820-C	20 ft. 18, 18 Ga.
1830-C	30 ft. 18, 18, 20 Ga.
1840-C	40 ft. 18, 18, 20, 20 Ga.
1850-C	50 ft. 18, 18, 20, 20, 18 Ga.
	STRAIGHT LENGTH
1610	10 ft. 1¼" x 16 Ga.
1615	10 ft. 1½" x 16 Ga.
1810	10 ft. 1¼" x 18 Ga.
2005	5 ft. 1¼" x 20 Ga.

Figure 72 — Roof mounts for TV antenna masts. (Courtesy Channel Master Corp.)

HOW TO PROVIDE LIGHTNING PROTECTION FOR ANY TV ANTENNA AND TV SET

- Mount lightning arrestor as close as possible to where lead-in enters house.
- Lead-in wire from antenna to lightning arrestor and mast ground wire should be secured to house with standoff insulators, spaced from four to six feet apart.
- Ground wires for both mast and lead-in should be copper or aluminum wire, number 8 or larger.
- In the case of a "ground-up" antenna installation, it may not be necessary to ground the mast if the mast extends four or more feet into the earth. Consult your TV service man for proper depth in your area.

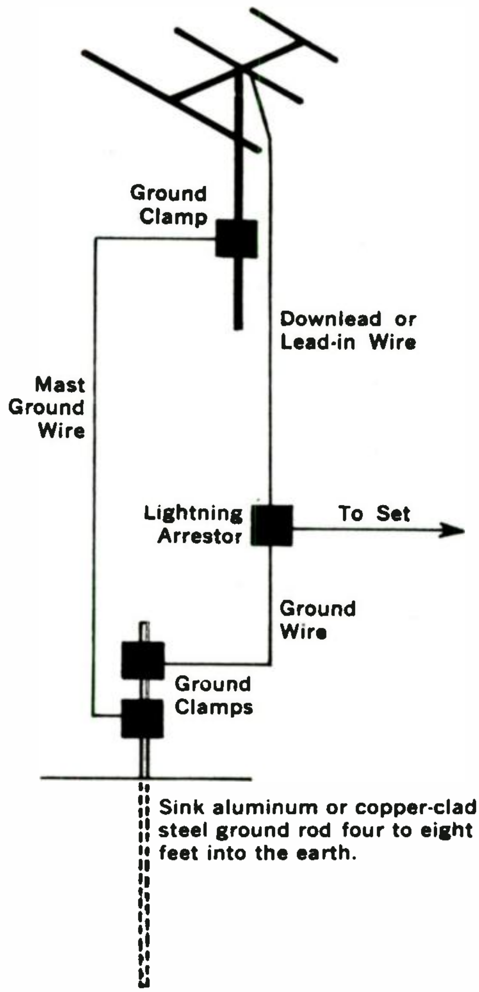


Figure 73 — Instructions for protection against lightning discharges. (Courtesy of Winegard Co.)

TEST

Lesson Number 81

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-081-1.

1. A half-wave dipole constructed of
- A. small diameter elements has a high Q and a sharp resonance point.
- B. large diameter elements has a low value of Q but has a sharp resonance frequency.
- C. small diameter elements has a low Q and a broad frequency response.
- D. both small and large diameter elements always has a high Q value.

2. The "directivity" of an antenna is a measure of the antenna's ability to
- A. receive a signal from any direction.
- B. receive signals in one direction and reject those from other directions.
- C. receive signals of one frequency while rejecting all other frequencies.
- D. match impedances.

3. The names bow-tie, corner reflectors, and parabolic reflectors are names of antennas generally used to receive signals in the
- A. UHF band.
- B. VHF band.
- C. UHF and VHF band.
- D. FM band only.

4. The principle reason for the use of a corner reflector on a UHF antenna is to
- A. reduce the directivity.
- B. decrease wind resistance.
- C. increase the impedance.
- D. provide greater directivity.

5. The charcteristic impedance of a transmission line takes into consideration the

A. length, height, and capacitance.
22 B. length, height, and resistance.
C. inductance, capacitance, and resistance.
D. resistance, capacitance, and height.

6. For an antenna installation where radiation losses are a major factor, ________ transmission line should be used.

A. open-wire
B. flat-ribbon
23 C. coaxial
D. tubular

7. A typical UHF/VHF splitter contains a

26 A. band-reject and band-pass filter.
B. high-pass and low-pass filter.
C. band-reject and low-pass filter.
D. band-reject and high-pass filter.

8. The power supply that is located close to the TV set supplies power to the preamplifier mounted up at the antenna, by

A. supplying power through the TV lead-in wires but only to a TV set that receives UHF stations.
B. changing the AC to DC and then supplying the power through the
32 transmission line.
C. supplying the power to it through the TV lead-in wires.
D. all of the above.

9. For the antenna rotator shown in Figure 65, antenna position is indicated by

A. a meter calibrated in compass headings.
44 B. a synchronous motor.
C. a neon lamp indicator arrangement.
D. the position of the control knob.

10. Antenna grounding systems

A. can only be used on single channel TV antennas.
B. are not needed on the roofs of tall buildings.
C. act as conductors to draw off any electrical charges that might accumulate before and during a thunderstorm.
D. none of the above.

Notes

Portions of this lesson from
Servicing UHF-TV
by John D. Lenk
Courtesy of Howard W. Sams Co., Inc.

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

AVENUES TO SUCCESS

It is true that time waits for no man, but we can learn to make the most of it. Take advantage of what time has to offer, explore new methods, new ideas, new opportunities—new avenues of success.

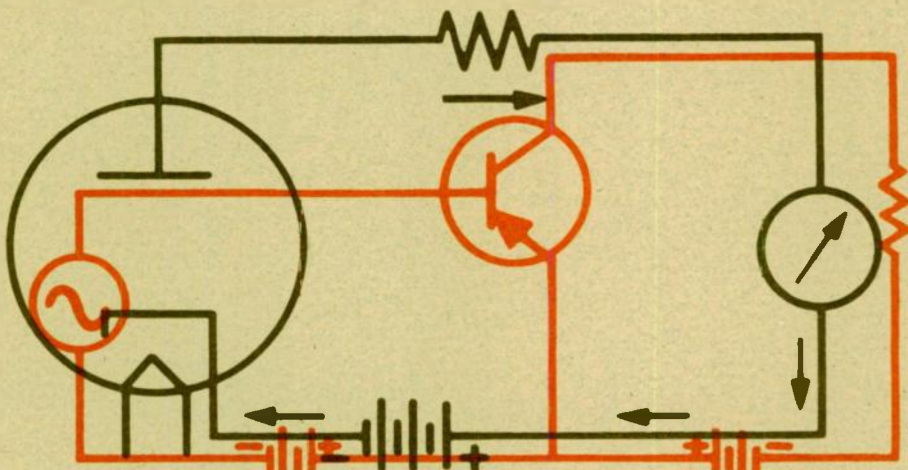
You have taken much of what time has to offer—you started up the avenue of success when you enrolled with ASI. You have gone a long way and can be proud of yourself.

Starting out in the business or professional world is a big step. There are many things you must consider. At times the way may seem hard and long, but don't fall by the wayside. Only YOU can determine how far down this road you will travel.

S. T. Christensen

LESSON NO. 82

REVIEW FILM OF LESSONS 78 THROUGH 81



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-082
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Reprinted October 1974

REVIEW FILM TEST

LESSON NUMBER 82

The ten questions enclosed are review questions of lessons 78, 79, 80, & 81 which you have just studied.

All ten are multiple choice questions, as in your regular lesson material.

Please rerun your Review Records and film before answering these questions.

You will be graded on your answers, as in the written lessons.

REMEMBER: YOU MUST COMPLETE AND MAIL IN ALL TESTS IN THE PROPER SEQUENCE IN ORDER FOR US TO SHIP YOUR KITS.

REVIEW FILM TEST

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-082-1.

1. **The output voltage of a magnetic phono cartridge is directly proportional to**
   A. the amplitude of stylus swing.
   B. the velocity of the needle.
   C. the swing of the stylus.
   D. the diameter of the needle.

2. **Tracking error pertains to**
   A. record changers.
   B. record players.
   C. phono tone arms.
   D. all of the above.

3. **A speaker's low frequency response**
   A. is proportioned to the magnet weight.
   B. is directly related to the baffle area.
   C. depends upon the voice coil impedance.
   D. depends upon the cone area.

4. **In the composite television transmitted signal the FM sound carrier is __________ from the AM picture carrier.**
   A. 6.0 MHz
   B. 3.58 MHz
   C. 1.25 MHz
   D. 4.5 MHz

5. The basic television tuner contains a/an
A. RF amplifier section.
B. mixer section.
C. oscillator section.
D. all of the above.

6. The video amplifier
A. provides high voltage to the picture tube 2nd anode.
B. supplies AGC to the tuner.
C. provides focus voltage for the picture tube.
D. amplifies the output of the video detector.

7. The bandwidth allocated for each television signal transmission is
A. 6.0 MHz.
B. 10 MHz.
C. 10.7 MHz.
D. 8.0 MHz.

8. Sync pulses are separated from video signals by a
A. clipper-limiter.
B. phase detector.
C. multivibrator.
D. sawtooth generator

9. The phase detector in the horizontal oscillator circuit
A. produces AGC voltage for the IF amplifier.
B. produces AGC voltage for the RF amplifier.
C. produces a correction voltage to correct horizontal multivibrator frequency.
D. produces high voltage for the picture tube.

10. The center impedance of a folded dipole antenna is
A. 45 ohms.
B. 150 ohms.
C. 300 ohms.
D. 600 ohms.

Notes

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

EVERY DAY IN EVERY WAY

The man who knows and practices the real meaning of "Service" is the man who will build success in the great field of Electronics.

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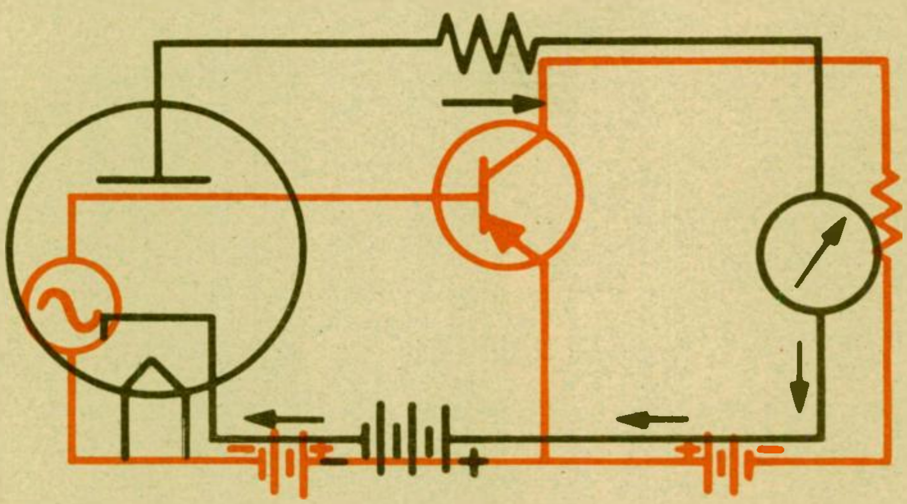
Employ the full meaning of "Service" every day in every way, and soon the success of "extra" effort will be yours.

S. T. Christensen

LESSON NO. 83

TELEVISION TUNERS



RADIO and TELEVISION SERVICE and REPAIR

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Contents

TELEVISION TUNERS

INTRODUCTION

A complete television signal consists of an AM picture signal and an FM sound signal. These two signals are contained in a bandwidth that is always 6 MHz wide. This bandwidth is positioned at different locations in the frequency spectrum. These different locations—that always occupy a bandwidth of 6 MHz—are known as channels.

Whenever a TV set is *tuned* to a channel, the first section in the TV set that receives the sound and the picture signals is the *tuner*. It is the tuner that is adjusted from channel to channel and which must process these signals before passing them on to the remainder of the TV set.

THE TV TUNER

The signal from the desired VHF TV station and the signals from all other stations in the area arrive at the VHF antenna. All of these signals travel down the transmission line to the tuner. The tuner selects only the desired signal and rejects all others. The desired signal is amplified by the RF amplifier in the tuner and is coupled to the mixer. In the mixer stage the amplified signal from the RF amplifier and a signal from the local oscillator are beat together (heterodyned) to produce a lower, or intermediate frequency. The mixer and the local oscillator in modern TV receivers are always two portions of the same tube.

When receiving a UHF signal, the procedure is slightly different. The signals from the UHF station also arrive at the antenna. The UHF signals travel down the transmission line and arrive at the UHF tuner, where the signals from the desired station are selected and applied directly to the mixer stage. Here the signal from the station and the signal from the UHF local oscillator are heterodyned to form the IF frequency. The IF output from the UHF tuner is then coupled to the VHF RF amplifier. When tuned to the UHF position, the VHF RF amplifier and mixer provide two stages of amplification of the IF signal. Note that actually two separate IF signals exist at the mixer output. One is produced by the video signal beating with the local oscillator. A typical video IF frequency is 45.75 MHz. The other IF frequency is produced by the sound signal beating with the local oscillator. A typical sound IF frequency is 41.25 MHz. Thus, the two frequencies are separated by the same 4.5-MHz difference established at the transmitter.

Intermediate Frequencies

For example, assume that it is desired to tune to a station operating on Channel 6, whose video carrier frequency is 83.25 MHz and sound carrier is 87.75 MHz. The local oscillator frequency in this example would be 129 MHz. Thus, when the local oscillator is heterodyned with the station signals, the following IF frequencies are generated:

Local Oscillator	129.00 MHz
Minus Video Carrier	83.25 MHz
Video IF	45.75 MHz
Local Oscillator	129.00 MHz
Minus Sound Carrier	87.75 MHz
Sound IF	41.25 MHz

Notice, that although the sound carrier in the composite video signal is transmitted at the higher frequency, the lower IF is produced by the sound carrier because the oscillator is at a higher frequency than either carrier, and there is an inversion of the frequency relationship between the sound and picture carriers. If the local oscillator were tuned to a frequency lower than the carrier frequencies, the video IF would be lower than the sound IF. Either method will work; however, the former is usually employed because of interference problems when the oscillator is tuned lower than the carrier.

TUNER DESIGN

The RF section (or tuner) of a television receiver consists of an RF amplifier, a local oscillator, and a mixer. This combination of circuit elements performs the same function as its counterpart in a conventional superheterodyne broadcast or short-wave receiver.

A number of complications not encountered in the reception of ordinary broadcast signals require a more complicated design of the TV receiver than is found in standard broadcast sets because:

1. The broadband nature of the television channel requires the acceptance and amplification of a band of frequencies 6 MHz wide.
2. The frequency allocation of television channels (54 MHz to 88 MHz and 174 MHz to 216 MHz for the VHF band; and 470 to 890 MHz for the UHF band) necessitates special types of coupling circuits to maintain uniform gain at the extremes of each band.
3. Balanced types of input circuits must be matched in impedance to the characteristic of available transmission lines.
4. Undesired or spurious responses to signals outside the desired television band must be avoided. These responses may be caused by:
   a. The adjacent-channel sound carrier.
   b. Cross modulation due to other television channels.

c. Direct transmission, through the RF system, of signals at the intermediate frequency.
d. Interferences due to other television channels and to FM stations.
e. Overloading of the input tube due to excessively strong signals from nearby broadcast stations.

5. Local-oscillator energy has a tendency to be radiated by the antenna. Such radiation must be suppressed to prevent interference with neighboring television receivers.

3

Television tuners can be classified according to the type of RF amplifier circuit employed or the mechanical means of channel selection. From the standpoint of the type of RF amplifier circuit, tuners can be classified as pentode, triode, tetrode, and cascode.

From the standpoint of mechanical means of channel selection, tuners can be classified as continuous (variable inductance and variable capacitance), switch, and turret types.

Pentode RF Amplifiers

The pentode RF circuit like the one in Figure 1 was the first to be used; it gets its name from the type of tube employed, a sharp-cutoff pentode. Its chief advantage is that it performs satisfactorily, without any neutralization, from a B+ supply voltage as low as 100 volts. The fact that this circuit generates more noise than a triode circuit does and is, therefore, not too suitable for fringe-area operation does not lessen its usefulness in strong-signal areas. For the most part, the circuit is quite stable, and tube replacement or minor component aging has only a small effect on its frequency-response characteristic.

The RF amplifier stage must govern most of the selectivity and sensitivity of the tuner. The grid circuit is very broadly tuned, and the plate circuit presents the RF signal with an impedance as high as possible to maximize the gain and selectivity. The necessary bandwidth is further governed by the degree of coupling between the RF plate and mixer-grid coils.

Triode RF Amplifiers

When a triode is used with a grounded cathode as an RF amplifier, a relatively high capacitance exists between the plate and the grid. A feedback signal will be impressed on the grid because of this capacitance, and the stage will oscillate. One way this oscillation can be eliminated is by neutralizing the stage by providing a second feedback path. An out-of-phase signal can be applied through this path to the grid to cancel the plate-to-grid signal.

The original solution to the oscillation problem was a grounded-grid circuit like that in Figure 2. If the grid is grounded and the signal is applied to the cathode, stable amplification can be attained because the grounded grid acts as a shield and eliminates all interelement coupling within the tube.

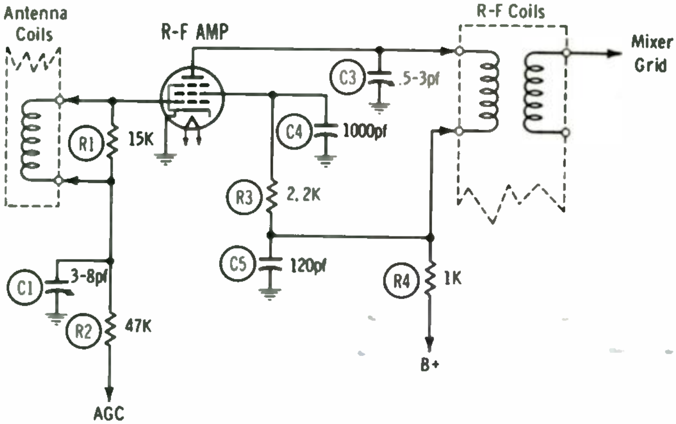


Figure 1 — Pentode RF amplifier circuit.

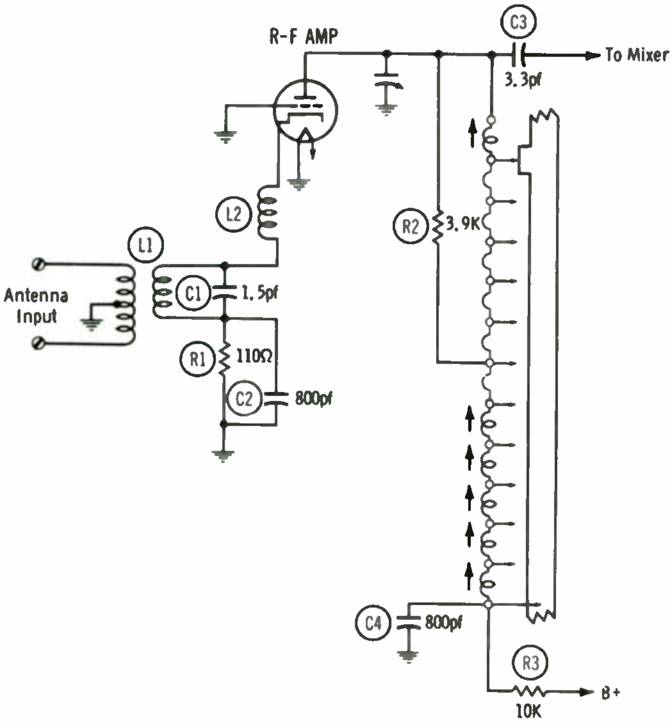


Figure 2 — RF amplifier using a grounded-grid triode.

Neutrode RF Amplifiers

A newer version of the triode RF amplifier called the neutrode circuit is shown in Figure 3. As the name implies, this circuit is a neutralized triode RF amplifier. The neutrode circuit is employed in some turret tuners using a printed-wiring board for the RF and oscillator-mixer circuits.

The RF amplifier is neutralized by a capacitor connected from the low side of the plate coil to the control grid. The required 180° phase inversion is obtained through the plate coil. The amount of feedback is controlled by adjustment of C_n to obtain the exact amount of signal required for most effective neutralization.

The performance of the neutrode tuner compares favorably with that of cascode tuners. Field tests have shown that about 32 db of gain with less than 8 db of noise can be achieved.

Tetrode RF Amplifiers

A further development in the continuing search for simpler circuits was the tetrode RF amplifier circuit in Figure 4. This circuit was designed around a tetrode series which includes the 2CY5, 6CY5, etc. These tetrodes feature a high transconductance (8000 micromhos) with a noise figure approaching that of some of the RF triodes.

Circuitwise, the tetrode RF amplifier is almost identical to the pentode RF amplifier. Of course, there is no suppressor grid in the tube; and there is a small inductance in series with the screen-grid bypass capacitor. This inductance is actually in the lead of the capacitor itself, and it has a stabilizing effect on the stage. The

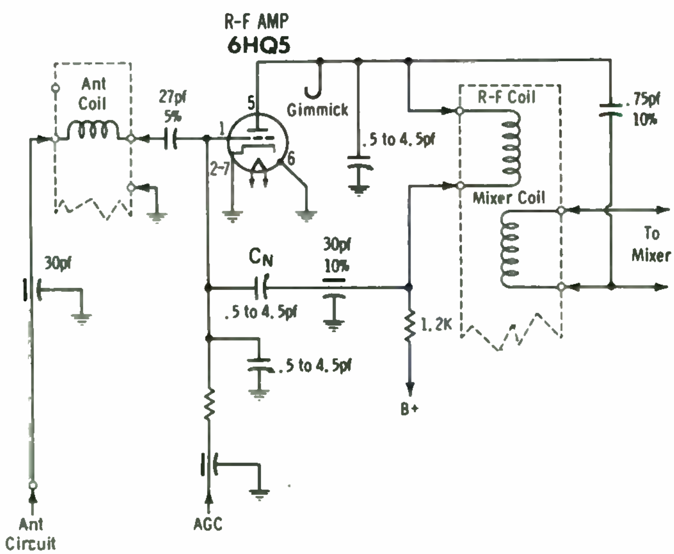


Figure 3 — A neutrode RF amplifier circuit.

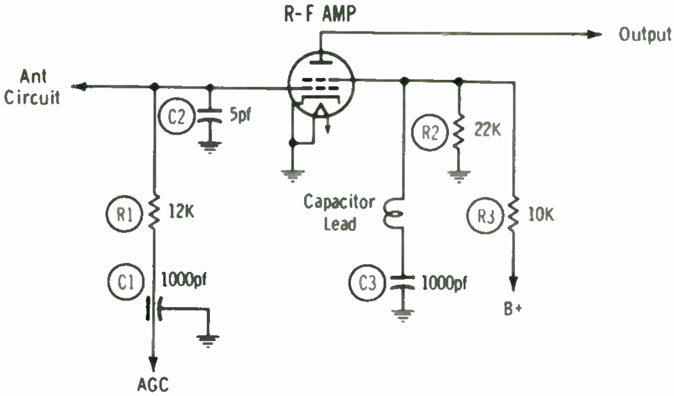


Figure 4 — The tetrode RF amplifier circuit.

tetrode tuner will provide about 35 db of signal gain at a 6- to 8-db noise figure, which is comparable to the performance of cascode RF amplifiers.

Cascode RF Amplifiers

The cascode circuit was developed as a result of efforts to improve the signal-to-noise ratios of TV tuners. High signal-to-noise ratios are needed for good fringe reception. The cascode circuit in Figure 5 consists of a grounded-cathode triode driving a grounded-grid triode; both triodes are connected in series as far as plate current is concerned. The cathode input impedance of the grounded-grid stage is the plate load for the first stage and is such that maximum power gain is attained for both stages. The cascode tuner has the high gain normally associated with a pentode amplifier and the low noise of a triode amplifier. The

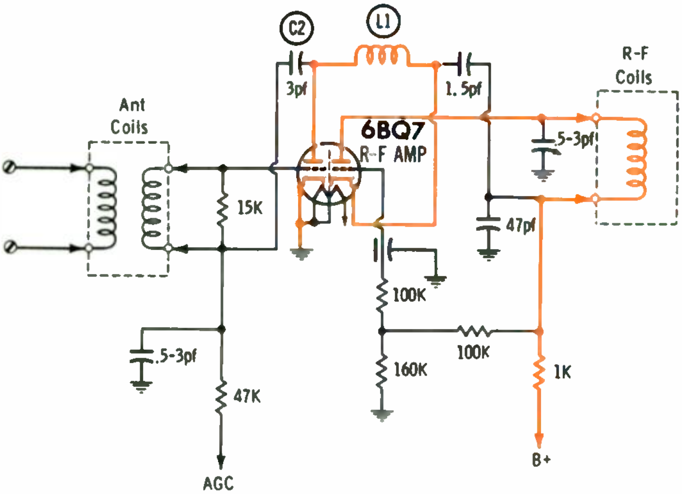


Figure 5 — The cascode RF amplifier circuit.

average cascode tuner will have about 35 db of gain with about 6 db of noise.

Like any other grounded-cathode triode amplifier operating at radio frequencies, the input triode must be neutralized. This is done by coil L1, which develops a small signal voltage that is then fed back to the bottom of the grid coil through capacitor C2.

VHF TUNING SYSTEMS

A wide variety of VHF tuning systems have been employed in television receivers. Some are no longer used; others are still used but in modified form. In this section we will describe briefly some of the early arrangements and then progress to the latest vacuum-tube and solid-state systems.

Tuning by Continuously Variable Inductor

Variable-inductance tuning was employed in some of the older types of tuners. Tuning was usually accomplished by the use of sliding electrical contacts or sliding iron cores to vary the inductance. Such a method was particularly adapted to VHF because a high ratio of inductance to capacitance and, consequently, higher circuit impedance at the high-frequency end of the range was made possible. A sliding contactor made of a high silver-content alloy traveled in trolley fashion on a silver-wire inductor to vary the inductance value. End rings on the inductor permitted connection to both ends of the inductance. The sliding contactor was used to short the unused portion of the inductance. A three-gang inductor was employed for tuning purposes. The three units were used in a coupled bandpass selector stage and in the local oscillator. The tuner was designed so that the acceptance band remained constant at 6 MHz over the entire tuning range. The tuning range extended continuously from 44 to 216 MHz and included not only the television channels, but also FM stations, two amateur bands, aviation channels, VHF radiotelephone, and commercial services. A unique dial arrangement made it possible to use the television receiver for reception of these signals.

Continuously Variable Tuning by Powdered-Iron Cores

Another early tuning system employed a special type of high-frequency, powdered-iron core which could be moved to change the value of the tuned-circuit inductances. This permitted selection of television channels on both low- and high-frequency bands. A separate set of inductors and sliding cores was provided for each band, and electrical switching was used to transfer from one band to the other. Since tuning was continuous in this circuit, a separate fine-tuning control was not needed. The tuning adjustment was set for the best performance of the sound channel, and this automatically assured a proper setting for the video carrier.

Broadband response was achieved in this tuner by loading the tuned circuits with low-value parallel resistors. In the high-frequency band, parallel resistors were not required because of higher circuit losses.

Artificial-Line Input Tuner

Figure 6 shows a type of input system found in many early receivers. A twin-triode was used to provide push-pull operation in each stage. The artificial equivalent of a quarter-wave transmission line, consisting of inductors with their associated distributed capacitors, was employed in the RF, converter, and oscillator circuits to perform the functions usually associated with lumped-tuned circuits. These lines were balanced with respect to the chassis or ground. The various television channels were tuned by switching a short circuit along the line.

In this circuit, RF amplifier tube V_1 was push-pull connected and was cross-neutralized by capacitors C_4 and C_5. This cross-neutralization increased the stability of the stage by preventing regeneration or oscillation and also reduced the transmission of oscillator energy through amplifier tube V_1 to the antenna.

The plate load of V_1 consisted of the equivalent of a quarter-wave transmission line and was made up of inductors L_1 through L_{26}. A rotary switch was employed to short out sections of the line so that it could be tuned to any one of the twelve VHF television channels.

Capacitors C_2 and C_3 and inductive link L_{36} served as coupling elements between the line in the RF plate circuit and in the corresponding line comprised of inductors L_{31} through L_{57} in the converter-grid circuit. Because of the value of these elements, the channel width was kept constant over both VHF television bands.

The oscillator circuit consisted of a transmission line similar to the ones just described, but with the additional feature that each channel inductance was separately adjustable (see inductors L_{76} through L_{87}). The oscillator tube derived its plate-to-grid feedback for sustained oscillation from a crossed pair of capacitors (C_{25} and C_{27}), the values of which were greater than those of the grid-to-plate capacitance of the oscillator tube.

Oscillator voltage was injected into the converter-grid circuit by magnetic coupling between the tuned transmission lines, augmented by coupling link L_{74}.

Input Systems with Switch-Selected Inductors

Figures 7 and 8 show an example of a switch-type VHF tuner in which a rotary wafer switch selects the proper inductances for tuning to the desired television channel. Several features not previously mentioned are evident in this circuit. The input circuit and the method by which tube V_{201} is connected constitute a means of coupling between a balanced-to-ground transmission line and a single-ended tube circuit. Both the grid and the cathode of V_{201} act as input elements. Interstage coupling between the RF amplifier and mixer is provided by transformer T_{101} which is broad enough to provide the proper bandwidth for all channels. The plate- and grid-circuit inductances are selected by the rotary switch.

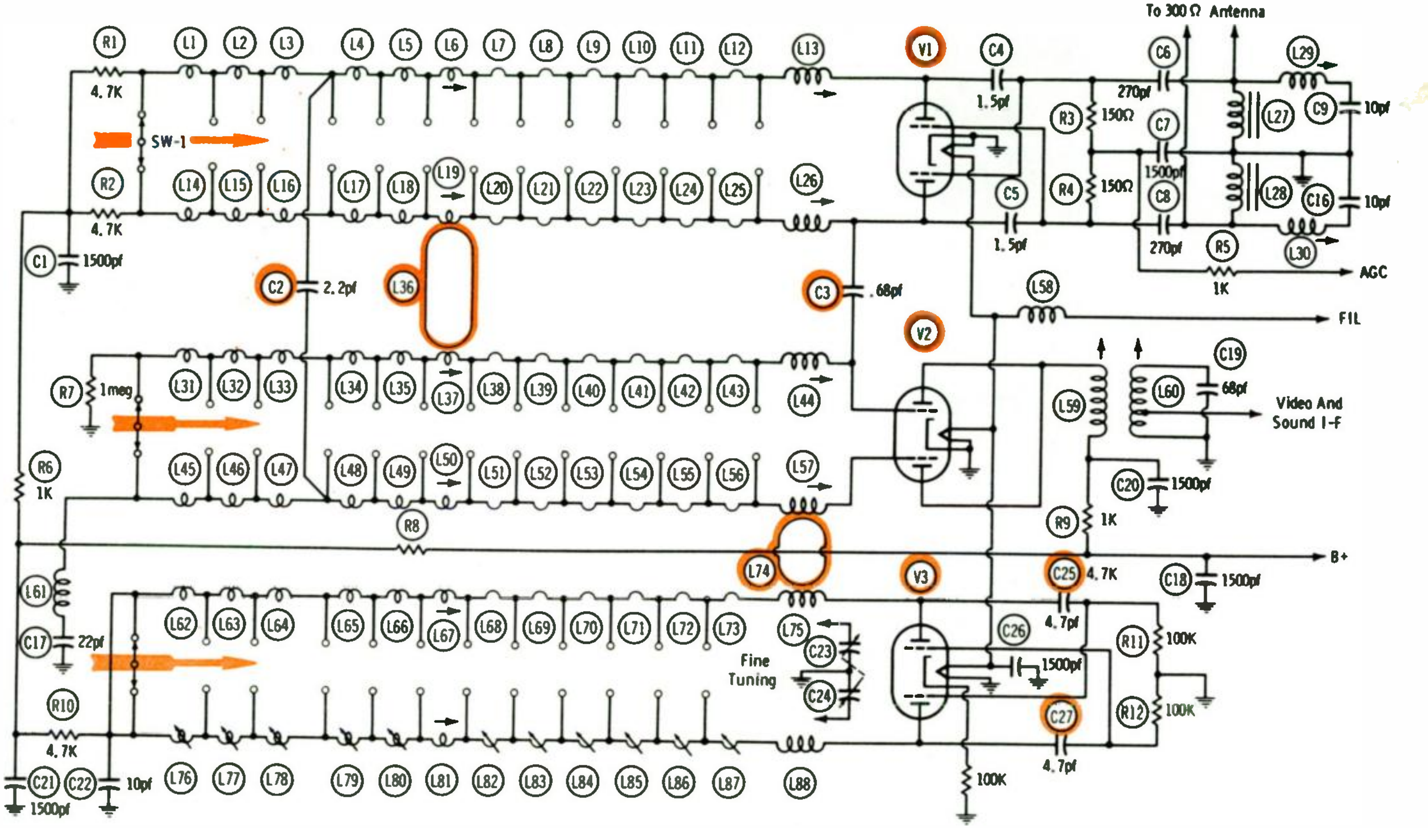


Figure 6 — Schematic of an early-model tuner which employed lumped equivalents of quarter-wave transmission lines.

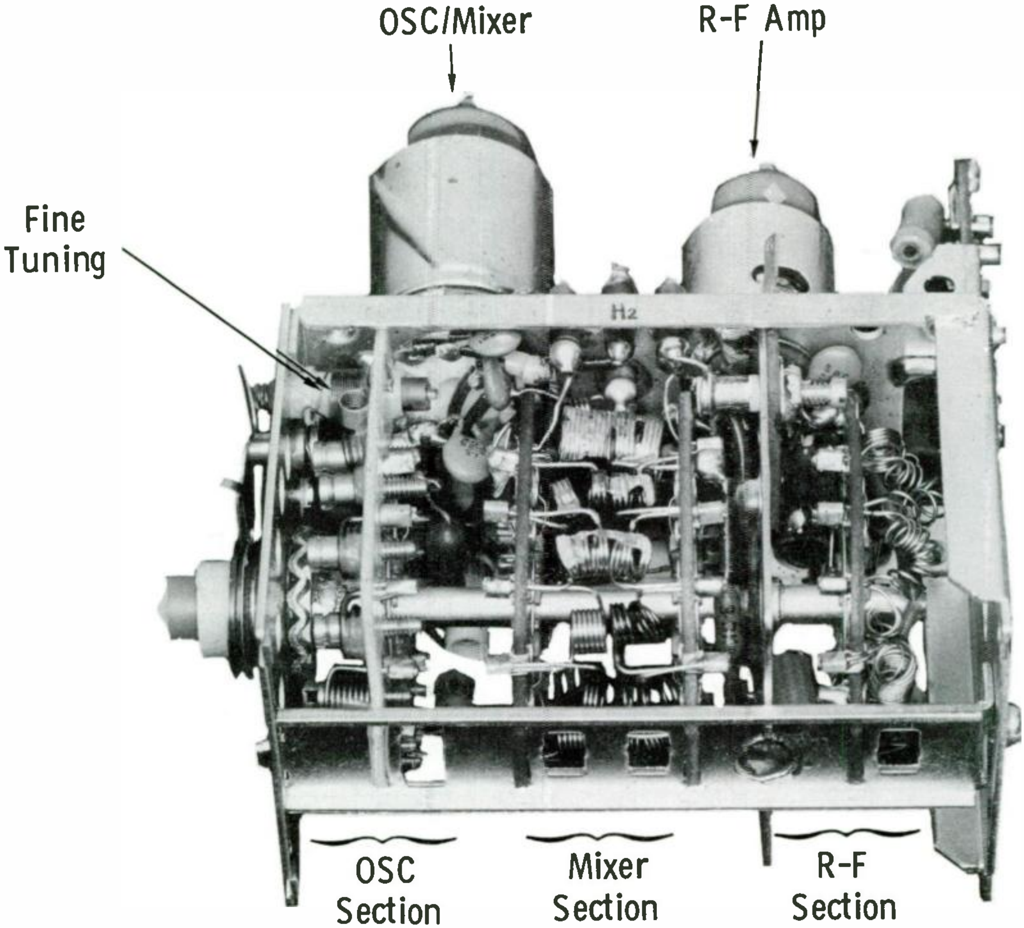


Figure 7 — Example of modern switch-type tuner employing vacuum tubes.

The oscillator-circuit switching involves the selection of individually adjusted inductors. Oscillator-tuning is made variable for fine tuning by means of a variable inductor connected in the oscillator plate circuit.

Turret Tuners

Figures 9 and 10 show a widely used tuning system in which the input, converter, and oscillator-tuned circuits are mounted on a rotating turret. Only the circuit elements associated with a single television channel are connected in the circuit at any one time. Spring contacts associated with the various tube circuits provide a means for connection to the terminals of the tuned circuits. As the turret is rotated by the channel-selector knob, studs at the end of each set of coils are positively indexed into contacting position by wiping action which assures low circuit resistance.

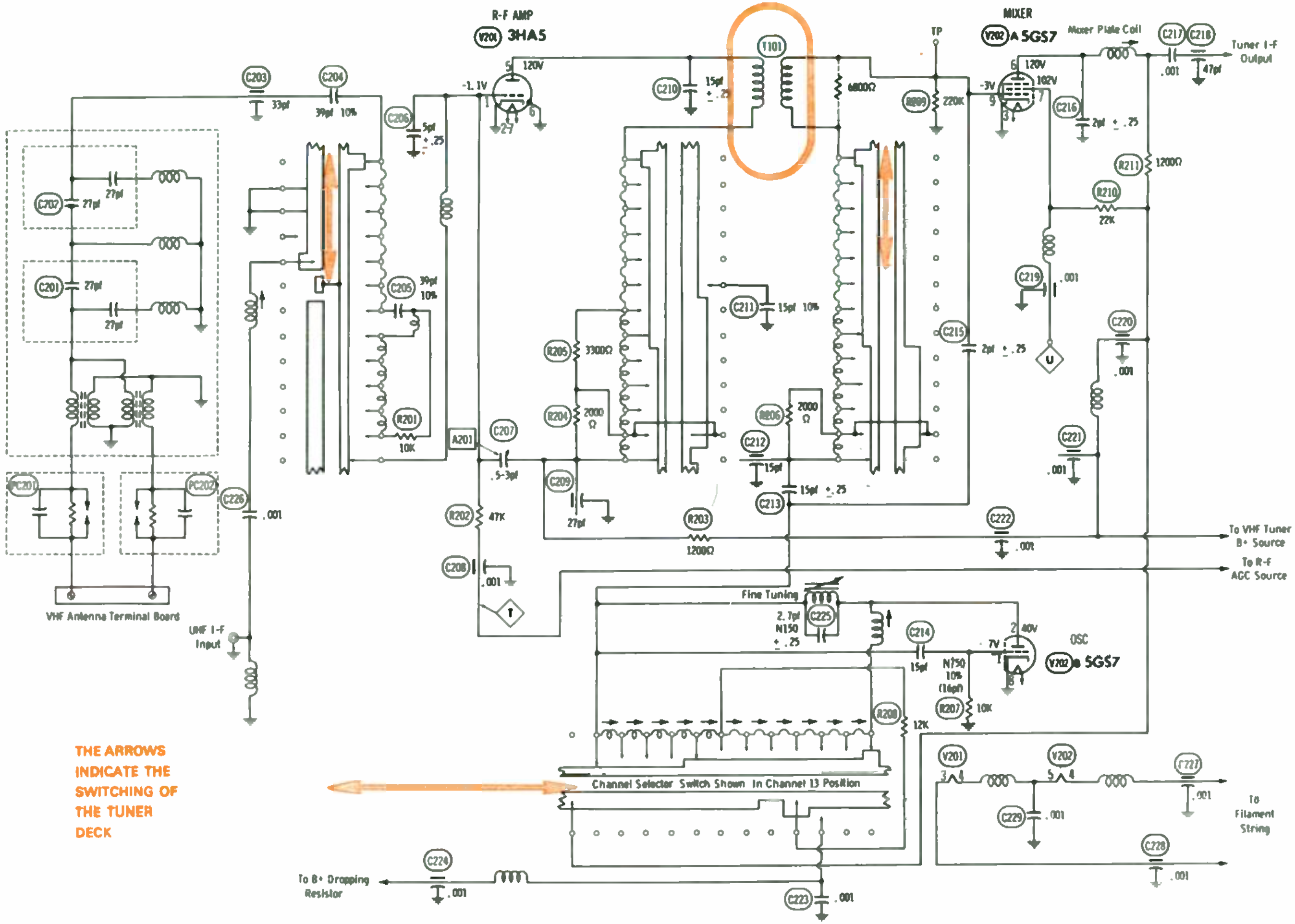


Figure 8 — Schematic of the tuner shown in Figure 7.

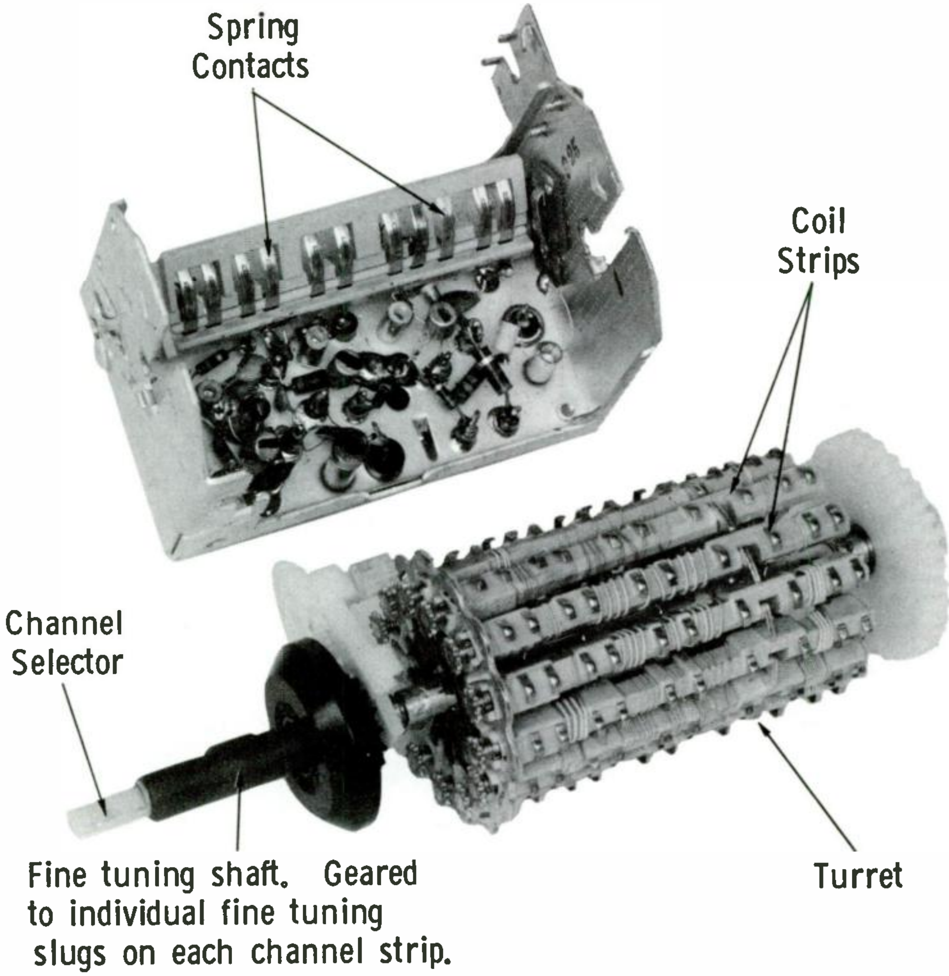


Figure 9 — A modern turret-type tuner.

The coils are mounted on strips which are clipped into the turret drum. The strips contain the input, RF plate, mixer grid, and oscillator coils. A spring-loaded mechanism and a detent lock the turret into position at the desired channel. The spring contacts are mounted on an insulated strip and contact the coil contact buttons. The fine-tuning mechanism is usually controlled by a shaft which is concentric with the channel-selector shaft. Each oscillator coil has a tuning slug which is oftentimes geared (in modern receivers) so that it can be controlled by the fine-tuning mechanism. In other sets, the slug can be reached through a hole at the front of the tuner.

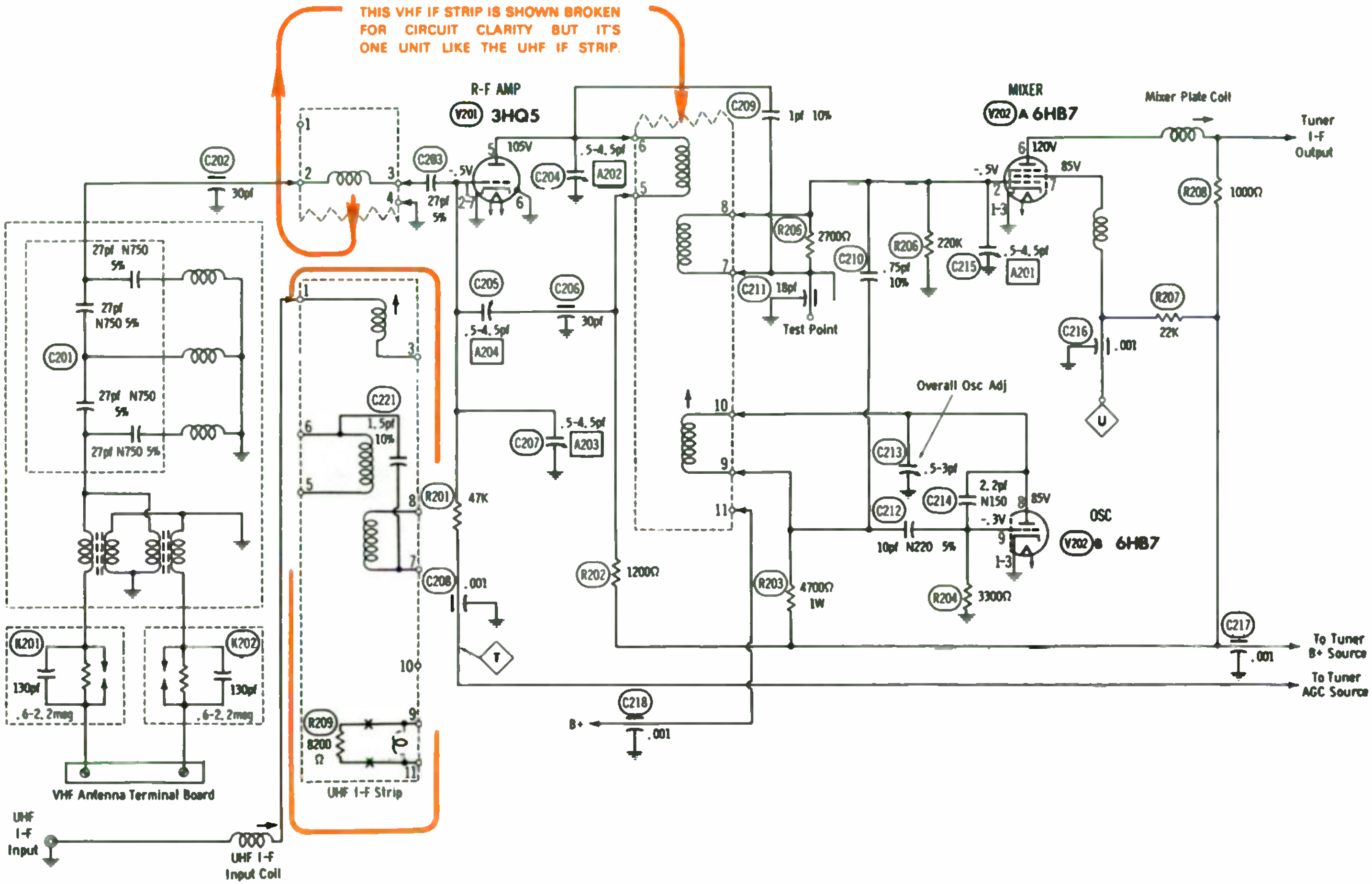


Figure 10 — Schematic of a turret-type tuner.

When the UHF tuner is employed in conjunction with the VHF turret tuner, a UHF IF strip usually occupies one position on the turret. The VHF tuner must then be set in the UHF position before UHF signals can be tuned in on the accompanying tuner.

Disc Tuners

A further development of the turret tuner is the disc tuner. Figures 11 and 12 show a disc tuner which combines certain principles of both the turret- and switch-type tuners. Attached to the shaft inside the tuner are large discs on which the tuning inductors are arranged. A detent mechanism resembling that of the turret tuner is provided to secure the rotating assembly in the desired channel position. Contact buttons and wipers, like those of the turret tuner, connect the disc to the external circuitry.

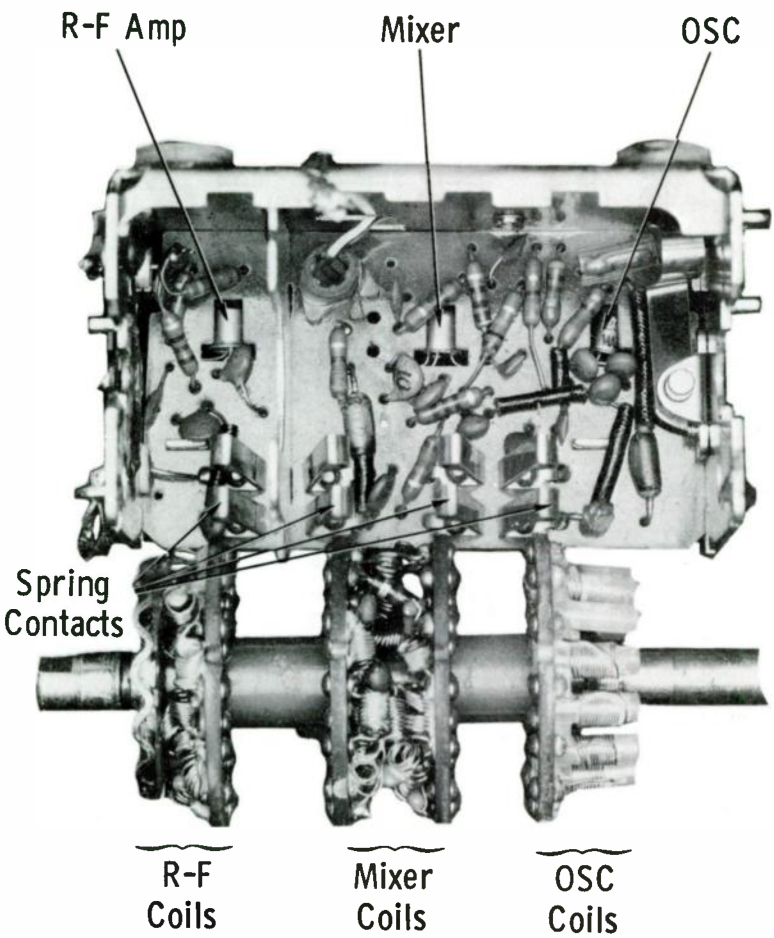


Figure 11 — Example of a modern disc-type tuner.

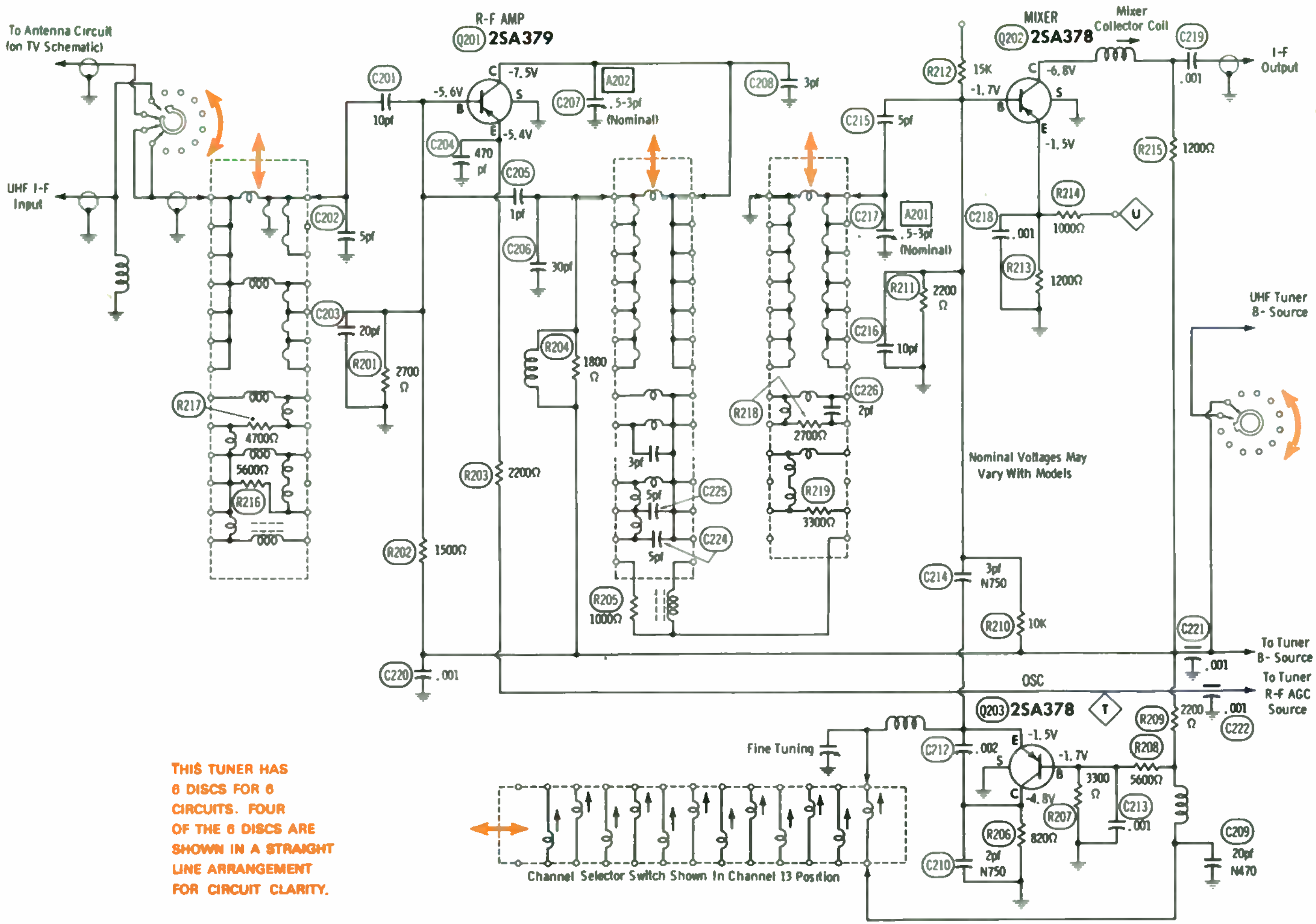


Figure 12 — Schematic of the tuner shown in Figure 11.

An important difference between the turret and disc tuners is that the disc tuner does not have a completely separate set of coils for each channel. There are several sets of basic coils plus incremental inductances which are switched in series with the basic coils to tune certain channels. The coils are broken into more separate groups in the disc tuner than in the typical switch tuner.

All of the contact buttons on the discs are arranged in a circular pattern. As the discs are rotated, their buttons make contact with stationary wipers mounted within the tuner as shown. All circuitry except that provided on the discs is included on a printed-circuit board.

Summary of the VHF Tuner Design

Of the different VHF tuner designs just discussed, the turret, disc, and switch types are the most popular in present-day receivers. Vacuum tubes and hand-wired circuits in VHF tuners are rapidly being replaced by solid-state components and printed-circuit wiring. Modern tuners, even those using tubes, are much smaller and more compact, and operate more efficiently than their older counterparts. Moreover, the newer tuners are provided with substantially better shielding and bypassing in order to prevent or minimize interference from other radio services.

UHF TUNING SYSTEMS

The tuners discussed so far have all been designed to receive the 12 VHF channels. Since the release in 1952 of the 70 UHF channels, however, tuners have been produced to receive these channels. In fact, *all* receivers built since 1964 are equipped with such tuners.

The reception of frequencies between 470 and 890 MHz presented many problems to the design engineer. The tubes available in 1952 were very inefficient at these frequencies. Also, the frequencies were too high for conventional lumped coil and capacitor tuning methods and too low for the waveguides and resonators employed in receivers operating at 1000 MHz and beyond. The methods which have been developed tend to strike a compromise between the lumped inductance and capacitance of low-frequency circuits and the distributed inductance and capacitance of high-frequency circuits. It is well to remember that a straight length of wire can possess inductance and that capacitance can exist wherever there is a difference of potential between two surfaces.

When the UHF channels were released, there were many VHF receivers already in the field. To enable these receivers to pick up the UHF broadcasts, UHF converters were designed. A UHF converter is simply a UHF tuner and mixer-oscillator circuit in its own cabinet and with an output signal on one of the VHF channel frequencies. This output frequency was usually adjustable, so that it could be placed on one of the unused VHF channels.

Those early receivers having turret tuners could be internally modified for UHF reception by removing unused channel strips from the turret and placing UHF channel strips in their places. Receivers without turret tuners had to use converters, however.

Many methods of tuning have been used for UHF reception. One of the most common has been the shorted quarter-wave or half-wave transmission line with a movable short. A transmission line possesses both inductance and capacitance, and these are distributed along the line. Any change in the length of the line will change the frequency to which it is tuned. To change the frequency, the movable shorting bar is ganged with the tuning control and dial indicator.

Another popular form of tuning is a transmission line with a variable capacitor across the open end of the line. This method is as good as the sliding shorting-bar method; an added feature is that no moving contacts are needed.

Figures 13 and 14 show a typical UHF tuner using capacitive tuning. Nearly all recent UHF tuners employ a transistor oscillator and a diode mixer as shown. Notice that a cavity-type arrangement is required due to the high frequencies involved.

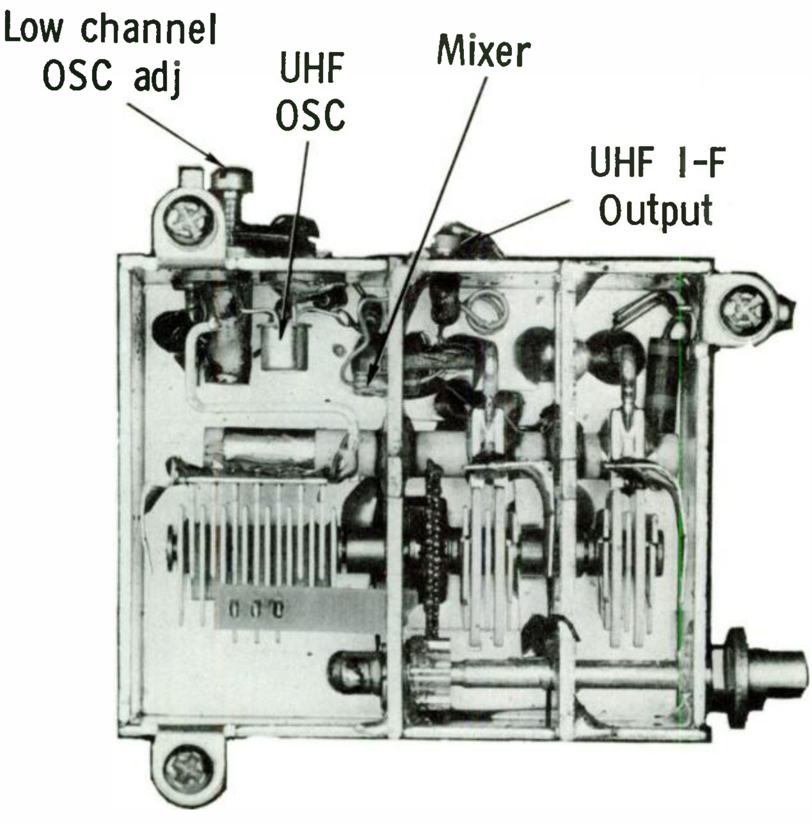


Figure 13 — Typical UHF tuner using capacitive tuning.

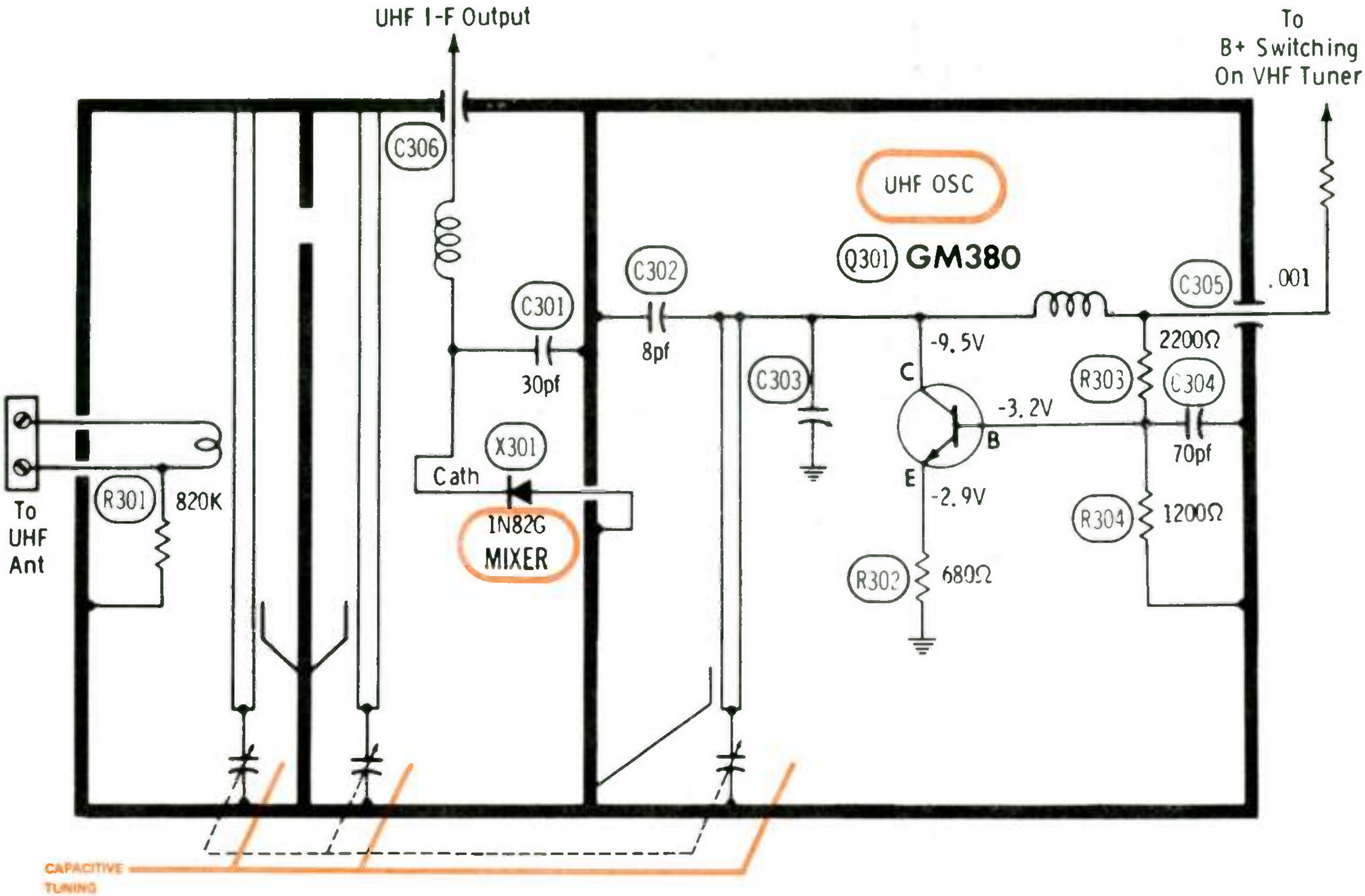


Figure 14 — Schematic of the UHF tuner shown in Figure 13.

TUNER PERFORMANCE CHECK

Manufacturers of TV sets usually publish complete alignment and adjustment instructions in their service manuals. In addition, they will include line drawings of different parts of the chassis to show the location of the different parts. A representative set of commercial instructions and a pictorial layout of the chassis are shown in Figures 15 and 16.

These two figures are reproduced exactly as they appear in the service manual published by Montgomery Ward. The manual contains 36 pages of installation and service instructions together with specific instructions on general alignment; video IF sweep alignment; bandpass, sound IF, detector, and trap adjustment; a replacement parts list; a complete wiring diagram; and pictorial views of both sides of each of the printed wiring boards. Manuals of this type generally have a separate wiring diagram of the tuner (Fig. 17). This manual also shows an exploded view of the mechanical parts of the tuner (Fig. 18).

TUNER OPERATION

In another service manual from Montgomery Ward, a complete description of the operation of a UHF tuner and a VHF tuner are given. These instructions cover a series of new chassis, and provide the service technician with complete information about the latest models. Figure 19 is the circuit diagram and Figure 20 describes the operation of the UHF tuner. The VHF portion of the tuner is shown in Figures 21 and 22.

Most tuners operate as described in Figures 20 and 22. Understanding the function and operation of each of the components in the tuners will provide the service technician with a firm basis when attempting to localize trouble. If the trouble has been found to be in either the VHF or UHF section of the tuner, it is sometimes better to have the tuner repaired by a shop that specializes in tuner repair and adjustment. Many experienced TV servicemen do not want to spend the money for all of the test equipment necessary to do a good repair job. In addition, the shop that specializes only in tuner repairs usually charges a nominal fee for each repair, thus making it possible for you to add a reasonable mark-up for your services. In addition, you are assured that you are providing your customer with an accurately adjusted tuner.

SUMMARY

Television tuners are designed to select a desired channel and convert both the picture signal and the sound signal to the proper IF frequencies. Modern day receivers usually use a video IF of 45.75 MHz and a sound IF of 41.25 MHz.

A well designed tuner will be able to accept both UHV and VHF channels, and will have nearly uniform gain over the entire bandwidth. It must also be able to reject adjacent, unwanted signals, and in addition it must prevent undesirable local-oscillator radiation.

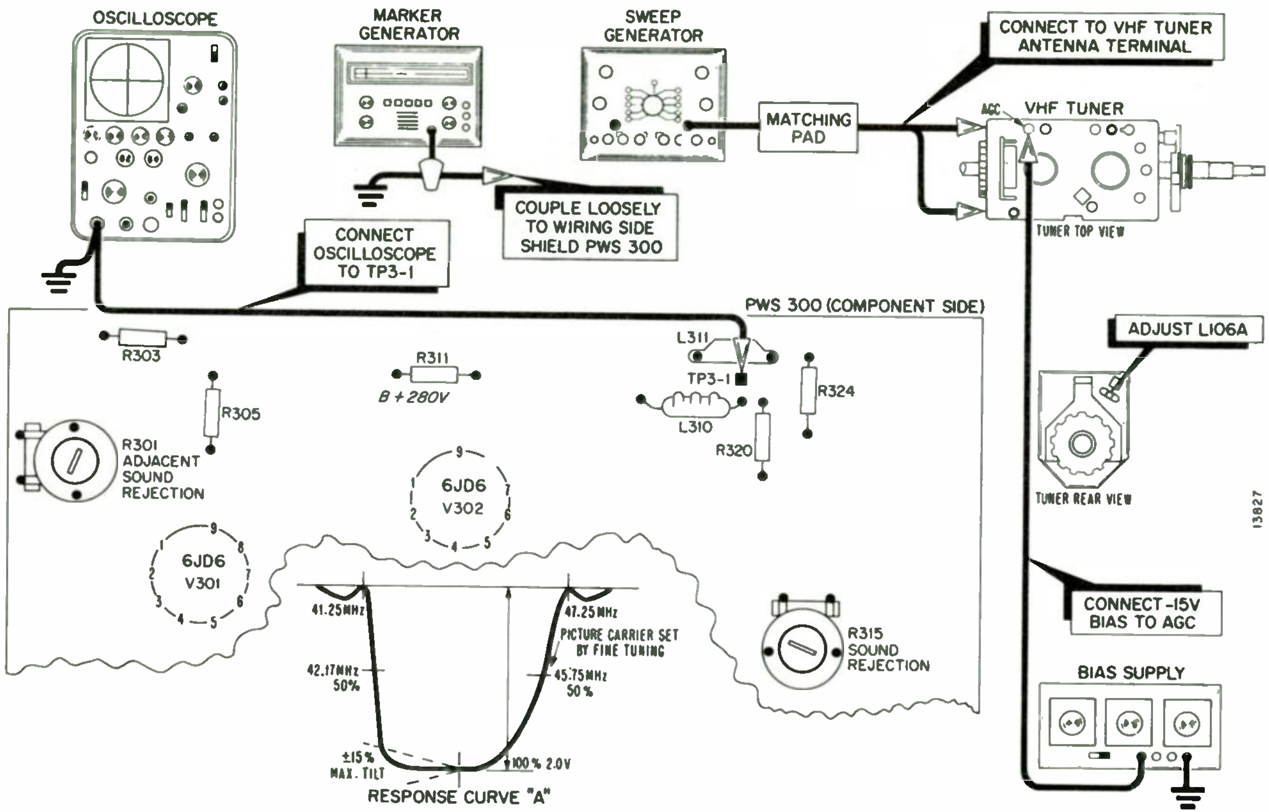


Figure 15 — VHF-UHF tuner performance check. Refer to Figure 16. Courtesy of Montgomery Ward.

VHF/UHF TUNER PERFORMANCE CHECK (Refer to Figure 15)

PRELIMINARY INFORMATION

Unless there is evidence of tampering or if electrical repairs have been made, tuner alignment is normally not required.

Response Curve "A" is an indicator of the quality of tuner performance. If the response curve is obviously bad on all channels, repair, rather than alignment, is indicated. Check the B plus voltages applied to the tuners. Also check for bad solder connections and contacts. Visually inspect the circuits for overheated components and obvious wiring defects.

If the response curve of the UHF tuner or individual channels of the VHF tuner are obviously bad while other VHF channels are normal, replacement of the UHF channel strip or the affected VHF channel strips may correct this condition.

NOTE: When checking overall RF-IF response curves, bear in mind that it is necessary to verify that the video IF circuitry is operating normally and is properly aligned before an evaluation can be made on the VHF RF-IF response curve. Also, it is necessary to verify that the video IF circuitry and VHF tuner are operating normally and that these circuits are properly aligned before an evaluation can be made on the UHF RF-IF response curve.

VHF TUNER PERFORMANCE CHECK

Test Equipment Connections

GENERAL . . . The set under test should be correctly fine tuned and the fine tuning should not be adjusted while performing this tuner check. Disable the horizontal sweep by removing the 6KD6 (horizontal output tube V702). Remove shield from component side of PWS300.

OSCILLOSCOPE . . . With a 2.0V P-P calibration, connect direct probe thru a 15K ohm resistor to test point TP3-1.

SWEEP GENERATOR . . . Connect output to the VHF tuner antenna terminals using proper matching pad.

MARKER GENERATOR . . . Connect markers at 45.75 and 42.17 MHz. loosely to wiring side shield of PWS300.

BIAS SUPPLY. . . Apply -2.5V bias to AGC terminal on VHF tuner. Adjust bias while chassis is operating.

CLIP LEADS. . . Use clip leads to ground terminal C (IF AGC) on PWS300.

Performance Check

Turn set "on" and allow a warm up period of ten minutes.

Starting with the VHF tuner placed in the Channel 13 position and the Sweep Generator set at the proper frequency, check the overall response curve as viewed on the Oscilloscope. This viewed curve should match, approximately, Response Curve "A". The same procedure should be used for Channels 12 through 2. If any channel does not have the proper response curve, replace the corresponding channel strip.

UHF TUNER PERFORMANCE CHECK

Test Equipment Connections

GENERAL . . . The video IF Alignment and VHF Tuner Check should be completed prior to this procedure. Disconnect the external antenna from UHF tuner. All equipment connections are the same as for the VHF Tuner Performance Check except the Sweep Generator.

SWEEP GENERATOR (UHF) . . . Connect output to UHF tuner antenna terminals using proper matching pad.

Performance Check

Turn set and test equipment "on" and allow a warm up period of ten minutes.

Place the VHF tuner in the UHF position.

Set the center frequency of the Sweep Generator at 700 MHz. and turn the UHF tuner to this frequency (approximately Channel 52) so that the overall RF-IF response curve can be observed on the Oscilloscope. Adjust L106A on the UHF channel strip so that the response curve is consistent with limits of the overall RF-IF Response Curve "A".

NOTE: The amplitude of the response curve should be kept at 2.0V P-P for this alignment.

Tune the Sweep Generator and the UHF tuner throughout the UHF range to check the overall performance.

NOTE: Slight adjustment of L106A may be necessary to keep the response curve within limits throughout the range.

Figure 16 — VHF/UHF tuner alignment. Refer to Figure 15. Courtesy of Montgomery Ward.

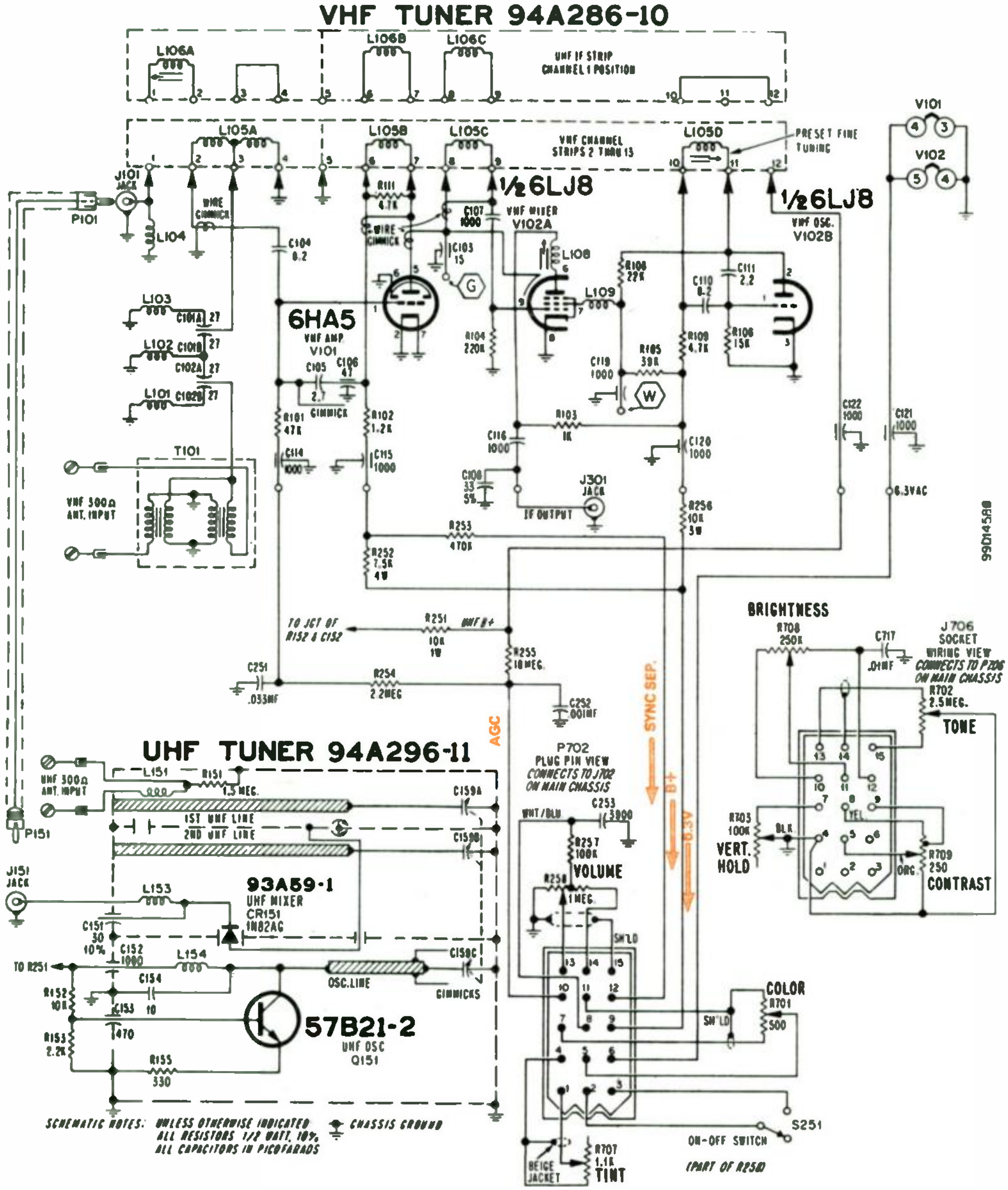
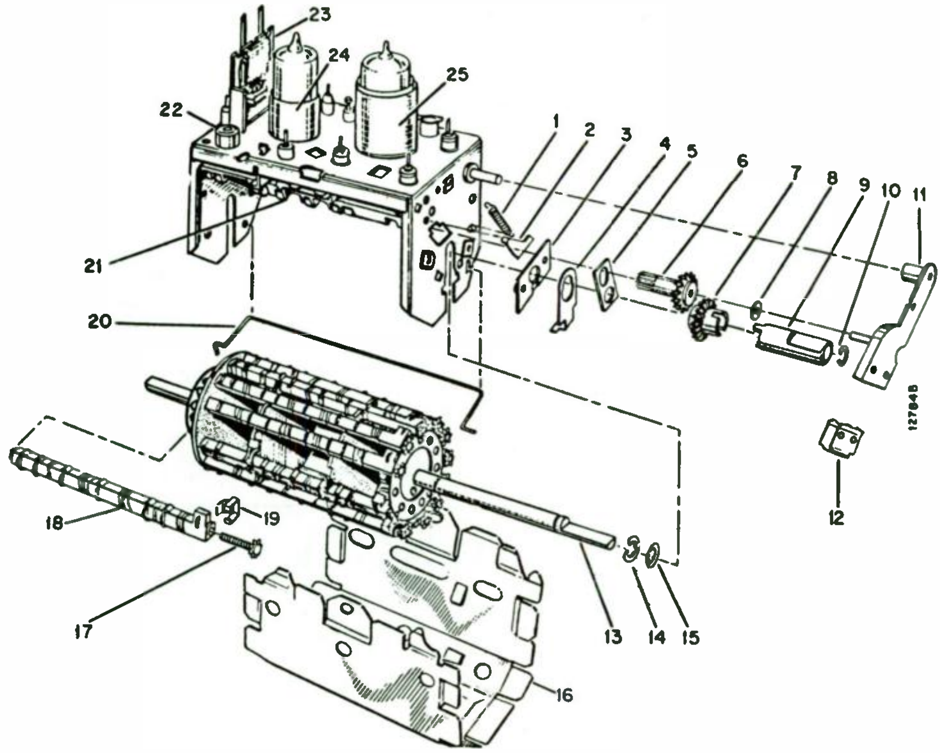
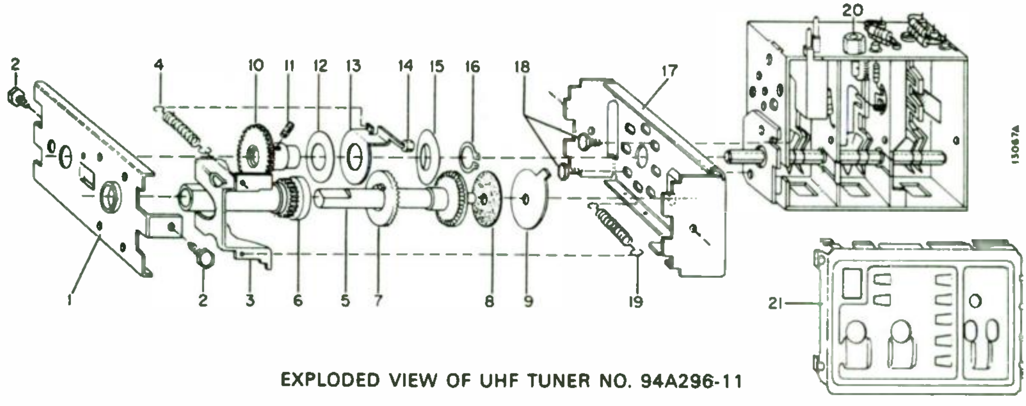


Figure 17 — Schematic of the VHF-UHF tuner assembly. Courtesy of Montgomery Ward.



EXPLODED VIEW OF VHF TUNER NO. 94A296-11



EXPLODED VIEW OF UHF TUNER NO. 94A296-11

Figure 18 — Mechanical design of the VHF/UHF tuner of Figure 17. Courtesy of Montgomery Ward.

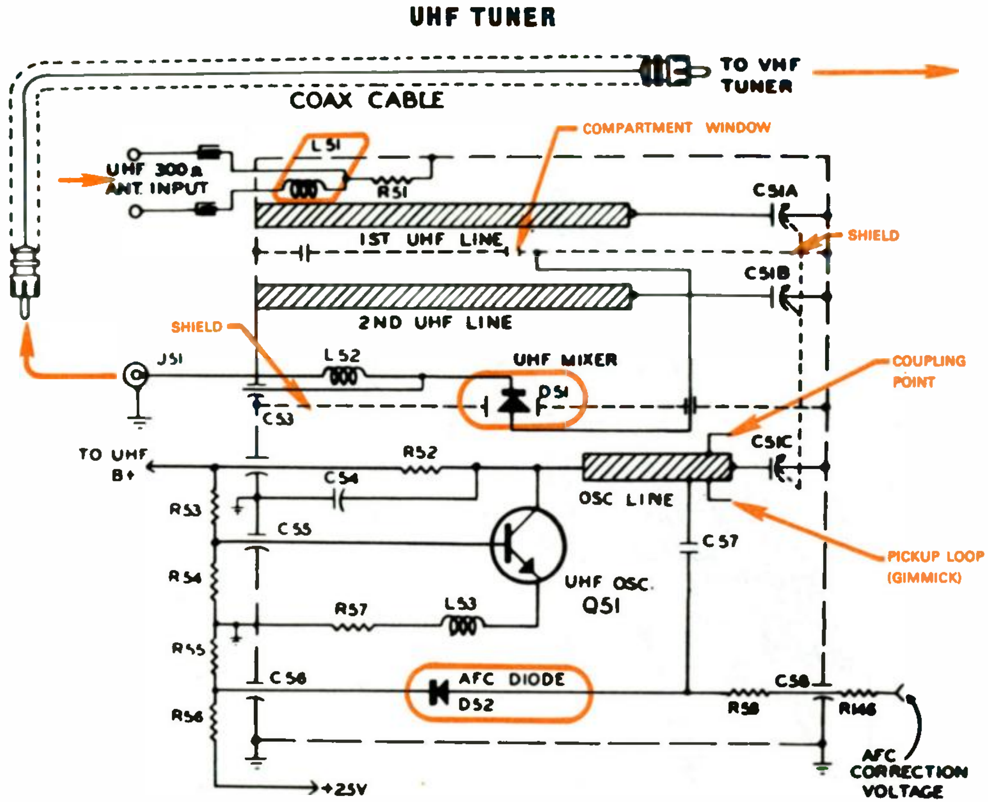


Figure 19 — Circuit diagram of the UHF portion of the tuner. Courtesy of Montgomery Ward.

UHF TUNER

These chassis use separate UHF and VHF tuners to cover all bands of frequencies assigned for television use.

The UHF tuner is the conventional three compartment type having antenna and mixer RF sections and a local oscillator section. Each compartment has a tuned line terminating in one of the capacitors of the tuning gang. These capacitors electrically shorten the line to function as quarter wave sections. These are operated at slightly below their resonance point where they appear as inductance.

The antenna terminates in a 300 ohm network and is coupled to the 1st UHF line by coil L51 located in the same compartment. The 1st UHF line is coupled to the 2nd UHF line by a small window between the two compartments.

Q51 transistor, located in the third compartment, generates a local oscillator signal at 45.75MHz above the desired picture carrier frequency. A pickup loop (or gimmick) couples this signal to the cathode of the mixing diode (D51) located in the second compartment. The station signal is coupled to the anode of D51 where the two signals heterodyne, producing a third frequency; the IF signal. This signal is coupled to the No. 1 (UHF) strip in the VHF tuner by the connecting cable.

AFC diode (D52) acts as a variable capacitance. If the reverse voltage applied to this diode is changed from a negative value to a less negative value, the capacitance of the diode increases in terms of picofarads. If the tuner oscillator is running too fast, the correction voltage applied to the diode will be less negative. A less negative voltage increases the capacitance of the diode which is in parallel with the oscillator resonant circuit. This action decreases the oscillator frequency in relation to the transmitted frequency. The advantage of C57 lies in the fact that the DC voltage on the variable capacitance diode and the resonant circuit can be separated and also the losses in the circuit are reduced.

When the VHF tuner is set at the UHF position, B+ voltage is supplied to the UHF tuner by contacts 11 and 12 on the No. 1 (UHF) strip. The VHF oscillator is killed by leaving contacts 10 and 11 open.

Figure 20 — Operation of the UHF tuner of Figure 19. Courtesy of Montgomory Ward.

VHF TUNER

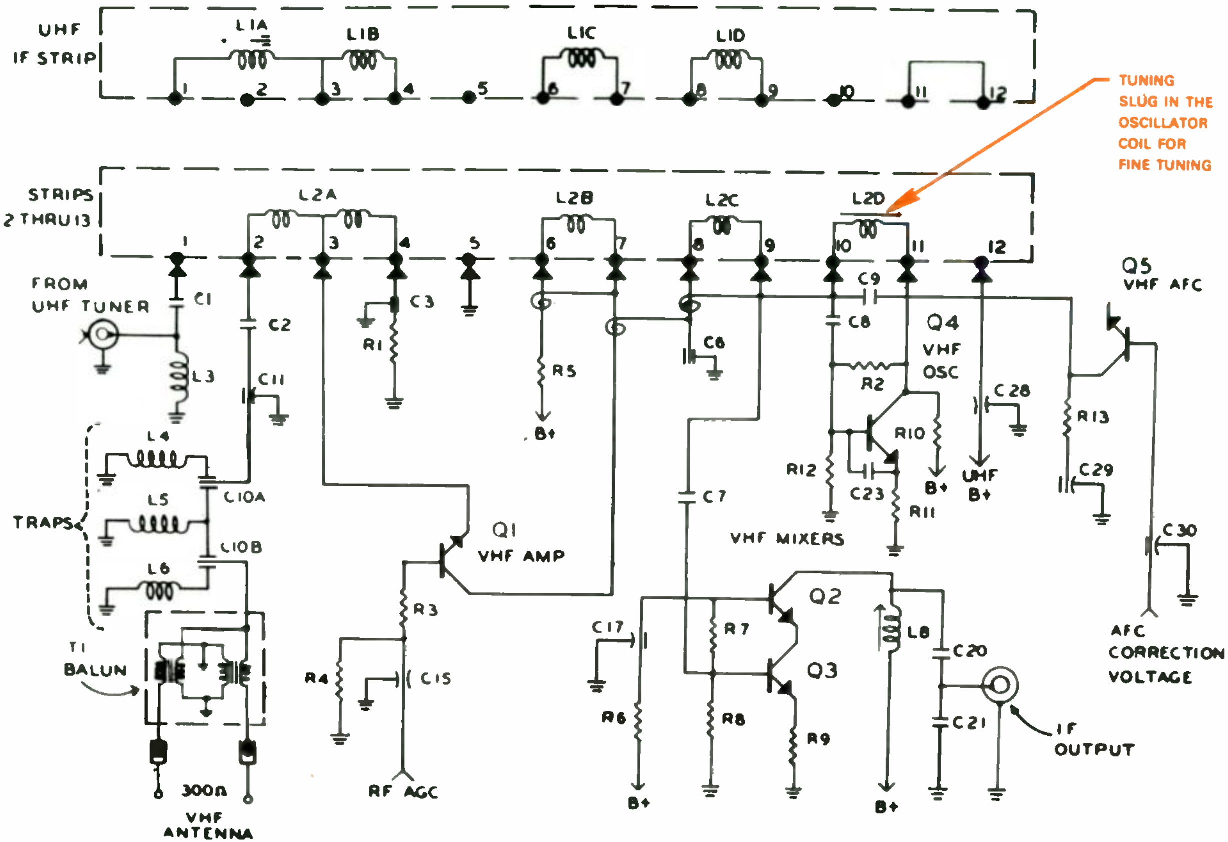


Figure 21 — Circuit diagram of the VHF portion of the tuner. Courtesy of Montgomery Ward.

VHF TUNER

The slug in the oscillator coil in each of the VHF strips is moved by a small gear on the end. As the fine tuning knob is turned, a friction lifting arrangement causes the gear train to mesh with the small gear on the oscillator coil; thus, enabling it to be precisely tuned for the station on that channel.

The antenna lead is attached to the 300 ohm balanced input terminals of the balun which converts the signal to 72 ohms balanced feed to the tuner. The signal passes through an IF trap and a FM band filter and is fed to the emitter of the VHF RF amplifier (Q1) by coil L2A.

Q1 is a common base NPN transistor which has better cross-modulation characteristics than the grounded emitter type. The base has delayed forward AGC applied to it. As this voltage increases, it turns the transistor on more, increasing the current flow which causes an increased voltage drop across R5, thereby reducing the amplification.

The collector of Q1 is inductively coupled to L2C and then capacitive coupled to the base of the VHF mixers (Q2 and Q3). Transistors Q2 and Q3 are connected in a cascade arrangement. Forward bias for Q2 is derived by the total current passing through R7. This is equal to the voltage divider current from ground through R8 which joins Q3 base current at the junction of R8 and R7 and then through R7 to B+. Q3 forward bias is developed by the current through R8. Q2 actually functions as though it were in a common-base circuit. This arrangement provides better stability over the entire frequency spectrum than the use of a single transistor arrangement.

The VHF RF oscillator (Q4) is also coupled to the base of Q2 and Q3 by capacitor C7. Here the signals heterodyne to form the (44MHz) IF frequency. This is amplified and is present across L8.

Figure 22 — Operation of the VHF tuner of Figure 21. Courtesy of Montgomery Ward.

Many methods have been used in tuners to select channels, with the two most popular being the disc- or deck-type and the turret-type for VHF. Tuners for UHF usually employ variable capacitors across the open end of what is a tuned transmission line. The service manuals issued by TV manufacturers usually contain specific instructions for checking the response of the tuner on all channels. If the tuner is found to be defective, it is best to have it repaired by a service organization that specializes in tuner repair.

TEST

Lesson Number 83

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-083-1.

1. A TV tuner selects the desired signal and applies it
   A. directly to the video amplifier.
   B. to the RF amplifier.
   C. directly to the lower oscillator stage.
   D. to the IF output of the UHF oscillator.

2. The signal from the RF amplifier and a signal from the local oscillator are heterodyned in the
   A. RF amplifier.
   B. IF amplifier.
   C. mixer stage.
   D. video detector.

3. Local oscillator energy
   A. must be suppressed to prevent radiation.
   B. will not radiate unless a signal is being received.
   C. cannot radiate as it is in a metal shielded housing.
   D. overloads the antenna and thus prevents radiation.

4. Transmission lines must always
   A. match the input impedance of the tuner.
   B. have an impedance of 300 ohms.
   C. have an impedance of 72 ohms.
   D. none of the above.

5. Modern TV tuners for VHF are either
   A. capacitive or inductive type.
   B. turret or capacitive type.
   C. deck or continuous type.
   D. deck or turret type.

6. Modern TV tuners employing vacuum tubes usually have
   A. the oscillator and mixer sections in two tubes.
   B. the RF and mixer sections in one tube.
   C. the oscillator and mixer sections in one tube.
   D. none of the above.

7. **UHF tuners usually employ the equivalent of**
   A. one tuned coil.
   B. transmission lines and variable capacitors. 17
   C. one tuned coil and one variable capacitor.
   D. a quarter-wave coil.

8. **The lumped coil and variable capacitor**
   A. method of tuning is not usable for UHF TV frequencies.
   B. method of tuning is suitable for use in UHF tuners.
   C. system in always used in UHF tuners.
   D. none of the above.

9. **The input, RF plate, mixer grid, and oscillator coils for each individual channel are mounted on a separate strip in the**
   A. disk tuner.
   B. artificial line input tuner. 12
   C. lumped equivalent tuner.
   D. turret tuner.

10. **The method of tuning employed by the UHF tuner shown in Figure 13 is**
    A. BFO tuning.
    B. miller tuning. 17
    C. capacitive tuning.
    D. inductive tuning.

Portions of this lesson from
Television Service Manual
by Robert G. Middleton
PHOTOFACT Television Course (3rd Edition)
by Howard W. Sams Editorial Staff
Courtesy of Howard W. Sams, Inc.

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

A FIRM FOUNDATION

As you near the completion of your Radio and TV Service and Repair lessons, it is right and proper that you review the principles of electronics, without which much of the equipment used would not even exist.

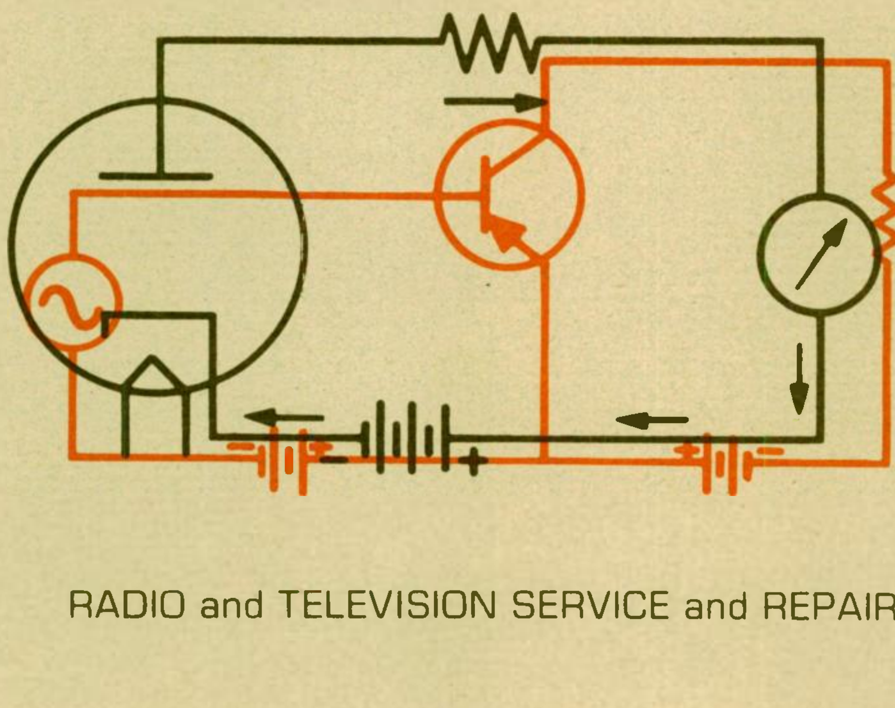
These important principles are worth reviewing not once but often—to refresh and recall information vital to forming a firm foundation on which to build your future as a skilled service technician.

S. T. Christensen

S. T. Christensen

LESSON NO. 84

TELEVISION IF SYSTEMS



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-084
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

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Contents

TELEVISION IF SYSTEMS

INTRODUCTION

Video IF amplifiers perform essentially the same functions in a TV set that IF sections do in AM and FM receivers. A video IF, however, must pass a broad band of frequencies. This is because each TV channel incorporates a band of frequencies 6MHz wide to include all the necessary picture, sync and sound information.

Certain problems appear unique to television IF systems. This is perhaps not due to differences in circuitry as much as it is to the fact that television sets display their symptoms visually. Trouble conditions (such as low IF gain, overload, oscillation or bandpass problems) can often be misleading due to their effect on the picture. There are numerous IF malfunctions that can affect picture quality or sync and confuse the serviceman.

Unstable sync that is due to an IF problem might cause an inexperienced troubleshooter to incorrectly assign the problem to the sync or sweep circuits. Similarly, poor picture quality might mislead the same technician into the video amplifier section.

Certain other problems that appear to originate in the IF section actually originate elsewhere. Automatic gain control (AGC) faults, for example, can *wash out* the picture, permit signal overload, picture distortion, loss of sync and many other ill effects. The affects on the signal occur in the IF section in these cases but the actual cause is elsewhere. In other words malfunctioning AGC circuitry for example, can causes the IF to malfunction.

In electronic products it is essential to understand the operation of various sections and stages before you can intelligently evaluate symptoms and localize problems. Unless you understand individual sections you cannot know how they work together and in the case of failure how performance is affected.

In this lesson we will provide functional descriptions of IF circuits along with how typical video

IF sections operate. Both vacuum tube and solid state units will be discussed.

SELECTION OF THE IF FREQUENCY

Very early TV receivers employed various IF frequencies but soon nearly all manufacturers had standardized with an IF in the 20 MHz region. Unfortunately, these sets were subject to interference from the 15 meter band. TV intermediate frequencies were subsequently changed during the 1950's to 40 MHz. Today's systems operate with the video carrier at 45.75 MHz and the sound carrier at 41.25 MHz. The receiver's IF must be capable of passing both the 41.25 MHz and 45.75 MHz frequencies, all the various frequencies between, and the upper sideband of the video carrier. The total required response or passband of a good quality TV IF must approach 5.0 MHz in order to reproduce an acceptable picture.

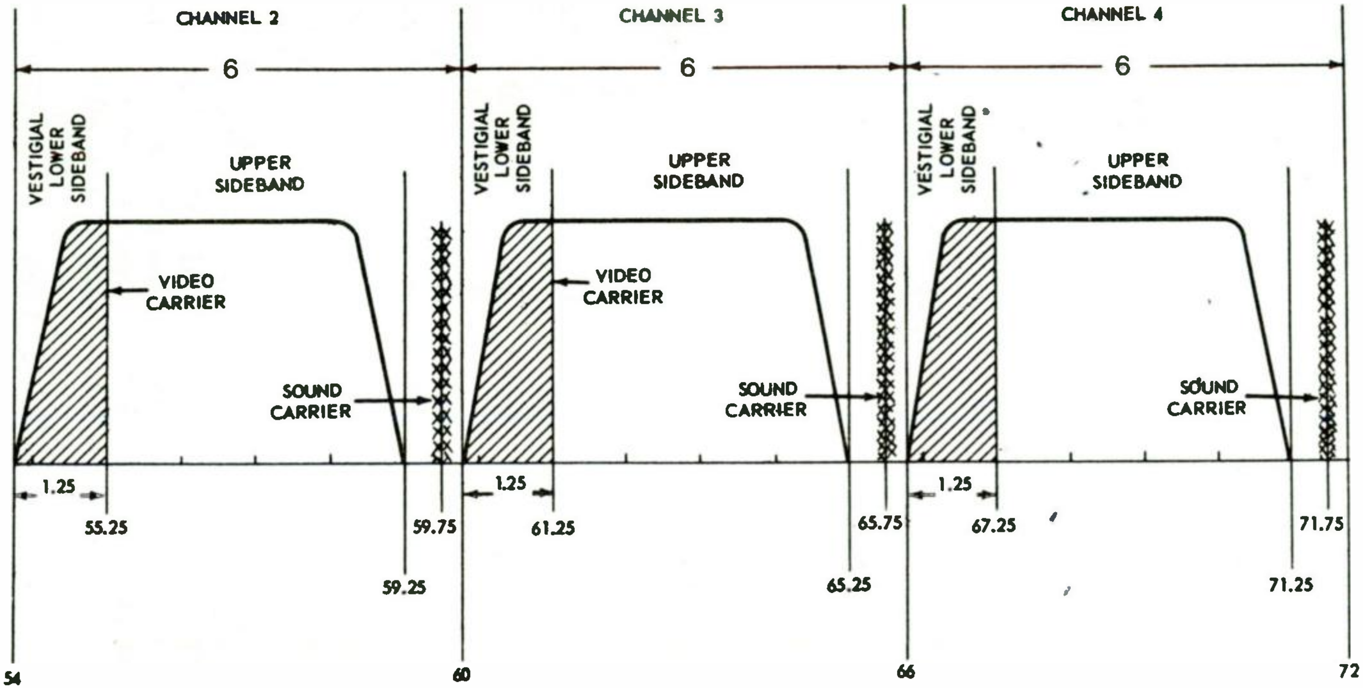
To obtain the required bandwidth a variety of techniques are employed. Basically these include over-coupling, stagger-tuning and stacked systems. In addition, LC or LCR traps are included to help shape the passband. These traps are primarily employed to eliminate interfering signals from the channels immediately above and below the station being received.

There are several reasons for the seemingly elaborate IF circuitry in television receivers. Several of these reasons will be discussed in the following text.

FIRST: For RF spectrum economy, the lower video sideband is greatly suppressed, and the video information is contained largely in the unsuppressed upper sideband. The remaining portion of the lower sideband is the vestigial sideband. The general form of the television RF spectrum is shown in Figure 1.

Because it is impracticable to remove all of the lower sideband, the response curve of the video IF stage must have a special form. In general, the response curve is similar to that shown in Figure 2. It may be seen that the video IF has a higher frequency than the sound IF. This results from the fact that the local oscillator operates at a higher frequency than that of the incoming signal.

That portion of the sidebands extending 1.25 MHz on both sides of the video carrier contains more energy than the sidebands beyond 1.25 MHz (Fig. 1). This results from the fact that both upper and lower sidebands exist in the 1.25 MHz bandwidth in the immediate vicinity of video carrier; whereas, beyond 1.25 MHz, only the upper sideband is present. If the IF amplifiers were flat over the video band, the frequencies between 0 and 1.25 MHz on each side of the video carrier would be overemphasized at the second detector. In other words, the amplitude of these signal frequencies would be greater than that of the remaining frequencies in the upper sideband of the video signal because of the increased energy associated with the frequencies between 0 and 1.25 MHz on each side of the video carrier.



NOTE: ALL FREQUENCIES SHOWN ARE IN MHz.

Figure 1 — RF spectrum for TV channels 2, 3, and 4.

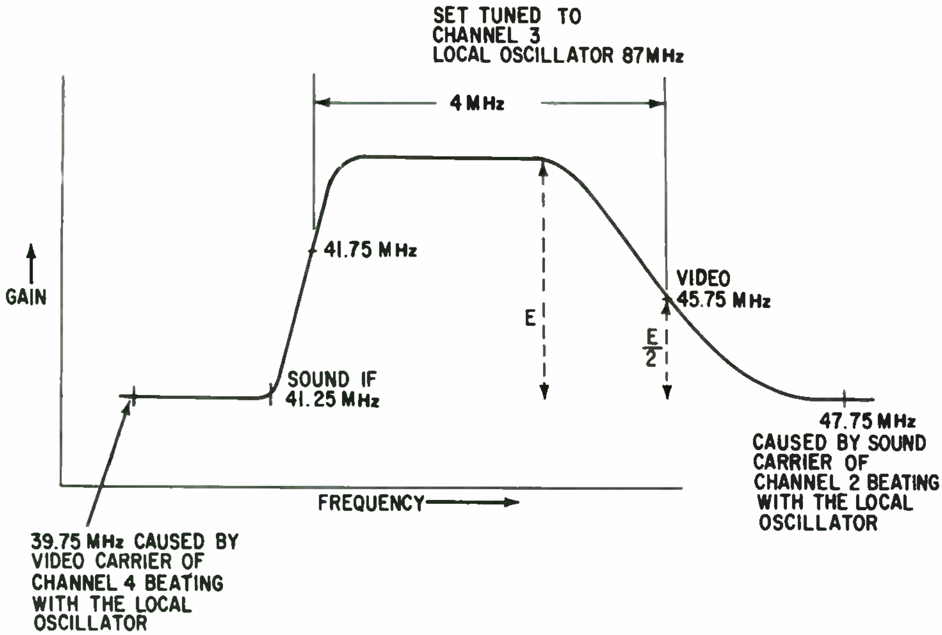


Figure 2 — Video IF response curve.

In order to achieve uniformity in the magnitude of the output video signal for all frequency components, the IF stages are adjusted so that the video IF carrier falls about halfway down on the upper slope of the response curve. The lows are therefore amplified less than the highs, and a more uniform response is achieved. For example, a receiver tuned to channel 3 having a video carrier of 61.25 MHz may have a local oscillator frequency of 107 MHz. The IF bandwidth will then extend from 107-61.25 = 45.75 to 107-65.25 = 41.75, or a total of 45.75-41.75 = 4 MHz. In the alignment of video IF stages, this adjustment is very important.

SECOND: Because the response characteristic of the RF and converter stages is intentionally broadened to pass the desired range of frequencies (6 MHz), the sides of the response curve taper off gradually. This means that undesirable frequencies may be passed through to the video IF system, which may cause horizontal bars to appear on the picture. For example, it is assumed that a television receiver employing a *split-sound* system is tuned to channel 3. (In a split-sound system the audio is taken off before the detector stage; whereas, in *intercarrier-sound* systems the audio is taken off after the detector stage.) The frequencies (39.75 MHz, 41.25 MHz, and 47.25 MHz) that may cause trouble on the television screen are indicated in Figure 2. The 39.75-MHz beat note, caused by the combining of the video carrier (67.25 MHz) of channel 4 with the local oscillator frequency (107 MHz), is close enough to the desired frequencies to be passed through to the video IF system. Likewise, the 47.25 MHz beat note, caused by the combining of the sound carrier (59.75 MHz) of channel 2 with the local oscillator frequency (107 MHz), is close enough to be passed also. Of course, the sound IF (41.25 MHz) of channel 3 is the signal most likely to get through and must be trapped out. In intercarrier systems this frequency, which beats with the video IF to produce the 4.5 MHz sound IF, must not be removed until after the sound IF (4.5 MHz) has been fed to the audio channels.

Some representative trap circuits are shown in Figure 3. An absorption trap is shown in 3A. The trap is tuned to the undesired frequency, and the output voltage (at the undesired frequency) developed across L is greatly reduced. It is therefore effectively removed from the input to the next stage.

A degenerative trap is shown in Figure 3B. At its resonant frequency (the undesired frequency) the trap offers a high impedance and this causes degeneration and reduced gain at that frequency.

A series-resonant trap is shown in Figure 3C. The trap is tuned to the undesired frequency and thus shunts these frequencies around the input of the stage.

The parallel-resonant trap, shown in Figure 3D, offers a high impedance to the undesired frequency. Thus, the offending voltage is dropped across the trap circuit and is not available at the input of the next stage.

Bridged-T Networks. Figure 4 shows a network of circuit elements known as the *bridged-T.* These circuits use a T-shaped branch consisting of two capacitors and a resistor (C_1, C_2, and R_1) bridged by inductor L_2 to reject the unwanted associated sound and adjacent-sound IF carriers.

This arrangement acts like a bridge circuit, but has the advantage of the input and output circuits having a common terminal at ground potential. Balance (for a null or low output) occurs when the reactance of the variable inductance equals the reactance of the capacitors in series and when the resistor in the center leg of the T is approximately one-fourth the parallel resistance of the tuned circuit. The circuit also acts as an anti-resonant trap in the line with a secondary balance for the resistance losses of the circuit. Much sharper null notches and greater rejection can be obtained with the bridged-T connection than with the trap circuit alone. Another variation of the bridged-T circuit (not illustrated) employs a center-tapped coil for the resistance branch and a single trimmer for the capacitance branch.

A bridged-T can eliminate a narrow band of frequencies and thus replace the function of two or more single frequency traps.

Although trap circuits are commonly employed in the video IF stages, they are sometimes also included in the video amplifier of television receivers.

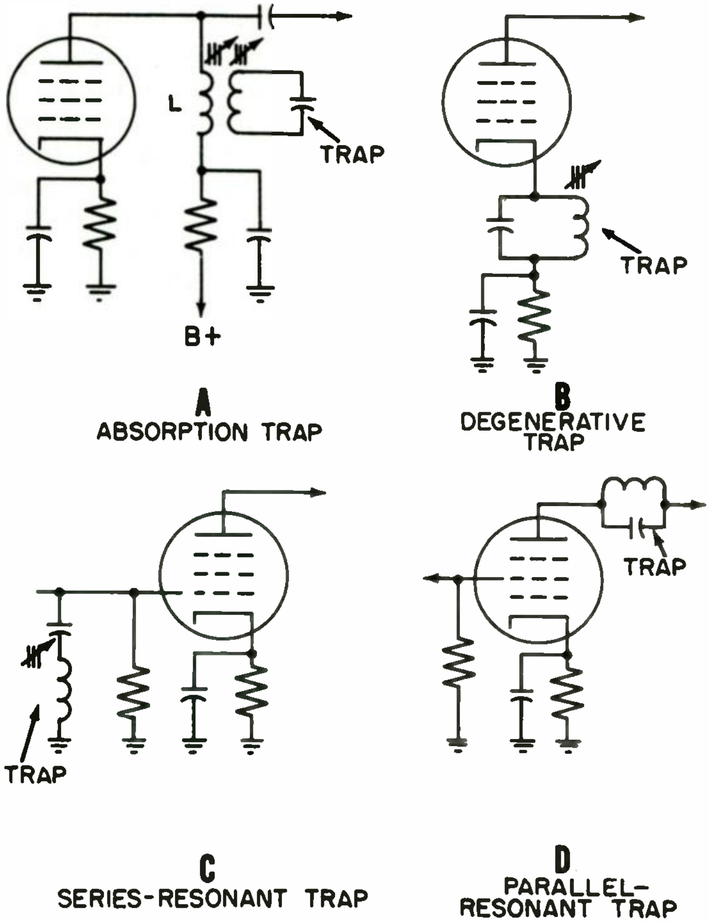


Figure 3 — Trap circuits.

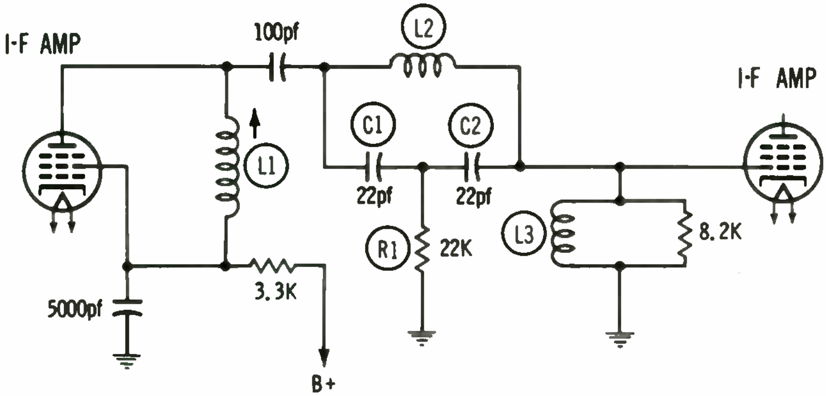


Figure 4 — The bridged-T network used as a trap.

THIRD: In order to pass the necessary wide band of frequencies, most television receivers employ a stagger-tuned IF system. Each stage is tuned to a slightly different frequency to broaden the overall response curve. As an example, it may be assumed that a quality television receiver, employing split sound and stagger tuning, is tuned to channel 3. It may be assumed also that the local oscillator operates at 107 MHz.

The video IF is
107 MHz - 61.25 MHz = 45.75 MHz
and the sound IF is
107 MHz - 65.75 MHz = 41.25 MHz

AN EARLY STAGGER-TUNED IF

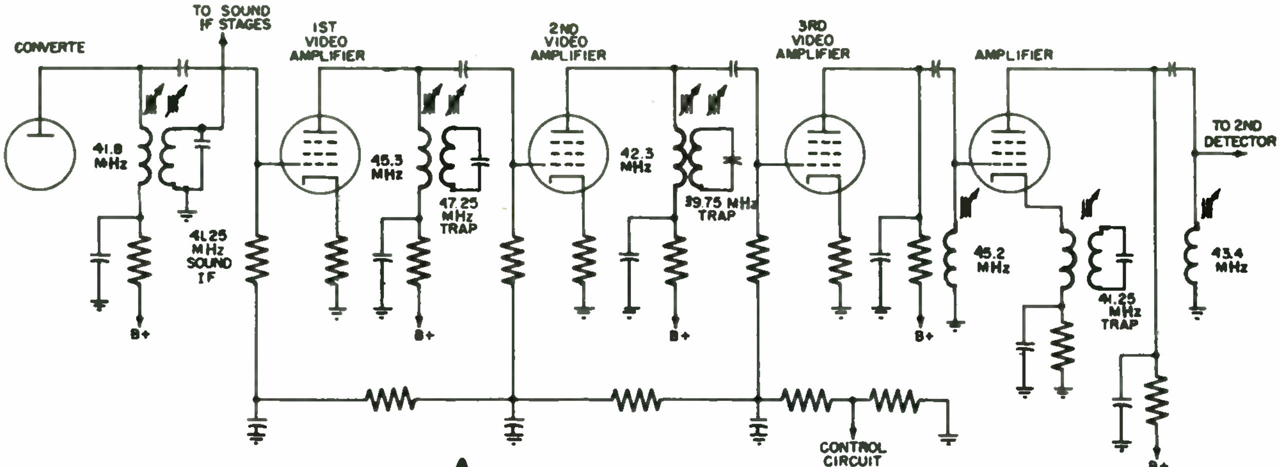
The IF passband requires precise alignment of all resonant circuits. Figure 5A shows schematically an older IF section typical of some TV sets of the early 1950's. The input coil is resonant to 41.8 MHz. An absorption trap is inductively coupled to the input IF coil and serves to trap off the sound carrier (41.25 MHz).

The second video IF is resonant to 45.3 MHz and it helps boost frequencies in that portion of the curve. A 47.25 MHz absorption trap is inductively coupled to the second IF and it serves to remove interference that might occur from the lower adjacent channel's sound carrier.

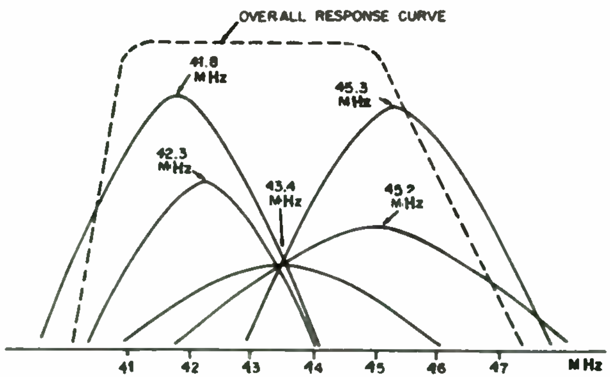
A third IF at 42.3 MHz in association with an absorption trap tuned to 39.75 MHz provides the steep slope necessary on the low frequency side of the curve. The steep slope assures immunity from interference from the adjacent channel but will pass required frequencies in the desired channel. The 39.75 MHz trap removes frequencies associated with the upper adjacent channel's video carrier.

A fourth and fifth IF are provided, with resonant frequencies of 45.2 MHz and 43.4 MHz respectively. Figure 5B shows how these tuned circuits effectively boost frequencies through the middle and upper portions of the curve. A final trap at 41.25 prevents sound from interfering with the video. An ideal response curve is shown in Figure 5B. A curve such as this will pass all the frequencies necessary for good picture quality and reject adjacent channel interference.

The prior discussion is related to a set having a separate sound channel. This method of handling the sound carrier is no longer used; having been replaced by the intercarrier's system. With the intercarrier system a sound IF of 4.5 MHz is derived after detection of the video as a result of the beat developed between the video carrier frequency and the sound carrier frequency. In the intercarrier system both video and sound carriers (with their sidebands) are amplified through the video IF section. A 4.5 MHz take-off coil removes the sound carrier at some point after the video detector. All future discussions relative to video IF and detector circuits relate to sets with intercarrier sound.



A SIMPLIFIED IF SECTION OF TV RECEIVER EMPLOYING SPLIT SOUND



B APPROXIMATE IF RESPONSE CURVES

Figure 5 — IF section and response curve.

CURRENT IF SYSTEMS

The video (picture) channel consists of the sections from the tuner to the picture tube—the video-IF amplifier, video detector and the video amplifier. These are the circuits which amplify and process the video signal for application to the picture tube to reproduce the picture.

The television receiver is a high-frequency superheterodyne, most of the gain is contributed by the IF amplifiers. Recall that there are actually two IF signals at the mixer output—the video IF and the sound IF. These two frequencies are separated by the 4.5 MHz at the transmitter. The response of the IF amplifiers is made wide enough that both frequencies are passed. In the video detector, the sound-IF and video-IF are beat together to produce the 4.5 MHz intercarrier sound signal.

In early television receivers the sound and video IF signals were separated directly at the mixer output, and separate IF amplifiers were employed for the video and the sound. This method was called *split sound*; however it is not employed in any modern receivers. All modern receivers use the intercarrier principle.

IF Requirements

The requirements of the television IF amplifier system are far more complex than the IF amplifiers in broadcast receivers. In broadcast receivers, the IF amplifiers must pass a band of frequencies only 10 kHz wide. In FM receivers, the bandwidth requirements are only 200 kHz. In a television receiver, however, the IF amplifier must pass a band of frequencies *5 megahertz* wide. In addition to the requirement of passing the wide band of frequencies, other frequencies must be attenuated so that they cannot cause interference in the desired channel. These frequencies are:

1. Sound carrier of the adjacent lower channel.
2. Video carrier with its modulation in the next higher adjacent channel.

In addition, the sound IF of the desired channel must be reduced to a level far below the video carrier within the IF amplifier system. If the sound carrier is not reduced, sound bars (interference) will appear in the picture.

The number of stages of amplification varies among the different manufacturers and the intended application of the receiver (fringe or local reception). Sets with only one IF amplifier or as many as five stages have been produced. Most receivers, however, employ two or three stages of IF amplification.

In the previous section, it was stated that the use of 45.75 MHz as the video IF and 41.25 MHz for the sound IF was practically universal in modern receivers. Formerly, many other frequencies were used as the sound IF. Some of them are listed in Figure 6.

Video-IF Response

Recall that in vestigial-sideband transmissions (Fig. 7A), the amplitude of the transmitted signal is

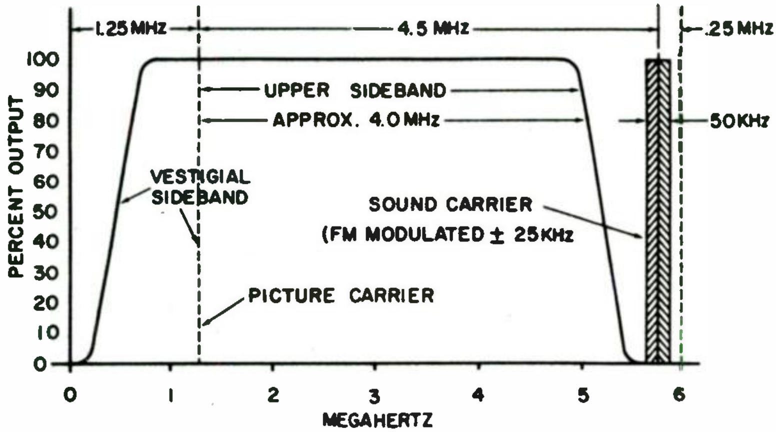
Video IF Carrier (megahertz)	Sound IF Carrier (megahertz)
15.2	10.7
22.9	27.4
25.75	21.25
26.1	21.6
26.2	21.7
26.4	21.9
26.25	21.75
26.6	22.1
26.75	22.25
37.3	32.8

Figure 6 — Some formerly used video and sound IF frequencies.

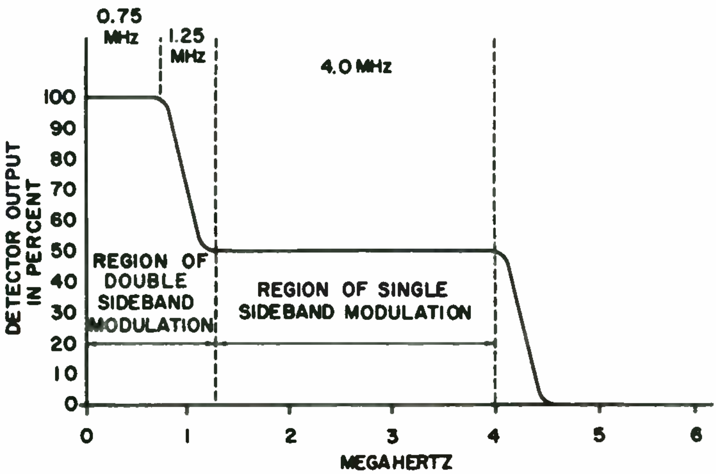
practically constant from approximately 0.75 MHz below the video carrier to 4.0 MHz above the carrier. Also between 0.75- and 1.25 MHz below the carrier, a portion of the lower sideband is transmitted. Thus, if such a carrier and its sidebands were to be applied to a linear detector, the output would be as pictured in Figure 7B. Obviously, such an output would not give the desired results. With the response of Figure 7B, all objects which result in a video frequency up to 0.75 MHz from the carrier would receive twice the amplification as those from 1.25 to 4.0 MHz. Between 0.75- and 1.25 MHz, the response tapers gradually from 100% to 50%.

Some method of compensating for the increased low frequencies due to the double sideband transmission must be provided in the video IF amplifier. This compensation is provided by reducing the amplification at the carrier frequency and increasing it at the higher frequencies. Thus, the ideal video response should appear as shown by curve B in Figure 8. Curve A in Figure 8 shows the transmitted carrier. In curve B, the video carrier is set at the 50% point, and the areas between 0.75 MHz above and below the carrier are less than 100% of the response. However, by adding the portion of the response between 0.75 MHz below the carrier and the carrier to the response between the carrier and 0.75 MHz above the carrier, the curve at D will result. Thus, these two portions of the curve when added together result in an overall 100% response between the carrier and the 0.75-MHz point.

It is impossible to obtain the straight-line response of curve B in Figure 8. Notice, however, the curve at C will also add to the desired response. At the high-frequency end of the response, the ideal curve is depicted by curves A and B. Usually, however, the high-frequency response is tapered off as shown by curves C and D. This tapering off at the high frequency end does reduce the fine details in



A Vestigial-sideband transmission.



B Response obtained by linear detection of A.

Figure 7 — The effect of linear detection of the carrier.

the picture but it is not noticeable in the average scene. In practice, few receivers provide more than 3.0 MHz response.

Up to this point, the discussion has been concerned with the frequencies as they are transmitted. That is, the video carrier in Figure 7 and 8 is shown at the low end of the response curve and the sound carrier is shown at the high end. Recall, however, that the receiver local oscillator frequency is higher than the transmitted carrier frequency; therefore, in the IF amplifiers, the sound-IF will be located at the low end of the response curve and the video-IF will be at the high-frequency end. Also, in an actual receiver, the ideal response of Figure 8 is seldom obtained. The

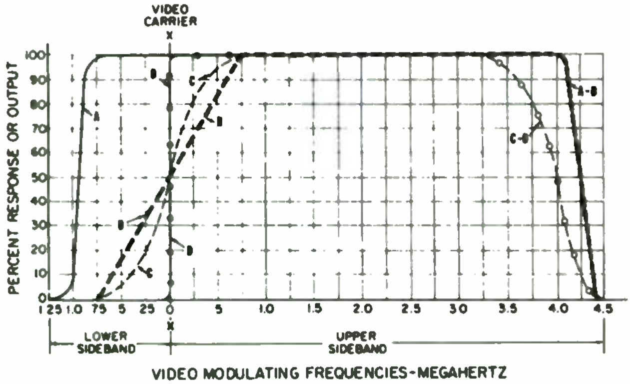


Figure 8 — Overall receiver characteristic required to compensate for vestigial-sideband modulation.

actual response of the IF amplifier section will usually appear similar to the curve of Figure 9.

IF Traps

In addition to providing amplification of the desired frequencies, the video-IF amplifiers must also prevent certain undesired frequencies from being amplified and passed on to the following stages. This function is performed by trap circuits in the IF amplifier stages. Based on the 41.25- and 45.75-MHz sound- and video-IF frequencies, traps are usually included for the following frequencies.

1. 39.75-MHz adjacent-channel picture carrier.
2. 41.25-MHz co-channel (desired) sound carrier.
3. 47.25-MHz adjacent-channel sound carrier.

Two types of traps are employed—shunt and absorption traps.

The shunt trap (Fig. 10) consists of a series resonant tank connected

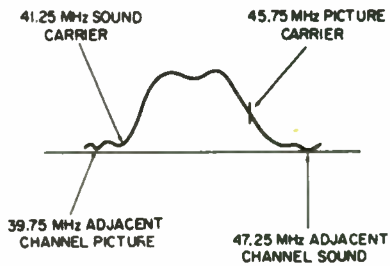


Figure 9 — A typical video IF response.

in shunt (parallel) with the input circuit. This circuit presents a low impedance to any signals at the resonant frequency of the coil and capacitor. Thus, any signals at these frequencies will be shunted to ground. The adjustment on the coil permits precise adjustment of the trap to the desired frequency. Either the coil or the capacitor can be made adjustable; however, in actual practice, the coil is usually made adjustable.

The absorption trap (Fig. 11) consists of a parallel-resonant circuit inductively coupled to the IF transformer. At the resonant frequency, maximum current flows in

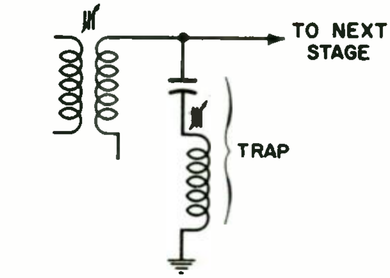


Figure 10 — The shunt trap.

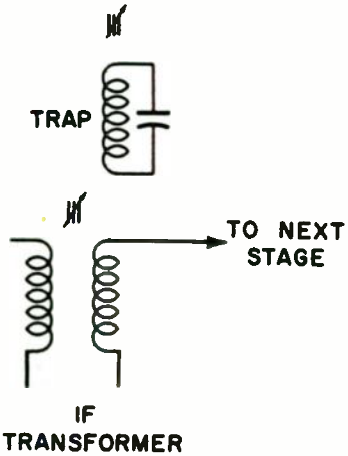


Figure 11 — The absorption trap.

the trap circuit. This current must be absorbed from the IF transformer; therefore, any currents at the trap resonant frequency present in the IF transformer secondary will be removed.

IF Amplifier Circuits

As mentioned previously the IF amplifier circuit must be capable of passing a wide band of frequencies. The video modulation extends approximately 4 MHz from the carrier. In addition, the sound-IF carrier located 4.5 MHz from the video carrier must be passed. The sound-IF carrier, however, must not be allowed to receive the same amount of amplification as the video carrier if the circuit is to function properly. Usually, the amplitude at the sound-IF frequency should be approximately 10% of the peak level. For this reason, traps tuned to the sound-IF frequency are usually included in the video IF circuit to reduce the sound-IF frequencies.

An ordinary amplifier stage would be unable to amplify the wide band of frequencies necessary in the IF system. Therefore, some means must be employed to increase the bandwidth. Three basic circuits are used for video-IF amplifiers. As mentioned previously they are:

1. Overcoupled amplifiers.
2. Stagger-tuned amplifiers.
3. Stacked and shifting amplifiers.

Overcoupled IF Amplifiers

A typical overcoupled IF amplifier circuit is given in Figure 12. If the primary and the secondary of a transformer are tuned to the same frequency and the coupling between the circuits is increased, a double-humped response curve is obtained as shown in Figure 13. By proper loading, the top of the curve can be flattened, and a wide-band response obtained. The overall gain is less than for the single-peaked response of loose coupling, but the bandwidth is increased. In Figure 12, L_1, L_2, and L_3 are overcoupled transformers—each primary and secondary is tuned to the same frequency. In circuits such as this, a

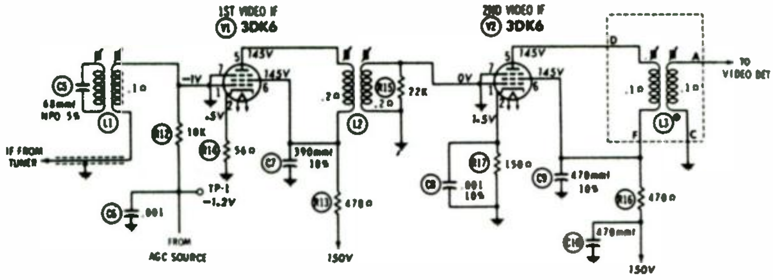


Figure 12 — A typical overcoupled IF amplifier.

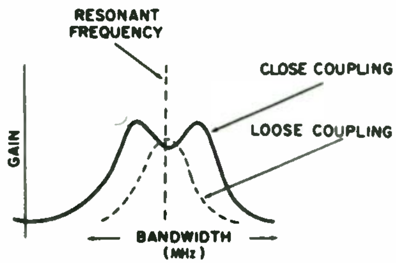


Figure 13 — The effect of loose and close coupling.

response approximately 3-MHz wide can be obtained. While some of the fine detail will be lost if only 3-MHz response is obtained, very little difference will be noted in the picture.

The primary of L_1 and C_5 in Figure 12 form an absorption trap at the sound-IF frequency. This is a popular variation of the circuit shown in Figure 11. An AGC voltage, which varies in step with the signal strength is applied to the grid of the first IF amplifier to control the gain of this stage.

Stagger-Tuned IF

In the stagger-tuned IF system, each IF stage is tuned to a different frequency in the passband. Figure 14 shows the effect of stagger tuning. Two stages are tuned to two separate frequencies. The response curves of the two individual stages are indicated by the solid lines in Figure 14. However, the overall response of the two stages will be as indicated by the dotted line. Thus, by proper choice of frequencies and circuits, the response can be widened to obtain the desired response.

Figure 15 shows a typical stagger-tuned, video-IF circuit. Notice that each tuned circuit is tuned to a different frequency. L3 is the 47.25-MHz adjacent-sound trap.

Stacked and Shifting IF Amplifier

The circuit in Figure 16 is very similar to a cascode RF amplifier circuit. All plate and screen current for V1 must flow through V2. Of course, to maintain the proper operating voltages, the cathode and grid of V2 are returned to the B+ circuit. Operation is the same as if they were returned to ground and a lower B+ voltage applied to the plate and screen.

Two advantages are obtained by stacking the first two stages: (1) the

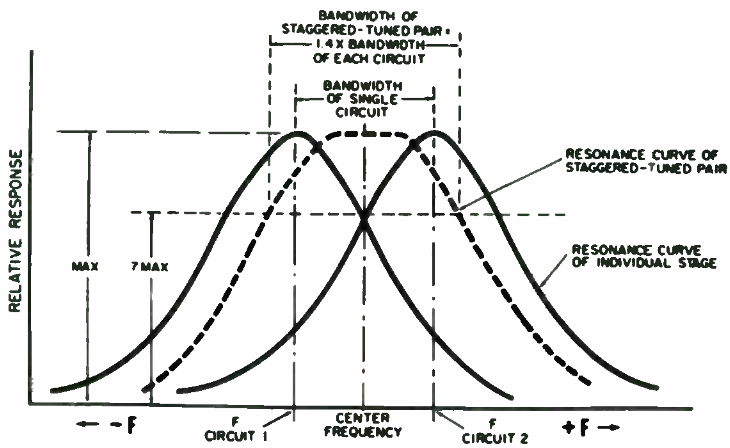


Figure 14 — The effect of staggered tuning.

overall current drain on the power supply is reduced, and (2) the second stage regulates the plate voltage of the first, improving the signal-to-noise ratio. By applying AGC voltage to the first stage, both stages are controlled.

Stagger-tuned transformers are used at L_{1B}, L_{3B}, and L_4. The final transformer (L_5) is overcoupled to obtain a broad overall response.

When a weak signal is received, the response of the first two stages shifts toward the sound-IF frequency, producing improved sound, and less fine detail (snow) in the picture. This shift is obtained by use of the *Miller effect*. The Miller effect is caused by the capacitance between the grid and plate of the tube multiplied by the gain. Ordinarily, components are chosen to minimize this effect, but in this circuit it is emphasized. When the AGC voltage is reduced, the gain of the stage increases. The Miller capacitance, in parallel with the grid tank of V2, increases, changing the resonant frequency of this circuit and shifting the overall response.

Notice, that three trap circuits are included in the input circuit of V1. In addition, a fourth trap can be connected in the circuit by closing switch M_5. An additional 47.25-MHz adjacent-sound trap (L_{3A}) is included in the plate circuit of V1. The circuit in Figure 16 is typical of those employed in higher-priced TV receivers. It has one more stage of amplification and many more components than the circuits of Figures 12 and 15.

Figure 17 depicts a basic transistor IF amplifier configuration. The third IF transistor operates as higher power than the first two because the video detector requires appreciable power input. Transistor Q25 operates with a collector voltage of approximately 15 volts, and an emitter current of about 15 ma. The collector load impedance is nominally 1000ohms; however, transformer T8 provides some step-up voltage for the video detector.

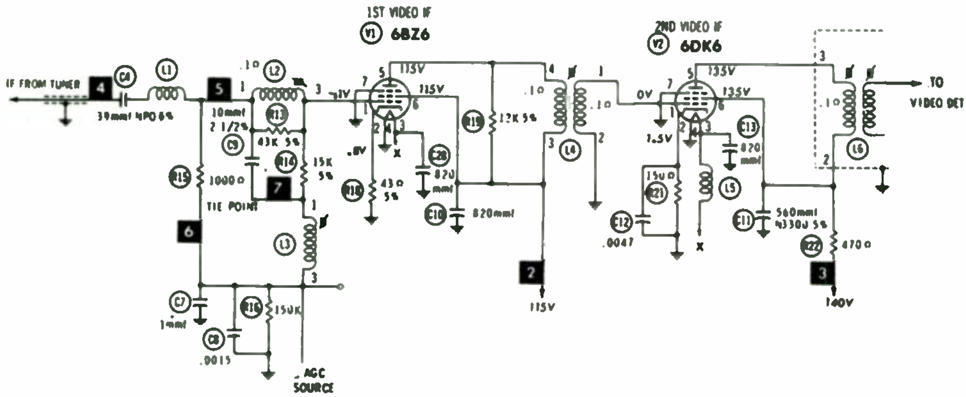


Figure 15 — A typical stagger-tuned video IF amplifier.

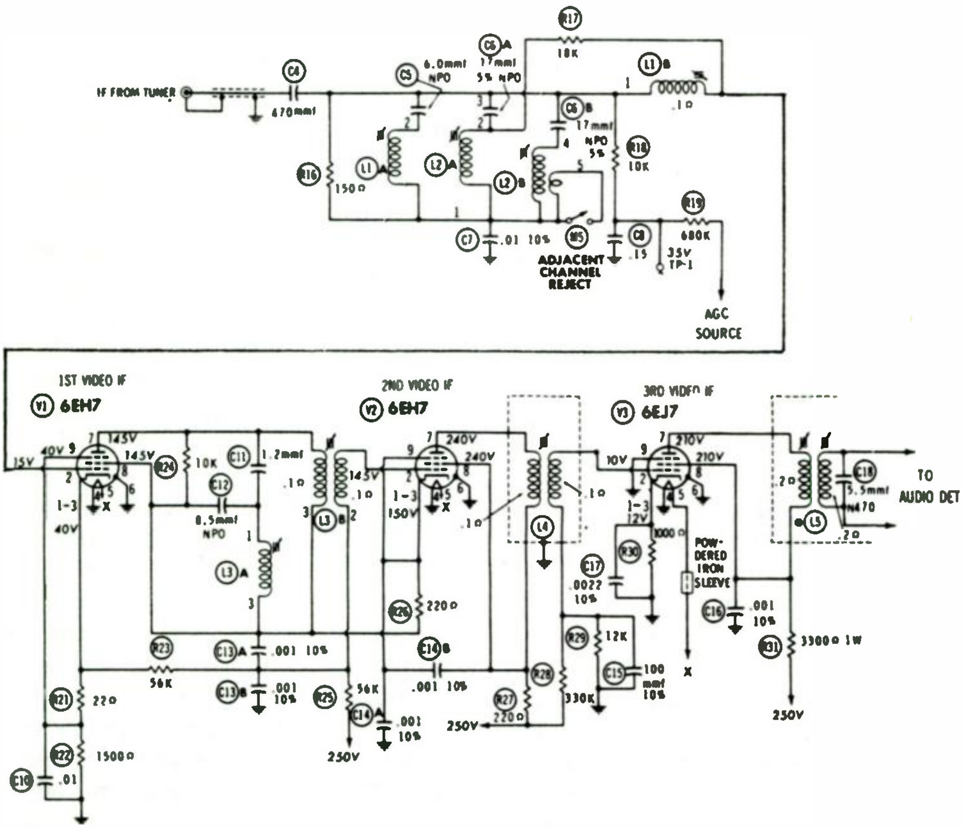


Figure 16 — A typical stacked-and-shifting video IF amplifier.

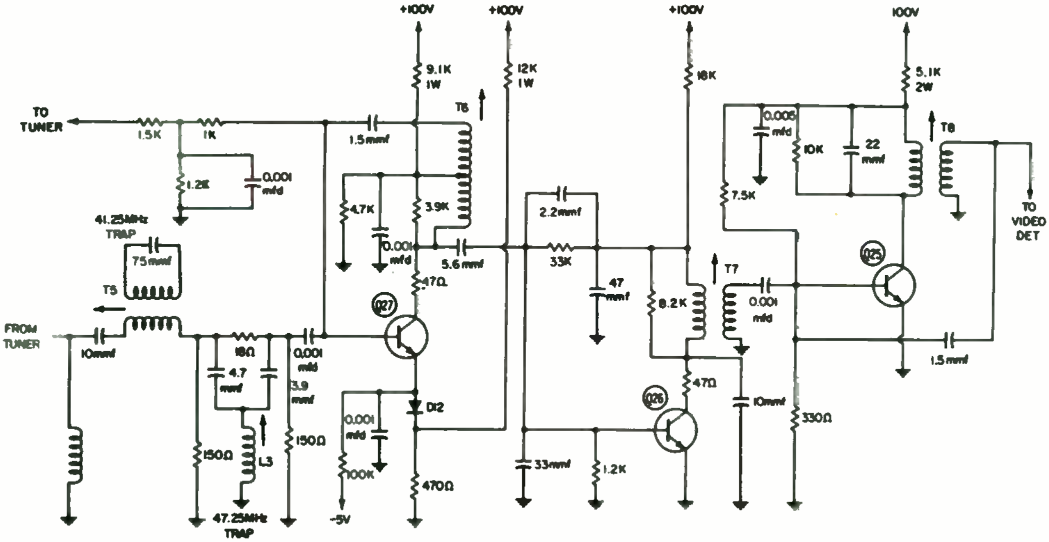


Figure 17 — Video IF amplifier circuit.

The power gain of this stage is about 18 db. It is neutralized by a 1.5-mmf capacitor connected from the base of Q25 to the secondary of the collector output transformer.

The first stage in Figure 17 operates at 15 volts on the collector and an emitter current of 4 ma. Reverse AGC is applied to the base of Q27; this is conventional AGC action in which the transistor is AGC-biased toward cutoff. The minimum collector current of Q_{27} under strong-signal conditions is approximately 50 μa. Q_{27} has a dynamic range of 40 db. Diode D_{12} is a clamp diode which becomes reverse-biased to prevent Q27 from being completely cut off when the AGC voltage reduces the RF tuner gain to a very low value. Q27 is neutralized by the 1.5-mmf capacitor connected from its base to T6.

Two traps are connected into the input circuit of Q27 in Figure 17. The first is an inductively coupled trap, and the second is a bridged-T configuration. These are the accompanying-sound and the adjacent-sound traps, respectively. The collector load for Q27 is a simple resonant circuit, with a tap to provide an out-of-phase neutralizing signal. Transistor Q26 is base-driven via capacitance coupling. This second stage is not AGC-controlled, and operates continuously at maximum gain. The base bias circuit for Q26 provides some negative feedback, which assists in obtaining a properly-shaped IF response curve. The collector for Q26 is a bifilar-transformer.

VIDEO DETECTORS

The video-IF amplifier is followed by the video detector, which is essentially the same as the second detector in AM broadcast or short-wave radio receivers. However, two significant circuit differences in the TV video detector must be taken into consideration: (1) a means of compensation must be used to prevent the loss of the higher video frequencies, and (2) the polarity of the detector output must be considered.

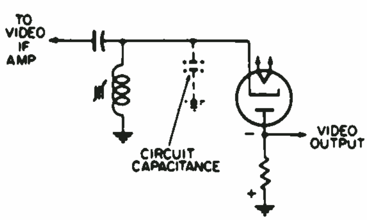
The video signal may be applied to the grid or to the cathode of the picture tube. To what element the signal is applied, and the number of amplifiers between the detector and the picture tube determine the polarity of the detector-output signal.

If there is an even number of video amplifiying stages between the detector and the picture-tube grid, the detector output must be negative-going. In other words, an increase in IF carrier strength at the detector results in a more negative video signal with respect to ground. Figure 18A shows a detector which supplies a negative picture polarity.

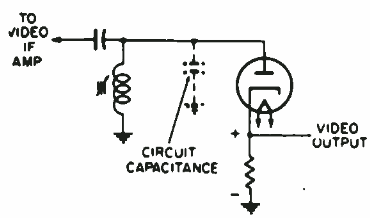
If an odd number of video amplifying stages are employed (in most instances, this will be a single stage) and the video signal is applied to the grid of the picture tube, the detector must be connected as shown in Figure 18B. This circuit with the plate of the diode connected to the high side of the video coupling circuit, produces a video output which becomes more positive as the video carrier strength is increased.

A typical video detection and amplifying system employing a video signal of negative polarity from the diode is shown in Figure 19. Load resistor R_2 has a value of 3,900 ohms and has associated with it a group of circuit elements, C_3, L_3, L_4, and R_1. These elements assist in producing a flat video response from 30 Hertz to more than 4 megahertz.

A significant difference between a radio detector and a video detector is in the value of the load resistor. In the second detector of a radio, a typical diode load varies from 0.5 to 2 megohms and maintains this high load resistance over the range of frequencies required for sound reproduction. In most instances, no frequencies higher than



(A) Video output increases negatively with respect to ground as carrier increases.



(B) Video output increases positively with respect to ground as carrier increases.

Figure 18 — Diode-video-detector output polarity.

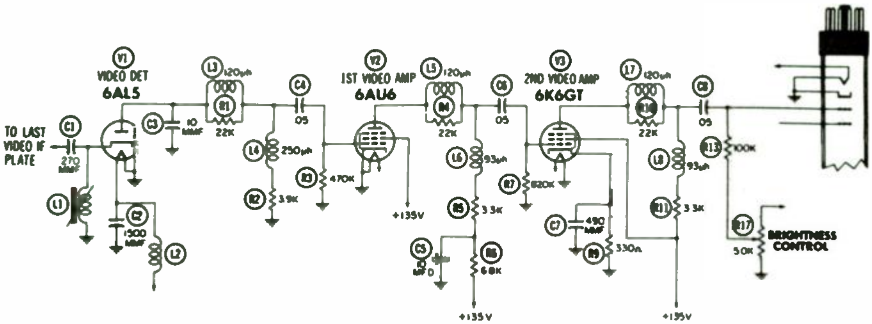


Figure 19 — Videodetector of negative polarity feeding picture-tube grid through two video-amplifier stages.

5,000 Hertz are involved. In the video detector, however the capacitance of the diode and the capacitance to ground of its associated circuit prevent the use of a high diode load resistance because flat response to at least 4 megahertz must be provided. At these high frequencies, the circuit reactance and tube capacitance would become lower than the load resistance and thus bypass the high frequencies. For this reason, the load resistance is made the low value; and the compensating elements just discussed produce a resonant rise of circuit impedance at the high end of the video band. L_3 is a series-peaking choke and L_4 is a shunt-peaking choke. These compensating elements are employed in each video stage. (See L_5-L_6 and L_7-L_8 in Fig. 19.) A more complete discussion of their function will be presented when video amplification is considered.

Figure 20 shows a video detection and amplification system employing the diode with its plate connected to the high side of the IF input circuit in order to produce a positive-going video signal. The polarity of the signal is inverted once by the single video-amplifier stage; thus, a more negative voltage is produced at the picture-tube control grid as the carrier strength increases. A combination of L_3 and C_4, together with the circuit capacitances, resonates at the high end of the video band and maintains a flat response from the detector.

In Figures 19 and 20, the video-output tube is coupled to the control grid of the picture tube. For circuit simplification in some receivers, the picture-tube input is inverted, and the video-output tube is coupled to the cathode rather than to the control grid. A positive-going rather than a negative-going signal must be fed to the picture-tube cathode. Figure 21 shows an example of a circuit employing a negative output detector V1 with a single-stage amplifier V2 feeding the cathode of picture tube V3.

The Crystal-Diode Detection. Small fixed crystal rectifiers (Fig. 22) are being used extensively as a substitute for the thermionic diode.

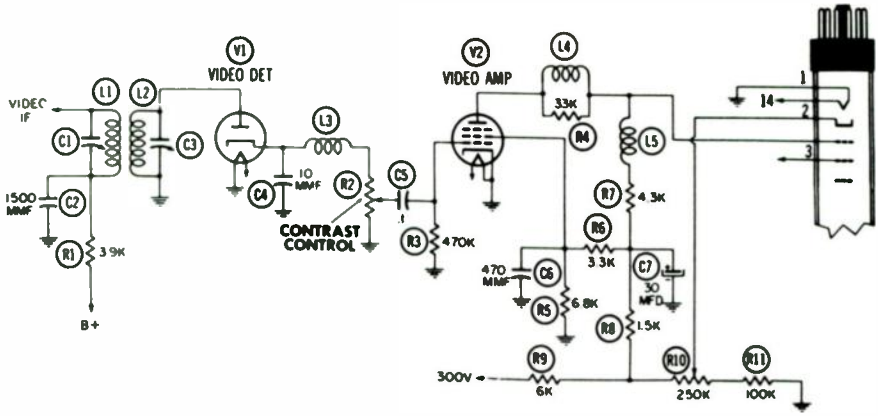


Figure 20 — Video detector of positive polarity feeding picture-tube grid through a single video-amplifier stage.

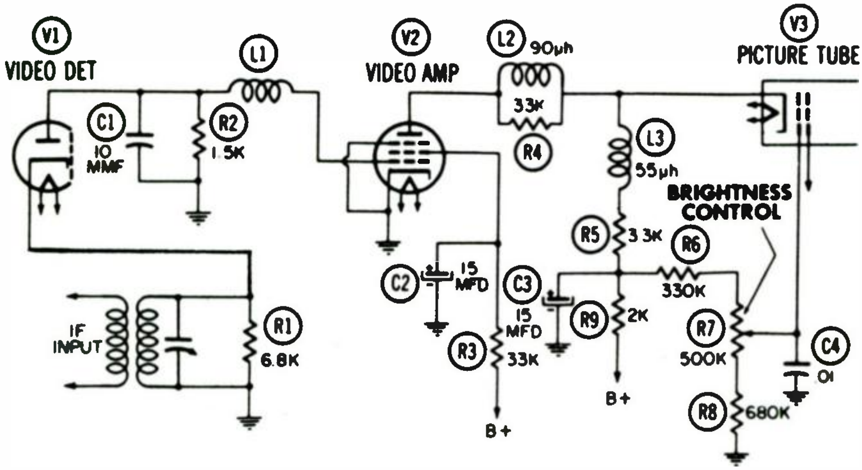


Figure 21 — A negative-output detector feeding the cathode of the picture tube through a single DC amplifier.

Figure 23 shows two typical applications of crystal detectors used as video demodulators. Figure 23A shows a load circuit consisting of resistor R_5 and high frequency-compensation network C_4, L_2, L_3 and R_4 connected in series with the diode. Figure 23B shows a shunt connection of similar elements.

The crystal diode is recommended over the vacuum-tube type for several reasons. These are: (1) lower dynamic resistance, (2) reduction of power consumption (no heater required), and (3) ease of mounting (no socket required). The lower capacitance and lower dynamic resistance of the crystal

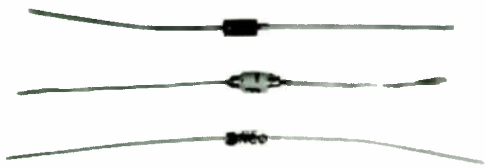
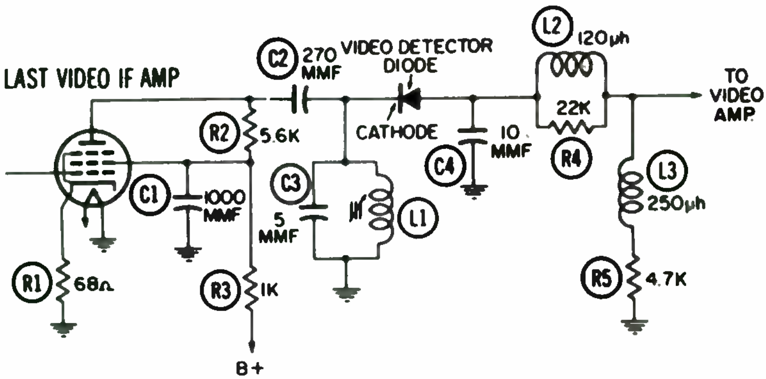
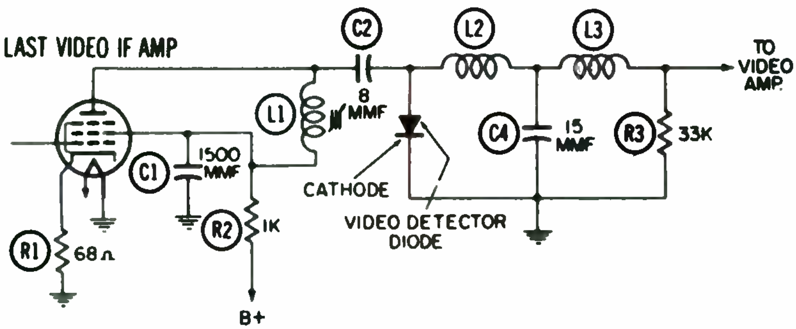


Figure 22 — Three types of fixed crystal detectors (shown actual size)



(A) Crystal diode with series load.



(B) Crystal diode with shunt load.

Figure 23 — The semiconductor crystal as a video detector.

diode improve its performance as a video detector by providing higher rectification efficiency for a given bandwidth. Its improved linearity at low signal levels helps preserve highlights in the picture.

ALIGNING FOR RESPONSE

Although correct video IF alignment is essential to good picture quality, serious alignment problems occur less seldom than many servicemen suspect. Novices, in particular, may be too eager to assign the cause of poor picture quality to misalignment.

Picture faults are more often due to a faulty component than alignment and the faulty component may not necessarily be in the IF section. Many other sections or stages can affect the IF and cause it to malfunction. The AGC, sweep circuits and power supply are just some of the sections that can affect operation of the video IF.

It is imperative, therefore, that you exhaust all other trouble possibilities before you hook up the alignment gear and commence turning screws.

Many of the sections that can (through failure) affect operation of the video IF section will alter the shape of its bandpass curve. Any attempt to realign the IF in a set with this kind of problem often results in misalignment and introduction of new problem symptoms that mask the old. By piling problem atop problem through haste and lack of diligent troubleshooting effort, some repairmen compound a routine service problem into a monstrous task.

How do you know when the video IF needs alignment? In order to know when a set needs realignment it is helpful to know the causes for misalignment. Tuned circuits of today are exceptionally stable and seldom change drastically unless there is a component malfunction. Occasionally a capacitor or coil in a resonant circuit will short or open and require replacement. In this case the stage or circuit must be realigned but seldom does the entire section require alignment.

9 Another cause for misalignment is aging of components. Coils in particular will change in value with age. Occasionally, you may encounter a vintage set that needs complete alignment to restore picture quality. Whether to realign or not, in this case, is a matter of economics and should be left to the customer's discretion. He may prefer to buy a new set rather than invest a considerable amount in repairing and realigning an old one. If the set is in otherwise good repair you might suggest that he have the job done. However, if extensive repairs plus alignment are needed, do the customer a favor, discourage him.

Rarely does a late model unit need alignment but occasionally one does escape from the manufacturer with less than perfect alignment. In this case some touch up may be required to please a discerning customer.

The most common affect of misalignment is poor detail in the picture. Poor detail is due to loss of high frequency video components. When this happens the sound may also be affected.

Large areas of a scene may be chopped up when the set suffers from low frequency distortion. In this event, noise will usually be present in the form of snow in the picture.

These conditions can also be due to peaking faults in the video amplifiers which follows the video IF and detector. In the event of a poor picture, investigate the video amplifier section first.

Poor alignment can probably be most easily determined by connecting the alignment equipment and viewing the response curve on an oscilloscope. If it agrees with the curve shown in the service literature, you have at least eliminated misalignment as a cause. If not, realignment is the solution.

To acquaint you with alignment procedures the following instructions are based on a service manual for a Philco-Ford solid state TV set. Although certain specific equipment is suggested, any good quality precision gear can be used. For circuit positions of the various IF's and traps refer to Diagram 5 in your diagram envelope. A pictorial of the equipment set up and connections for this particular set are included in 6-5 from your *Diagram Envelope*.

Since the shape of a response curve changes somewhat with signal level due to different values of AGC voltages the AGC line must be held constant during alignment. This is accomplished by connecting a stable DC bias supply to the AGC line. The generator recommended by this manufacturer contains a bias source for the purpose. Many others do not and when one of these is used a separate bias source will be required.

In the preliminary information of alignment instructions (6-1) there are instructions for mechanically positioning the trap cores prior to alignment. Also included are the recommended settings of certain controls (contrast, brightness, etc). The detector bias adjustment VR1 must also be set as specified (6-1).

IF sweep alignment begins with the sweep generator set to 44 MHz with a sweep width of 8 MHz. Thus, the sweep signal is varying from 40 to 48 MHz at a regular rate (usually 60 Hz). Various marker frequencies are turned on as needed to mark a position on the curve that is being adjusted.

For final adjustments the sweep's center frequency is changed to 69 MHz and inserted into the tuner. In this way the overall response can be checked from the antenna input terminals . . . through both the tuner and the video IF. The curves that should be displayed on the oscilloscope during various steps in the alignment procedure are shown in curves A & B (6-3) and C & D (6-4).

Many manufacturers do not use receiver power while aligning the IF and tuner in transistorized sets. They leave the power cord unplugged and use a separate DC power source. With this method only the IF and tuner are under power and interaction from other sections is eliminated.

SUMMARY

In this lesson you have learned that nearly all sets use an IF of 45.0 MHz. The sound carrier is positioned at 41.25 MHz and the video carrier appears at 45.75 MHz. The lower video sideband appears within a range of 1.25 MHz between the carrier and a cutoff point at 47.0 MHz. This is called the vestigial sideband because all sideband frequencies greater than those 1.25 MHz removed from the video carriers are suppressed at the transmitter. The other video sideband, however, extends in excess of 3.0 MHz from the video carrier, down to 41.75 MHz (approximate).

Although very early sets used a separate sound IF channel usually at 41.25 MHz, almost all current sets use intercarrier sound. The sound carrier is amplified through the video IF along with the video carrier and its sidebands. At some point after the video detector a 4.5 MHz beat results from the difference between the (AM) video carrier and the (FM) sound carrier. Since the video carrier is of fixed frequency the 4.5 MHz sound carrier contains the same deviation in frequency and tone as the original carrier . . . broadcast at the station.

Traps are included in video IF sections to prevent adjacent channel interference. Were it not for these traps interference would occur at specific points on the waveforms and produce bars in the picture. These frequencies are the upper adjacent channel's video carrier and the lower adjacent channel's sound carrier. They beat with the local oscillator and appear at the output of the mixer at 39.75 MHz and 47.25 MHz respectively for the upper adjacent video carrier and the lower adjacent sound carrier. Traps, of course, prevent them from being amplified in the IF.

For acceptable performance the IF response curve must be broad enough to pass the required video, sound carrier and sync frequencies. This requires a video passband that approaches 5.0 MHz.

The broad band response is accomplished by one of three techniques. These are: stagger tuning, overcoupling or stacking. Precise alignment of tuned circuits are necessary for good picture quality.

Although misalignment can produce poor picture quality and other malfunctions the average small shop rarely encounters an alignment problem. Many do not even own alignment equipment because of the large investment required. For the few cases when they do encounter an alignment problem they take the sets to a larger shop or the nearest factory service agency for that brand of set.

Portions of this lesson from
Television Service Manual
by Robert G. Middleton

PHOTOFACT Television Course
by Howard W. Sams Editorial Staff
Courtesy of Howard W. Sams, Inc.

TEST

Lesson Number 84

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-084-1.

9

1. **Two adjacent channel interference signals must be eliminated in the video IF. One is the upper adjacent channel video carrier and the other is**
   A. upper adjacent channel sound carrier.
   B. lower adjacent channel sound carrier.
   C. upper adjacent channel video sideband.
   D. lower adjacent channel video sideband.

2. **Each television channel occupies a band of frequency ______ MHz wide.**
   A. 4.5
   B. 5.0
   C. 1.25
   D. 6.0

3. **The sound and video carriers are separated by ______ MHz.**
   A. 4.5
   B. 6.0
   C. 1.25
   D. 5.0

9

4. **On the 45.0 MHz TV IF response curve the upper adjacent channel video carrier appears at ______ MHz.**
   A. 45.75
   B. 41.25
   C. 39.75
   D. 47.25

12

5. **On the 45.0 MHz TV IF response curve the lower adjacent channel sound carrier appears at ______ MHz.**
   A. 45.75
   B. 41.25
   12 C. 39.75
   D. 47.25

6. **The sound carrier on the 45.0 MHz TV IF response curve appears at ______ MHz.**
   A. 45.75
   12 B. 41.25
   C. 39.75
   D. 47.25

7. **The video carrier on the 45.0 MHz TV IF response curves appears at ______ MHz.**
   12 A. 45.75
   B. 41.25
   C. 39.75
   D. 47.25

8. **To prevent over emphasis of the low frequency video components the video carrier is**
   A. placed below the peak on one side of the response curve.
   B. moved to the upper adjacent channel.
   C. moved to the lower adjacent channel.
   D. totally suppressed during reception.

9. **Overall realignment is seldom necessary unless the**
   A. set is new.
   22 B. CRT has been changed.
   C. set is an older unit.
   D. set is near a strong station.

10. **Professional alignment equipment is**
    A. inexpensive.
    24 B. expensive.
    C. a must for even the small shop.
    D. of poor quality.

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We hear so much about being positive thinkers—and we can be, if we have the assurance that our background is sound and knowledgeable.

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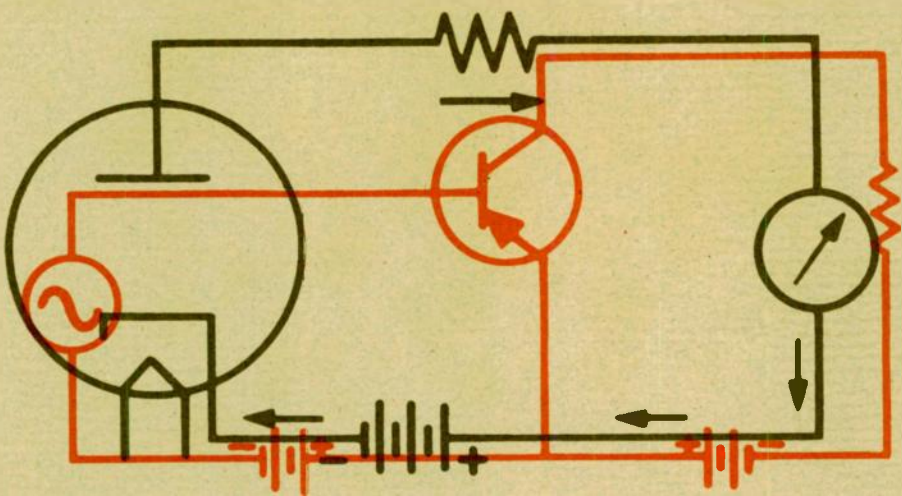
S. T. Christensen

LESSON NO. 85

TELEVISION AUDIO SYSTEMS



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-085
410

ADVANCE SCHOOLS, INC.
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Contents

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52-085

TELEVISION AUDIO SYSTEMS

INTRODUCTION

The sound systems employed in TV receivers are usually classified according to the type of detector circuit employed. In this lesson two circuits, the gated-beam and ratio detectors, will be discussed. Both of these circuits employ similar principles of operation. A stage of 4.5 MHz amplification usually precedes the detector circuit. However, because of the self-limiting feature of these circuits, the IF amplifier stage may be eliminated. Because of the high-level output from these circuits, no voltage amplifier is required; usually only a single stage of power amplification follows the detector.

GATED-BEAM FM DETECTOR

Figure 1 shows the principal circuit action occurring in a circuit using a gated-beam type of detector. This specific circuit appears only occasionally in modern receivers, but its principles of operation are used in a more popular adaptation. The gated-beam circuit requires a special tube.

Identification of Components

This gated-beam detector circuit includes the following functional components:

L_1—Plate-load inductor for V1.
L_2—Secondary winding of transformer in output circuit of V1.
L_3—Inductor portion of resonant quadrature circuit at second control grid of V2.
L_4—Primary winding of audio-output transformer.
L_5—Secondary winding of audio-output transformer.
L_6—Speaker winding.
C_1—Decoupling capacitor between V1 plate circuit and power supply.
C_2—Resonant tank capacitor.
C_3—Neutralizing capacitor between output and input circuits of V1.
C_4—Neutralizing capacitor between screen grid and input of V_2.
C_5—Screen-grid decoupling capacitor for V2.
C_6—Resonant-tank capacitor in quadrature circuit.
C_7—Detector output capacitor.
C_8—Coupling and blocking capacitor.
C_9—Cathode-bypass capacitor for V3.
C_{10}—Screen-grid decoupling capacitor for V3.
C_{11}—RF bypass capacitor.

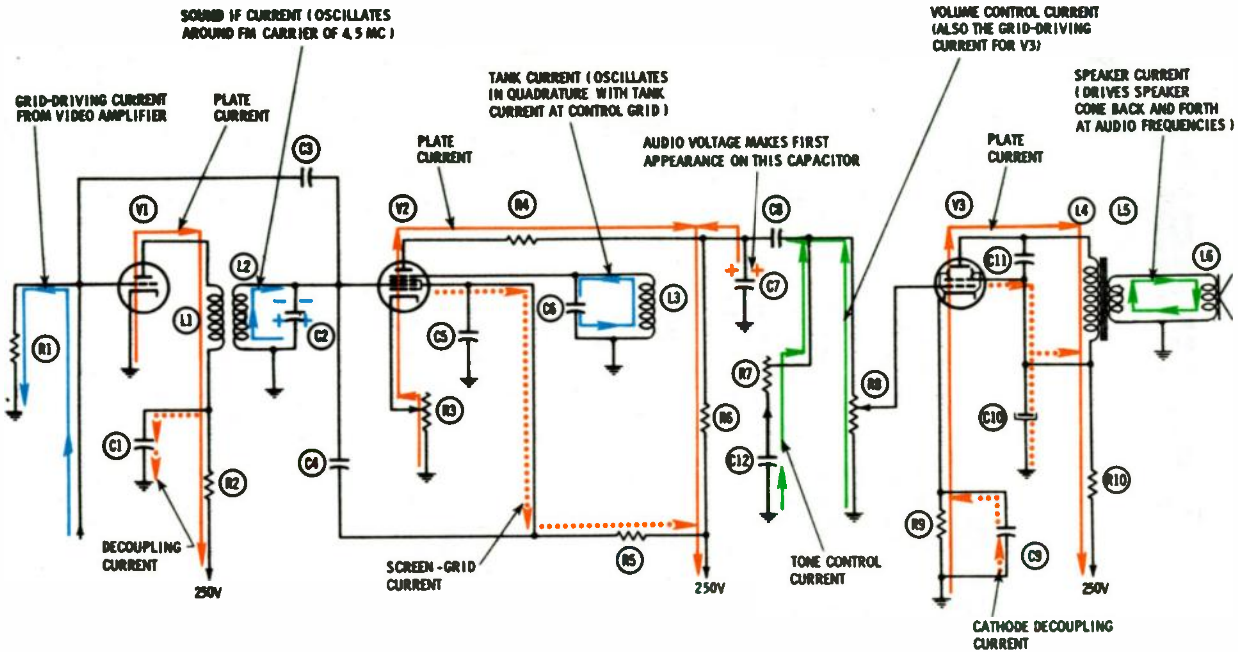


Figure 1 — Operation of a typical sound system employing a gated-beam FM detector circuit.

C_{12}—Tone-control capacitor.
R_1—Grid-driving resistor for sound-IF amplifier V1.
R_2—Plate-decoupling resistor for V1.
R_3—Cathode-biasing and "buzz-control" resistor for V2.
R_4—Small resistor used for feedback purposes to quadrature circuit.
R_5—Screen-grid dropping resistor for V2.
R_6—Plate-load resistor for V2.
R_7—Tone-control resistor.
R_8—Volume-control resistor.
R_9—Cathode-biasing resistor for V3.
R_{10}—Decoupling resistor between V3 plate and power supply.
V1—Sound-IF amplifier tube.
V2—Gated-beam detector tube.
V3—Beam-power audio-amplifier tube.

Identification of Currents

The following electron currents flow in this circuit during normal operation:

1. Grid-driving current for sound IF amplifier V1 (solid blue).
2. Plate currents through each of the three tubes (solid red).
3. Screen-grid current through V2 and V3 (dotted red).
4. Resonant signal currents in two tank circuits (also in solid blue).
5. Audio tone-control current through R_7 (solid green).
6. Grid-driving current through volume-control resistor R_8 (also in solid green).
7. Speaker driving current through L_5 and L_6 (also in solid green).
8. Power-supply decoupling currents through C_1 and C_{10} (also in dotted red).
9. Screen-grid filter current through C_5 (also in dotted red).

Details of Operation

The important functions which must be performed by an intercarrier sound system such as this one include:

1. Amplification and limiting (or leveling) of the 4.5-MHz frequency-modulated sound carrier.
2. Detection or demodulation of the frequency-modulated signal without responding to any variations in signal amplitude surviving the limiting process.
3. Amplification of the resulting audio-frequency signal to the point where it can drive a speaker.

Most modern receivers are intercarrier types, meaning the frequency-modulated sound carrier is carried through all stages of the video-IF amplifier strip, and passed through the second, or video, detector. This signal may also be passed through the video amplifier or video-output stage, before being filtered away from the picture signal and passed to the sound section of the receiver. In Figure 1, the sound signal (solid blue) is being driven downward through grid-driving resistor R_1. This signal current flows back and forth between R_1 and the video amplifier at an instantaneous frequency which must be within 25

KHz of the 4.5-MHz center frequency (between 4.475 and 4.525 MHz, in other words).

V1 functions as a conventional amplifier tube operated under Class-A conditions; its plate current (solid red) flows continuously and pulsates each time the grid is made positive by the upward movement of signal current through R_1. These pulsations in plate current flow downward through L_1 and induce an alternating current to flow up and down through secondary winding L_2. Inductor L_2 and C_2 constitute a tuned tank circuit which resonates at the 4.5-MHz center frequency. This circuit cannot be sharply resonant, because any signal within the band of 4.475 to 4.525 MHz must be passed.

Broadening the response curve of a tuned circuit is normally accomplished by placing a resistor across it. No such resistor is used here, but the same effect can be accomplished in the coupling process. Primary winding L_1 is considered to be in parallel with the internal resistance of V1; thus an equivalent portion of this resistance is coupled to the tuned tank. Details of this type of coupling action are difficult to portray pictorially; however, the desired widening of the tuned-tank response curve, with an attendant loss in gain, results.

The second grid of V2 serves as a control grid. The oscillation of electrons between L_2 and C_2 periodically makes this control grid positive so that a pulse of electron current is released through the tube. On alternating half-cycles of this tank voltage, the grid is made negative enough to cut off the plate current entirely. As each pulsation of plate current passes the fourth grid, it induces a small current flow in the second tank circuit (L_3 and C_6). This is a sharply tuned circuit which is also resonant at the 4.5-MHz center frequency. The induction of current reoccurs once each cycle, setting up and sustaining an oscillation of electrons in the tank circuit. The oscillation is said to be "in quadrature" with the first oscillation. This means that the two oscillatory voltages are 90° out of phase with each other. This oscillation in the second tank (L_3 and C_6) "leads" the oscillation in the first tank by a quarter of a cycle, meaning that it will achieve a positive voltage peak a quarter of a cycle in advance of the first oscillation.

V3 is so constructed and biased that it requires a relatively small voltage swing on either control grid to drive the tube between the two extremes of cutoff and saturation. This feature assures that the tube will function as a limiter, since limiting results whenever any amplitude variations of the signal can be rendered ineffective in controlling the flow of plate current through the detector tube. Figure 2 shows the current movements and associated voltage peaks in two tuned tank circuits operating 90° out of phase with each other—in other words, in quadrature. The voltage in the upper tank reaches a positive peak at the start of the first quarter-cycle, indicated graphically by the positive peak in the waveform. The voltage in the lower tank reaches its positive peak 90° later, at the start of the second quarter-cycle, as indicated by the blue waveform. Thus the red waveform leads the blue waveform by a quarter of a cycle.

If we assume that the lower tank represents the quadrature tank (L_3 and C_6) of Figure 1 and the upper tank represents the input tank (L_2 and C_2), we can then predict what will happen to the plate-current stream through V2. This tube will conduct plate current only when *both* of the control grids are positive. When the voltage on either control grid becomes negative, it effectively prevents the passage of electrons through the tube. The waveforms in Figure 2 indicate that this condition exists throughout the entire first quarter-cycle *and at no other time* during the whole cycle. A square wave representing the pulse of plate current through the detector tube is shown below the sine waves in this illustration. This current is shut off entirely until the moment when the second control-grid voltage (represented by the blue waveform) becomes positive. Then the tube begins to conduct and is very quickly conducting the maximum possible amount of plate current, which is frequently called "saturation current." The tube continues passing this saturation value of current until the first control-grid voltage (represented by the red waveform) goes from positive to negative at the end of the first quarter-cycle. At this time the plate-current flow through the tube is stopped entirely. The tube then remains in a cutoff condition for the next three

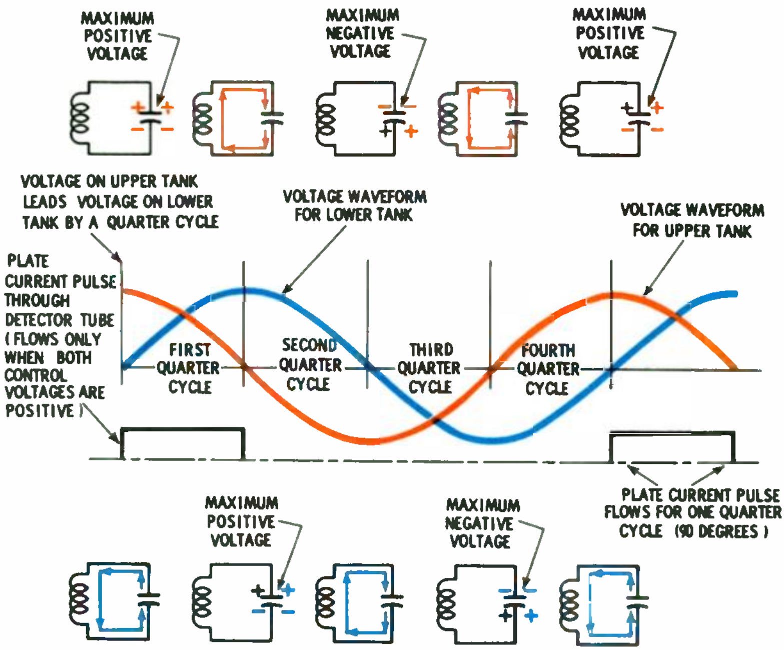


Figure 2 — Five successive quarter-cycles in the operation of two resonant tanks which are in quadrature with each other.

quarter-cycles, since at least one control grid is negative at all times during this period. At the end of the fourth quarter-cycle, both control grids are positive again, and the tube once again conducts plate current.

All of this plate current must eventually flow downward through load resistor R_6 to the 250-volt B+ source (Fig. 1). Before it can enter this resistor, however, it accumulates on the upper plate of C_7. This accumulation results in a somewhat lower positive voltage existing on C_7 than would otherwise exist. In the prolonged absence of any plate current through V2, the upper plate of C_7 would charge to the power-supply voltage (250 volts). The time constant of the RC combination (C_7 and R_6) is made large enough so that C_7 will not discharge electrons through R_6 in any significant quantity during the short interval between plate current pulses. The result is that under the conditions described, the voltage on C_7 is essentially a DC voltage.

The preceding conditions occur only in the absence of any frequency modulation of the sound carrier. Both oscillations are occurring exactly at the 4.5-MHz center frequency, and the quarter-cycle phase difference between the two oscillatory voltages is fairly accurately maintained.

Phase Shifts When Modulation Is Present

5 When the incoming sound carrier is frequency-modulated by audio information, the phase relationship between the two oscillating tank voltages will be significantly altered. When the IF signal goes below the center frequency, the voltage in the quadrature tank moves closer to an in-phase condition with the voltage in the input tank. This condition is depicted in Figure 3, which shows five successive current/voltage pictures in the tuned circuits. Each picture represents an eighth of a cycle, so the five pictures cover only one-half of a cycle rather than an entire cycle, as they did in Figure 2. The upper tank, which represents the input tank circuit L_2 and C_2, achieves its positive peak voltage at the start of the second eighth of a cycle. This positive peak is indicated by the plus signs massed on the upper plate of the capacitor, and by the red waveform. One-eighth of a cycle later, the lower tank, which represents the quadrature tank, achieves its positive peak of voltage. This is indicated by the plus signs massed on the upper plate of the tank capacitor and by the blue waveform.

Since the two waveforms are now closer to being in phase with each other, the period of time when they are both positive is increased from a quarter of a cycle to three-eighths of a cycle. This period begins when the blue waveform becomes positive at the left-hand side of Figure 3, and it ends when the red waveform crosses the zero line and becomes negative. Since each tank is connected to a control grid of V2, this tube will conduct a longer pulse of plate current than when the tanks are exactly in quadrature. Thus, a greater quantity of electrons flows as plate current

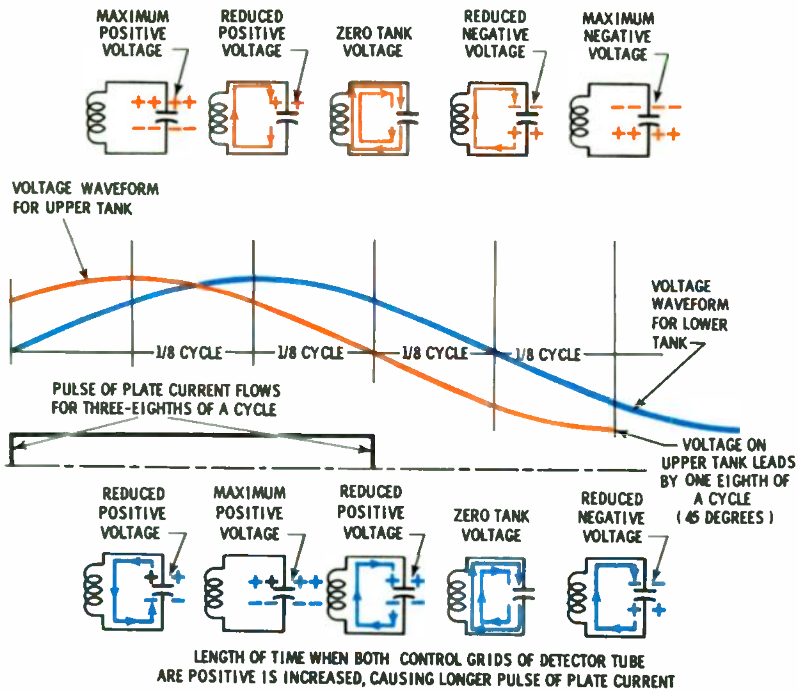


Figure 3 — Current movements during a half-cycle in two tanks whose voltage phases are less than a quarter-cycle apart.

under these conditions, and these electrons accumulate on the upper plate of C_7, causing a lower positive voltage to exist at this point. The long time constant of C_7 and R_6 preserves this low positive voltage from cycle to cycle for as long as the input signal current frequency is below the center frequency.

When the IF signal goes above the center frequency, the instantaneous phases of the two oscillatory tank voltages move farther apart (Fig. 4). The upper tank achieves its positive voltage peak at the start of the first one-eighth of a cycle. This is indicated by the plus signs on the upper plate of the capacitor and by the red waveform. The lower tank voltage is negative at this instant; it does not become positive until an eighth of a cycle has elapsed. Both tanks are then positive for one-eighth of a cycle; it is only during this shortened time period that plate current is permitted to flow through V2. The shortened pulse of plate current is shown below the colored waveforms. This pulse represents a reduced quantity of plate current electrons which will be delivered to the upper plate of C_7. As long as the input frequency remains above the center frequency, the time-duration of the plate-current pulses will be shortened, and the result is that the positive voltage on C_7 will increase.

By varying the signal frequency above and below 4.5 MHz, we have a means of varying the positive voltage on the upper plate of C_7. There are two important characteristics of an FM signal voltage

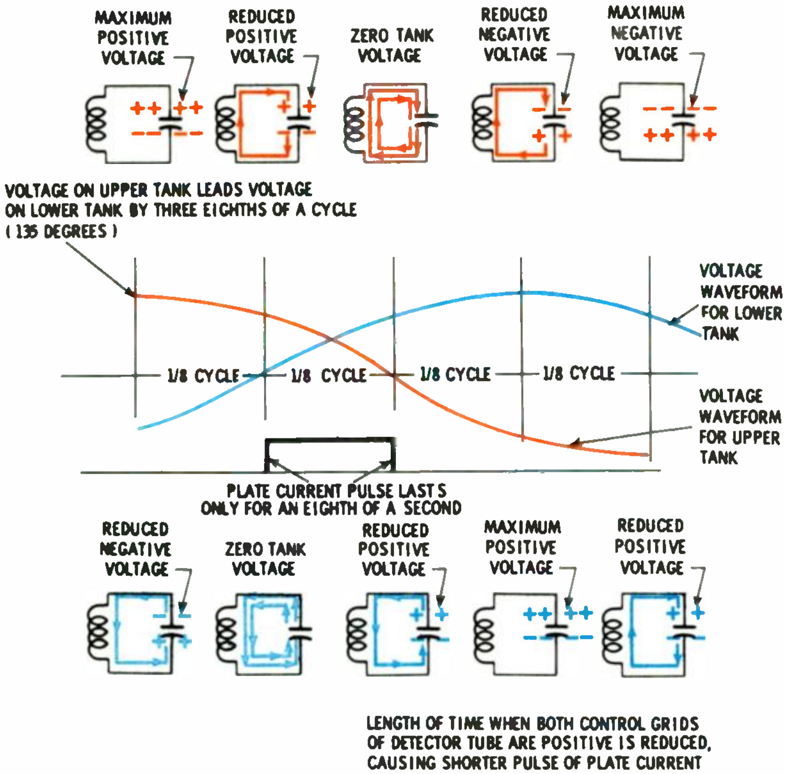


Figure 4 — Current movements during a half-cycle in two tanks whose voltage phases are more than a quarter-cycle apart.

which can be used to carry audio information. These characteristics are the rate of the frequency excursion, and the amount of the frequency excursion. An *excursion* in carrier frequency is defined as the number of hertz or kilohertz per second by which the carrier is made to differ from the center frequency. When the excursion of a carrier frequency is very slight (perhaps only a few hundred hertz), the resulting change in phase between the input voltage and the quadrature voltage will also be slight, and the amount of electron current contained in the plate-current pulses will vary over a small range. This small variation in current, in turn, causes small variations in the positive voltage that accumulates on the upper plate of C_7.

The voltage on C_7 marks the first appearance of the audio signal in the receiver. A very weak audio sound will result when the voltage variations on C_7 are small, as in the preceding example.

If the signal frequency varies above and below the center frequency by large amounts (perhaps by 10 or 20 kHz), the successive amounts of electron currents contained in the plate-current pulses will vary over a much wider range. These variations in plate-current pulses, in turn, will cause wider variations in the positive voltage on the upper plate of C_7. A strong or loud audio signal will be the result. Thus, we see that the *loudness* of an audio signal depends directly on the *amount* of the FM-signal frequency excursion.

The *pitch* of an audio signal depends on the *rate* at which the frequence excursions of the carrier are made to occur. For example, if the carrier signal is made to vary above and below its center frequency 100 times per second, then the pitch of the resultant audio voltage which appears on C_7 will be 100 cycles per second. The positive voltage on C_7 will rise and fall at this rate. It will rise when the shortened pulses of plate current (Fig. 4) are flowing, and fall to a lower positive value when the longer pulses of plate current flow (Fig. 3).

As a result of these fluctuations in the positive voltage on C_7, an audio current will be driven up and down through parallel resistors R_7 and R_8. In Figure 1 these currents are being drawn upward. This might be termed a positive half-cycle; it would occur during a period when shortened pulses of plate current are flowing through the detector tube. Negative half-cycles of audio will occur when the lengthened pulses of detector current flow. The audio current (green) would then flow downward through R_7 and R_8. R_8 functions as the volume control. By adjusting this resistor, the listener can tap off any desired portion of the audio signal for amplification by the audio-output circuit constructed around V3.

R_7 and C_{12} constitute a tone-control device. This device enables the listener to eliminate some signal strength of the higher-frequency tones in the audio without a comparable attenuation of the lower-frequency sounds. If the variable tap on R_7 is lowered to its lowermost position, most of the high-frequency tones will flow in and out of C_{12}. Thus, the high-frequency tones are bypassed to ground, rather than flowing through the somewaht higher impedance offered by R_8. The lower-frequency currents in the audio signal find the reactance of C_{12} to be much larger than the resistance of R_8, so these currents flow up and down through R_8 in a normal fashion and develop an audio voltage across the resistor.

If the variable tap on R_7 is moved to its uppermost position, then both the high-frequency and the low-frequency currents in the audio signal will be confronted by equal amounts of this resistance so that the high-frequency tones will be attenuated less *with respect to the low-frequency tones* than before.

When wide variations in adjustment of R_7 are made, it may be necessary to readjust the volume control (R_8) to maintain the same sound level from the speaker. The reason is that, as the total impedance of the R_7-C_{12} combination increases, more and more of the total audio current being driven through the two paths is diverted through R_8, and less flows through R_7 and C_{12}. Thus the audio voltage developed across R_8 is increased.

Also, when the tone-control adjustment is moved downward on R_7 (decreasing the resistance), more of the total audio current flows through it at the expense of that current which develops the audio-output voltage across R_8.

R_3 in the cathode circuit of V2 is called a buzz control. Its purpose is to adjust the gain of the detector and to eliminate the possibility of amplifying some portion of the horizontal-sync signals that may have survived the various filtering and limiting actions. Sync signals and other noise will not be heard unless the incoming signal strength drops to the point where it does not drive the detector tube to saturation. If the tube is not driven to saturation, the limiting function cannot be carried out.

The plate current through V3 pulsates at the audio frequencies. As this current flows downward through L_4 it induces an alternating current to flow up and down through secondary winding L_5. This current becomes the speaker current (solid green). As this current flows back and forth through the speaker winding L_6, it causes the speaker diaphragm to vibrate at the same audio frequencies, thus reproducing the desired sounds.

In order to prevent the gated-beam circuit from feeding energy back from output to input and thereby oscillating, a specially constructed tube is used for V2. The input control grid is surrounded by a shielding grid. This grid is connected to the positive power supply through R_5; therefore, it will attract considerable electron current within the tube. This current (dotted red) flows through R_5 toward the power supply. The shielding provided by this grid prevents the oscillatory voltage in the quadrature tank from being "sensed" in the control grid circuit. Instead of this happening, the shielding grid intercepts these voltage impulses and bypasses them harmlessly to ground via C_5. This capacitor also filters the pulsations from the screen current so that electrons flow through R_5 in a steady stream. This filtering action assures that the voltage on the shielding grid will be maintained at a constant value.

Feedback through the interelectrode capacitance between tube elements is used to strengthen the oscillation in the quadrature tank. R_4 is a low-value resistor (a few hundred ohms) in the plate circuit of the tube. Its function is to develop a small component of voltage at the plate each time a pulse of plate current comes through the tube. A small component of voltage (negative at the plate side) is developed across this resistor with the passage of each pulse of plate current. Each such component of negative voltage at the plate is sensed at the quadrature grid, and it occurs in appropriate phase to reinforce the oscillation occurring between L_3 and C_6. This is not the only source of support or replenishment for this oscillation, since it is also sustained by an induction process from the plate current electron stream as it pulsates through the tube. This coupling process occurs as the electron stream passes the second control grid (quadrature grid) and is usually referred to as electron coupling.

RATIO DETECTOR

The audio detector circuits previously discussed are the most popular circuits in modern TV receivers. However, in the past, the ratio detector and Foster-Seeley discriminator circuits enjoyed wide usage. They will still be encountered in some present-day sets and many older sets still in use have one of these circuits.

A dual-diode tube (or two crystal diodes) is employed as the audio detector in both of these circuits. While the 4.5-MHz audio-IF amplifier stage may be omitted in some receivers with a gated-beam detector, it is always used in receivers with one of the detectors described below. In fact, two such stages, with the final stage acting as a limiter, are often employed. (A limiter stage is essential with the discriminator circuit.) In addition, because the diodes do not provide any gain, a stage of voltage amplification will be added between the detector and the audio power output stage.

A complete sound system utilizing a radio-detector circuit for the demodulation of the frequency-modulated sound carrier is given in Figure 5. As previously mentioned, this circuit has been largely supplanted by the quadrature detector. The principal disadvantage of the ratio detector, when compared to the previous circuits, is insufficient output strength; additional amplifier stages are required after the detector.

Identification of Components

This circuit is made up of the following components which perform the indicated functions:

L_1, L_2—Sound-IF amplifier output transformer.

L_3—Tertiary winding to provide quadrature coupling from V1 plate circuit to detecting diodes.

C_1—Cathode-bypass capacitor for V1.

C_2—Power-supply decoupling capacitor.

C_3—Capacitor portion of resonant tank circuit.

C_4—Audio-output capacitor.

C_5—Electrolytic capacitor across biasing resistor R_5.

C_6—High-frequency filter capacitor across R_5.

C_7, C_8—Audio-coupling capacitors.

C_9—Coupling and blocking capacitor.

C_{10}—Cathode-bypass capacitor for V4.

R_1—Grid-driving resistor for V1.

R_2—Cathode-biasing resistor for V1.

R_3—Plate-decoupling resistor for V1.

R_4—Combines with C_4 as a long time-constant network to audio-output frequencies.

R_5—Initial biasing resistor for ratio-detector diodes.

R_6—Manual volume control.

R_7—Grid-driving resistor for V3.

R_8—Plate-load resistor for V3.

R_9—Grid-driving resistor for V4.

R_{10}—Cathode-biasing resistor for V4.

V1—Final sound-IF amplifier tube.

V2—Ratio-detector tube.

V3—Audio-amplifier tube.

V4—Audio-output tube.

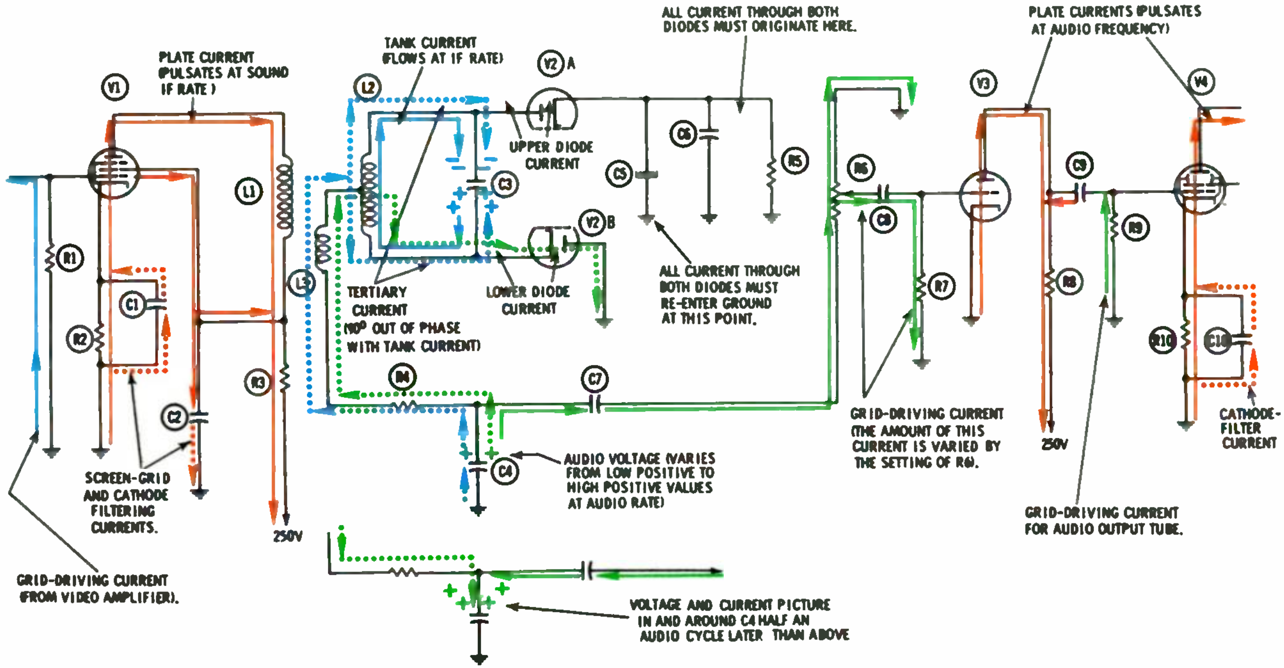


Figure 5 — Operation of a sound system employing a ratio detector.

Identification of Currents

The following electron currents will flow in this sound system during normal operation:

1. Amplifier plate currents for V1, V3, and V4 (solid red).
2. Cathode-filter currents for V1 and V4 (dotted red).
3. V1 screen-grid current (also in solid red).
4. Resonant current through secondary winding L_2 (solid blue).
5. Grid-driving current for V1 (also in solid blue).
6. Current induced in tertiary winding L_3 (dotted blue).
7. Unidirectional currents through diodes (dotted green).
8. Audio-drive current through C_7, R_6, C_8, and R_7 (solid green).
9. Audio-drive current through R_9 (also in solid green).

Details of Operation

The principal functions to be accomplished by this sound system can be summarized as follows:

1. Amplification of the frequency-modulated sound signal in the plate circuit of V1.
2. Coupling of this amplified FM signal *by two separate and independent methods* from the plate circuit of V1 to detector diodes V2A and V2B.
3. Unequal conduction of the two diodes, and the resultant development of an audio voltage on the upper plate of C_4.
4. Amplification of this audio voltage in the circuits associated with V3 and V4.

The functions performed by the sound-IF amplifier circuit will not be described in detail since they are the same as previously discussed.

The grid-driving current (solid blue) is driven from the video amplifier at any frequency within the FM passband of 4.475 to 4.525 MHz. It moves up and down through R_1 and develops an alternating positive and negative voltage at the upper terminal of this resistor. The instantaneous value of the alternating voltage controls the quantity of electrons passing through the tube as plate current.

The fluctuations in plate current flowing downward through L_1 induce an alternating current to flow up and down through secondary winding L_2. This alternating current sets up an oscillation of electrons between L_2 and C_3, which constitute a resonant tank circuit at the 4.5-MHz center frequency. The resonant current resulting from this coupling action is shown in solid blue in Figure 5. When the oscillating electrons move to the upper plate of C_3 (as indicated in Figure 5), they make this plate (and the plate of V2A) negative. V2A does not conduct electrons during this period. The lower plate of C_3 (and the cathode of V2B) will be made positive by this same action; therefore V2B will also be unable to conduct electrons during this period.

A half-cycle later, these oscillating electrons make the upper plate of C_3 positive and the lower plate negative, causing the two diodes to conduct equal amounts of electrons.

If only this single means of coupling between L_1 and L_2 were employed, the two diodes would conduct simultaneously once each cycle in equal amounts. Thus, neither a positive nor a negative voltage can accumulate on the upper plate of C_4. Varying the signal frequency above or below the 4.5-MHz center frequency will not change this fact, because the two diodes are connected to opposite ends of the same resonant tank. The strength of the resonant voltage and current (solid blue) in the tank would change when this detuning action occurs, but the two diodes would still conduct equal amounts of electrons and the net voltage developed on C_4 would still be zero.

Momentarily disregard the preceding action and consider the results of the coupling action between L_1 and L_3 (the tertiary winding). Since L_3 is connected to the center tap of L_2, the induced voltage polarity at the top of L_3 will be applied simultaneously to the plate of V2A and to the cathode of V2B. A moment is being depicted when the voltage across L_3 is negative (Fig. 5). Therefore, electrons are driven away from the center tap of L_2 in both directions so that they appear to flood simultaneously onto both plates of capacitor C_3. The current that carries these electrons is shown in dotted blue.

The resultant negative voltage at the cathode of V_{2B} causes V_{2B} to conduct some electrons (dotted green). Diode V_{2A} is unable to conduct during this half-cycle because of its negative plate. However, in the half-cycle which follows it, the top of L_3 is positive. Now electrons will be drawn toward the center tap through both halves of L_2. This electron current places a positive voltage on the plate of V2A, causing it to conduct. It also places a positive voltage on the cathode of V2B, causing it not to conduct.

Even though the two diodes conduct on alternate half-cycles (due to the mode of coupling to the center tap of L_2), the diodes conduct equal quantities of electrons so that there can be no accumulation of negative electrons or positive ions on the upper plate of C_4.

During the normal operation of a ratio detector, both of the coupling actions described in the foregoing are used. When the signal is exactly on the 4.5-MHz center frequency, the two diodes will conduct equal amounts of electrons so no voltage can build up on C_4. This condition exists when the carrier is unmodulated by any audio signal. When the carrier is modulated, however, the two diodes conduct unequal amounts of electrons so that an audio voltage can be built up on C_4. When the carrier frequency goes above the center frequency, V2A conducts more electrons than it does normally, and V2B conducts fewer electrons. This leads to an excess of electrons lodged somewhere between the two diodes; these electrons accumulate on the upper plate of C_4 as a negative voltage. This constitutes a negative half-cycle of audio.

When the carrier frequency deviates below the center frequency, the lower diode will conduct more electrons than normal, and the upper diode will conduct fewer electrons than normal. This leads to a deficiency of electrons between the two diodes and manifests itself as a positive voltage on the upper plate of C_4. This becomes a positive half-cycle of audio voltage.

The graphs given in Figures 6, 7, and 8 will explain why the diodes conduct unequal amounts of electrons when the frequency varies on either side of the center frequency. Figure 6 shows sinewave representations of the voltages that must be considered in analyzing the circuit operation. Figure 6 depicts the conditions at resonance; that is, the incoming signal is at the 4.5-MHz center frequency. The four voltages which must be considered are:

1. The voltage applied to V2A by the resonant-tank current.
2. The voltage applied to V2B by this same current.
3. The voltage applied to V2A by the center-tapped coupling method.
4. The voltage applied to V2B by this same method.

For the sake of simplicity, the two types of voltages are assumed to have the same strength, or amplitude. Line 1 shows the two voltages as they are applied to upper diode V2A. The dotted-blue waveform, which represents the voltage coupled to the center tap of L_2 by L_3, starts the first quarter-cycle at zero amplitude, and increases to its positive peak a quarter of a cycle

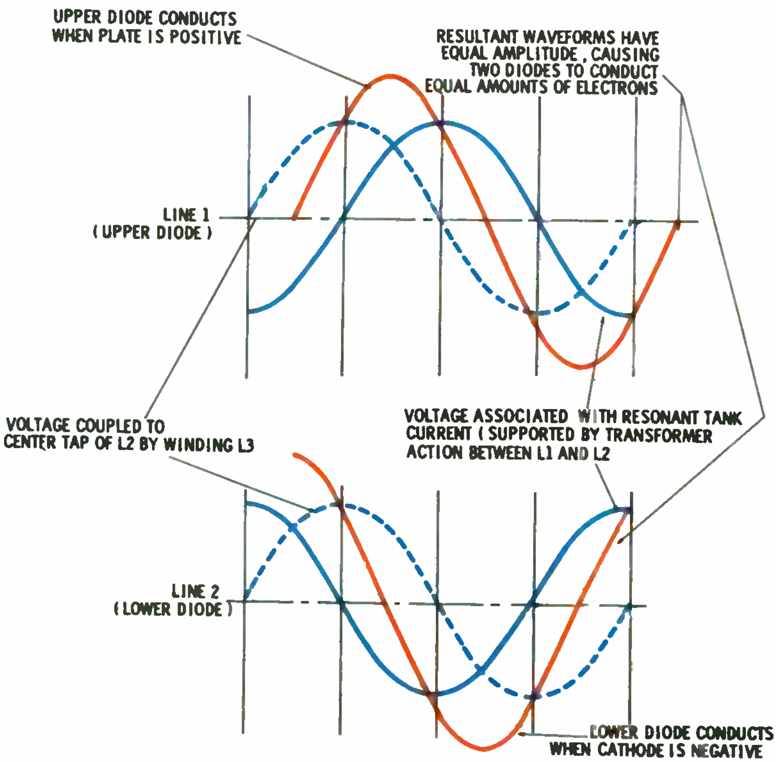


Figure 6 — The two input signal waveforms and the resultant applied to each diode when the signal is on the center frequency.

later. This waveform is in phase with the voltage waveform across L_1.

At the start of the second quarter-cycle the solid blue waveform has zero amplitude; it increases to a positive maximum at the end of the second quarter-cycle. The amplitude of this waveform at any instant represents the voltage at the top of the tuned circuit caused by the resonant current (solid blue in Figure 5).

This voltage is displaced by 90° (quarter of a cycle) from the voltage which induces it from L_1. It is characteristic of two inductively-coupled tuned circuits that, when operating exactly at resonance, the two oscillating voltages will be exactly a quarter of a cycle out of phase with each other. Then, as the operating frequency varies above resonance, this phase difference decreases. When the operating frequency varies below resonance, this phase difference increases.

The summation of the two applied sine-wave voltages is shown in red in Figure 6. The amplitude of the red waveform in Line 1 at any instant represents the voltage applied to the plate of diode V2A. V2A will conduct whenever its plate is positive with respect to its cathode.

Line 2 (Fig. 6) shows the two voltage waveforms applied to the cathode of lower diode V2B and

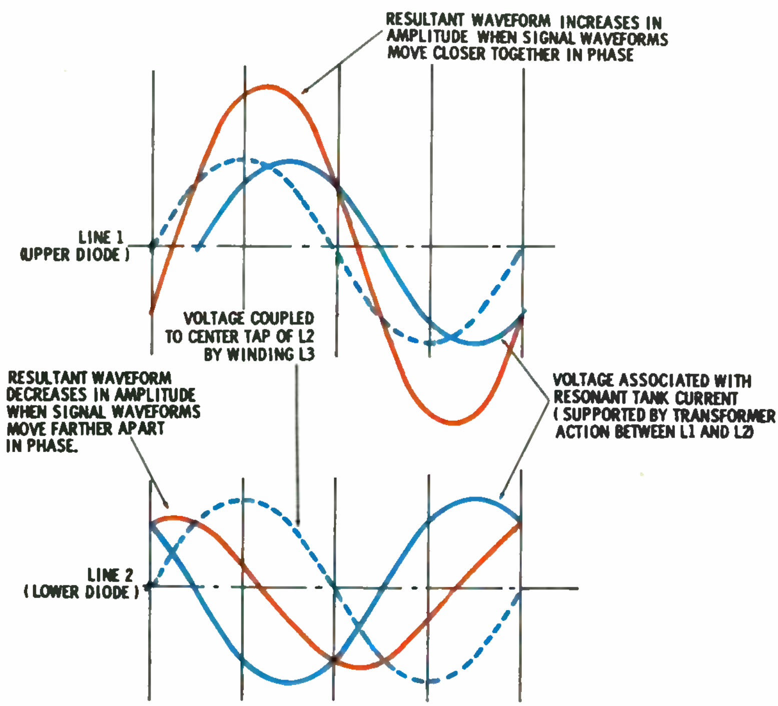


Figure 7 — The two input signal waveforms and the resultant applied to each diode when the signal is above the center frequency.

their resultant. The dotted blue waveform, which is the voltage applied from L_3 through the center tap on L_2, is in phase with the one shown in Line 1, since the upper and lower ends of the tank circuit receive identical impulses from L_3. The solid blue waveform is a "mirror image" of its counterpart in Line 1, since this is a measure of the resonant tank voltage. When the top of the tank is positive, the bottom of the tank must be negative, and vice versa. The red waveform is the algebraic summation of these two applied voltages. Whenever the cathode of V2B is made more positive than its plate by these combined voltages, V2B can be expected to conduct electrons.

It can be seen from inspection of the two combined (red) waveforms that they appear to be symmetrical. The positive peak amplitude achieved in Line 1 (and applied to the plate of V2A) appears to equal the negative peak amplitude achieved in Line 2 (and applied to the cathode of V2B). Thus, when a condition of resonance exists, the two diodes will conduct on alternate half-cycles, and they will conduct equal amounts of electrons so that no voltage can accumulate on C_4. This is as it should be, because when an FM signal is exactly at its center frequency, it is carrying no modulation.

When the carrier frequency deviates above or below the center frequency, the 90° phase differences between the voltage sine waves are altered. Figure 7 shows a sample situation when the carrier frequency goes above the center frequency. The phase of the tank voltage moves closer to that of the inducing voltage from V1. The solid blue waveform in Line 1 of Figure 7 moves a fraction of a quarter-cycle to the left, bringing it closer to an in-phase condition with the dotted blue waveform. This increases the peak amplitude of the red waveform, which is the algebraic sum of the two applied waveforms. This increase in the resultant applied voltage leads to increased conduction through V2A.

Line 2 of Figure 7 reveals that the peak amplitude of the voltage applied to V2B (red waveform) is decreased, because the negative voltage peaks applied to V2B move farther apart rather than closer together. This causes V2B to conduct fewer electrons than at resonance. The result of this unequal condition of diodes causes an excess of electrons to accumulate on the upper plate of C_4, creating the negative half-cycle of audio voltage.

Figure 8 shows how the phase relationship of the two coupled voltages are altered when the signal deviates below the center frequency. The solid blue waveform has been shifted a fraction of a cycle to the right so that it now lags the dotted blue waveform by more than 90°. The red waveform in Line 1 of this illustration has a decreased positive amplitude above the center line, indicating that V2A will conduct fewer electrons than it normally does. At the same time, the red waveform in Line 2, which represents the total voltage applied to the cathode of V2B, will be increased in amplitude so that V2B will conduct more electrons than it normally does.

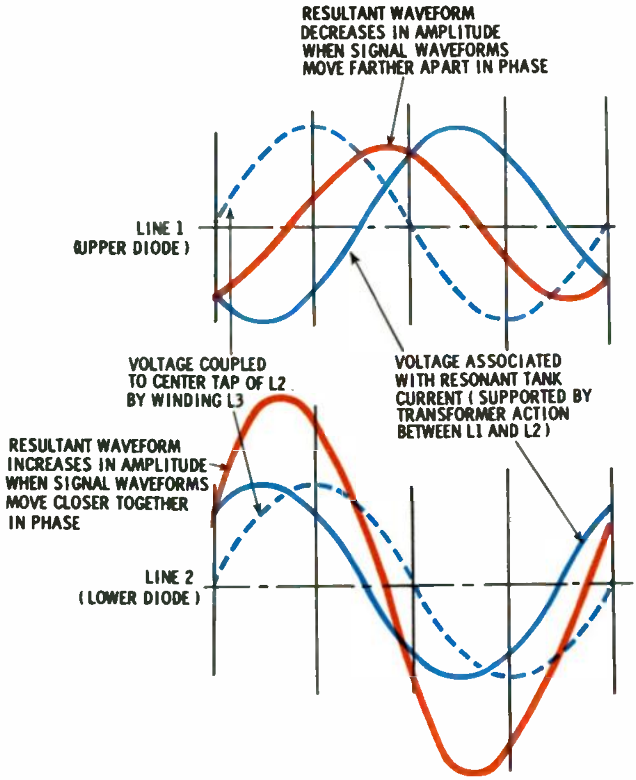


Figure 8 — The two input signal waveforms and the resultant applied to each diode when the signal is below the center frequency.

As a result of this unequal conduction of the two diodes, a deficiency of electrons will exist on the upper plate of C_4; this becomes a positive half-cycle of audio voltage. The peak value of these positive and negative half-cycles of audio voltage will be determined by the amount by which the relative phasing between the two input voltage waveforms (solid and dotted blue, respectively) is shifted. This shift, in turn, depends on the amount by which the carrier frequency deviates from the center frequency. The *amount* of the audio voltage on C_4 determines the *loudness* of the sound. The *rate* at which the carrier frequency is deviated above and below the center frequency determines the *frequency* of the audio voltage; thus it determines the pitch of the sound.

The Limiting Function

It is essential in the demodulation of FM signals that the detector not respond to any amplitude variations in the incoming signal. Variations in signal strength can occur due to unusual atmospheric conditions or temporary aberrations in the amplification processes carried out earlier in the receiver, such as in the video amplifier or the sound-IF amplifier. Any such variations in amplitude are spurious and bear no relation whatsoever to the intelligence conveyed by the carrier to the receiver. The most obvious means of eliminating amplitude variations (usually called modulation) is to amplify the incoming signal so that all portions of it will have some predetermined minimum amplitude, and then to cut off, or limit, all attempts of the signal to exceed that predetermined value.

The ratio detector of Figure 5 is not preceded by a conventional limiting stage; it employs a novel method for accomplishing the same purpose or function. This method is embodied in the RC filter network connected to the cathode of diode V2A. Capacitor C_5 is a large electrolytic capacitor (about 2 microfarads) and R_5 is approximately 25,000 ohms. The product of these two components, which determines the time-constant of the combination, is 1/20 of a second. This is a "long" time period when compared to the cycle duration of typical audio frequencies; therefore a positive voltage, which will not vary from audio cycle to audio cycle, will appear on the upper plate of C_5. This voltage results from the continual loss of electrons due to the current being drawn into the cathode of V2A. This positive voltage constitutes a fixed biasing voltage for the ratio detector as a whole.

Because of the fact that the upper plate of C_5 assumes a positive voltage which is proportional to the incoming-signal strength, it can be used as a source of automatic gain control (AGC) voltage. However, if it were so used, it would have to be applied to the cathodes of the various amplifiers rather than to the control grids. This is because it increases in the positive direction as the signal strength increases. Positive voltages applied to amplifier cathodes cause decreases in amplifier gain; thus, the desired effect from an AGC circuit when confronted by an increase in signal strength would be obtained using this voltage.

The audio voltage which appears on C_4 (Fig. 5) drives electron current in and out of coupling capacitor C_7, and up and down through volume-control resistor R_6 toward ground. Thus, an audio voltage is developed across R_6. Any portion of this voltage may be tapped off R_6 for subsequent amplification by the two audio amplifier stages V3 and V4.

When this audio-output current (solid green) is driven upward through R_6, it is also driven to the right through C_8, and downward through the grid-driving resistor (R_7). An alternate picture of the voltage condition one half of an audio cycle later than that shown in the main schematic is given directly below C_4 in Figure 5. The main schematic is for a negative half-cycle, and the lower conditions are for a positive half-cycle. During these positive half-cycles the audio current (solid green) will be drawn away from the left plate of C_7, downward through R_6, and upward through R_7 onto the right-hand plate of C_8.

Since there are no new and unique principles employed in the audio amplifiers, the two amplifiers constructed around V3 and V4 will not be discussed here.

Sound De-emphasis

A similar version of this receiver may employ the audio output capacitor connected from the left-hand terminal of R_4 (Fig. 5) to ground. R_4 and C_4 would then provide the function known as *de-emphasis* of high audio frequencies. The reactance of any capacitor decreases as the frequency increases. As the audio-frequency voltage on C_4 increases in frequency, the reactance of C_4 decreases. Another way of saying this is that C_4 will begin to short-circuit the higher audio-frequencies to ground, rather than permitting them to flow only in and out of C_7. This technique is used deliberately, because in the original transmission of the sound signals the higher-frequency sounds were pre-emphasized. That is, they were intentionally increased in amplitude in comparison with the lower-frequency sounds. Pre-emphasis is employed because much of the audio-frequency interference generated during the modulation process at the transmitter, and within the receiver, consists of the higher audio frequencies. Pre-emphasis within the transmitter improves the signal-to-noise ratio of the higher audio frequencies, but it obviously requires the de-emphasis process within the receiver to restore both high- and low-frequency audio tones to their correct proportions with respect to each other.

PHASE DISCRIMINATOR OPERATION

Figure 9 shows a typical phase discriminator circuit for the demodulation of the frequency-modulated sound-IF signal. This circuit differs from the ratio detector of Figure 5, primarily in the arrangement of the diodes. The two diodes in Figure 9 are connected in parallel with each other so that separate currents flow through each one. In Figure 5 the two diodes were in series with each other so that whatever electron current flowed through one of them eventually had to flow through the other one also.

Details of Operation

The operation of the IF amplifier (V1) is straightforward and similar to the one discussed in connection with the ratio detector circuit. The input signal current (solid blue) is driven from the video amplifier and moves in and out of C_1 and up and down through R_1 at the instantaneous frequency of the FM sound signal. The center frequency for this signal is 4.5 MHz; however, the modulation may cause it to vary between the limits of 4.475 to 4.525 MHz. The plate current through this tube (solid red) is caused to pulsate at the instantaneous input frequency; these pulsations set up an oscillation of electrons between L_1 and C_3, which are resonant at the center frequency of 4.5 MHz.

The secondary tank circuit (L_2 and C_5) is also resonant at this same frequency. Since L_1 and L_2 are two windings of a transformer, the inductive coupling process which goes on between them sets up and sustains another oscillation (solid blue) of electrons in the secondary tank circuit. This is the last spot at which the FM sound signal

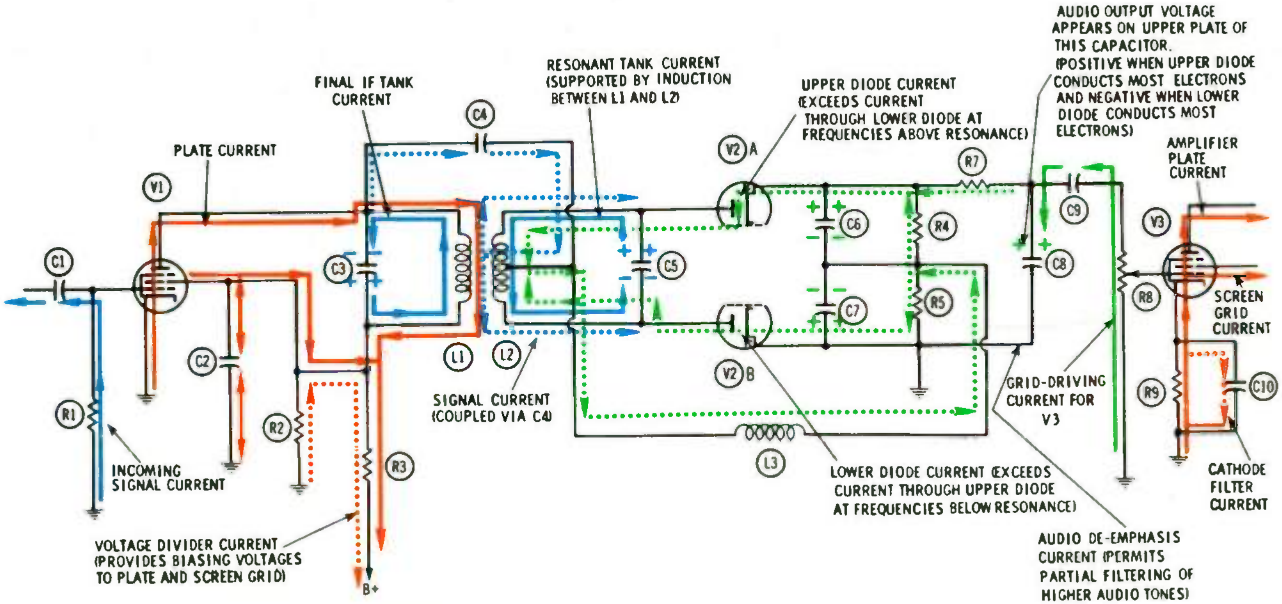


Figure 9 — Operation of a sound system employing a phase discriminator.

appears in the receiver. In Figure 9 this secondary current is moving downward through L_2 so as to deliver electrons to the lower plate of C_5 and to withdraw electrons from the upper plate. If this were the only signal current flowing in these secondary tank components, the positive voltage indicated by plus signs on the upper plate of C_5 would cause electrons to flow through V_{2A} from cathode to plate. Half a cycle later this same amount of positive voltage would have been built up on the lower plate of C_5, causing V_{2B} to conduct an equal quantity of electrons. The net amount of electron current available to flow away from the area of each diode plate toward the junction of load resistors R_4 and R_5 (through L_3) would be equal, so that equal and opposite voltages would be developed across the two resistors. These two equal and opposite voltages add up to zero.

Even when the FM signal varies above and below its center frequency, the condition of equal conduction of the two diodes during alternate half-cycles would not be disturbed, since the two diode plates would be driven to equal values of positive voltage by the tank voltage. Consequently, without the additional means of coupling provided by C_4, the rest of the circuit cannot function as a demodulator. Capacitor C_4 connects the top of the primary tank circuit with the center tap of secondary winding L_2. This results in applying the primary tank voltage, simultaneously in the same phase, to the plates of the two diodes. This statement may be clarified by explaining that when the voltage at the top of the primary tank is negative, as it is in Figure 9, a negative voltage is simultaneously applied to the plates of V_{2A} and V_{2B}. The physical means by which this is accomplished is a minute flow of electron current (dotted blue) from the top of the primary tank onto the left-hand plate of C_4, with an equal quantity being driven away from the right-hand plate through the two halves of center-tapped inductor L_2. This flow through the two halves of L_2 is, of course, in opposite directions toward the two diode plates. A half-cycle later, when the voltage at the top of the primary tank has become positive, this minute electron current will reverse its direction and be drawn toward L_1. This action will simultaneously draw electrons away from both diode plates, making them positive, and causing both diodes to conduct equal amounts of electrons.

If this were the only signal current flowing in the discriminator, it could not function as a demodulator, because with each positive half-cycle of the FM signal, whether it is occurring at the center frequency, or above or below it, both diodes will conduct equal quantities of electrons, so that equal and opposite voltages will be developed across load resistors R_4 and R_5. They would again add up to zero so that the output voltage measured across *both* resistors (from ground to the top of resistor R_4) would be zero.

The dual-diode circuit of Figure 9 will function as a detector only when the FM signal is coupled to the diode circuit by both of the methods just discussed—transformer coupling between L_1 and L_2, and capacitive coupling via C_4. The waveform diagrams of Figures 6, 7, and 8 apply with equal validity to this phase-discriminator circuit. When the FM signal is exactly on its center frequency, the oscillation in the secondary tank circuit will be exactly 90° out of phase with the oscillation in the primary. This is indicated in Figure 6. The solid blue waveform achieves its maximum positive value exactly a quater of a cycle *after* the dotted blue waveform reaches its peak in Line 1, and in Line 2 it reaches its peak a quarter of a cycle *before* the dotted blue waveform reaches its peak. The resultant waveform (red) in Line 1 is the voltage applied to the plate of upper diode V_{2A}, and the red waveform of Line 2 is the voltage applied to the plate of lower diode V_{2B}. The positive portions of each of these waveforms cause the respective diodes to conduct.

When V_{2A} conducts, its plate-current path takes it from the cathode to the plate within the diode, downward through the upper half of L_2 to the center tap, through L_3, and upward through R_4 to the cathode. These electrons, in flowing upward through R_4, develop a positive voltage at the top of this resistor. This positive voltage is indicated by plus signs on the upper plate of C_6.

When V_{2B} conducts, its current flows from cathode to plate within the diode, upward through the lower half of L_2 to the center tap, through L_3, and downward through resistor R_5 to the cathode again. In flowing downward through R_5 a voltage is developed across this resistor which is negative at the top and positive at the bottom. These voltages are indicated by appropriate plus and minus signs on C_7.

When these two diode currents flow through their respective load resistors (R_4 and R_5) in exactly equal amounts, then equal voltages must be developed across the two resistors. Since the currents flow in *opposite* directions through these resistors (upward through R_4 and downward through R_5), the sum of these voltages, which is measured from the top of R_4 to ground, must be zero. This condition will be satisfied only when the two input signals are in exact phase quadrature, as shown in Figure 6. This happens only when the tuned tanks are operated at their natural resonant frequency of 4.5 MHz.

When the signal deviates above the center frequency, the condition shown in Figure 7 exists. The two input waveforms *as measured at the top of the tank* move closer in phase, whereas the two input waveforms which exist at the bottom of the tank move farther apart in phase. The most extreme cases which could occur would be for the two voltage waveforms at the top of the tank (shown in Line 1) to be exactly in phase with each other, while the two voltage waveforms at the bottom of the tank would be exactly a half-cycle out of phase. The resultant (red) waveform in the first case would then be twice the amplitude of the input waveforms, and the resultant in the second case would be zero—in other words, a straight line. The lower diode would not conduct at all under these conditions. These extremes are not even approached in normal discriminator operation.

During operation above resonance, the plate of V_{2A} will be driven to more positive values than the lower diode plate, because of the differing sizes of the applied waveforms (red in Figure 7). V_{2A} will conduct more electrons than V_{2B}. Thus, the amount of current flowing upward through R_4 will exceed that which flows downward through R_5 and a net positive voltage will be developed at the upper terminal of R_4. This can be described as a positive half-cycle of audio voltage. In order to meet this temporary demand for electrons to flow into the upper diode, electrons will be drawn away from the left plate of C_9 and upward through grid-driving resistor R_8. This creates a positive voltage at the grid of V_3.

Figure 8 shows what happens to the two signal voltages when the signal deviates below the center frequency. The two input waveforms at the top of the tank move farther apart in phase so that their resultant waveform (red) decreases in amplitude. At the same time the voltages being applied to the bottom of the tank have moved closer together in phase, and their resultant waveform (red) is greater. This applies a higher positive voltage to the plate of V_{2B}, so it conducts more electrons than V_{2A}. This develops a negative voltage at the top of R_5 which is greater in magnitude than the positive voltage being developed across R_4, so that a net negative voltage exists at the top of R_4. This is a negative half-cycle of audio voltage, and it is characterized by a downward movement of electron current through R_8.

R_7 and C_8 constitute a de-emphasis circuit for partially attenuating the higher audio frequencies in the sound signal. Because the impedance of this capacitor, like any capacitor, decreases as the frequency increases, the higher audio frequencies will be partially bypassed or filtered to ground through C_8, and smaller amounts of current will be driven up and down through R_8 at these frequencies.

In addition to accumulating an audio voltage on the upper plate of C_6, this capacitor along with C_7 serves to filter out the IF pulsations which characterize the current through the upper detector. While one audio cycle may last for a thousandth of a second, there will be four thousand or more pulsations of diode current during this period. Each time one of these pulsations goes through the diode, there will be an upward movement of electrons from ground through C_7 and C_6. When each pulsation stops, the electron movement through these capacitors reverses. No comparable requirement exists to provide a filter function for the cathode of lower diode V_{2B}, since this electrode is connected to ground.

C_8 also functions as an IF filter capacitor, but to a lesser extent. As each pulsation of electron current is drawn into the upper diode, some electrons will be drawn through R_7. These electrons must be drawn from someplace, and the only two available paths are from the upper plate of C_8 and the left-hand plate of C_9. If the electrons are drawn from C_9, however, an equal number must be drawn upward through R_8 in the process. Because the reactance of C_8 is much lower at the sound carrier frequency of 4.5 MHz than the impedance of C_9 in series with R_8, the great bulk of this filtering action will occur through C_8 to ground.

The amount by which the carrier signal deviates above and below the center frequency is what determines the loudness of the final audio signal.

AUDIO SERVICING

There are many types of audio troubles, but they are generally simpler to diagnose than picture problems. The circuits are simpler, and consequently, the trouble is easier to localize, although some of the problems can be troublesome and can require a great deal of time to solve. It will be found, however, that a systematic review of the probable causes of the trouble will not only save time but will serve to pinpoint the problem area. An example of how a very troublesome audio problem was solved is described in the following troubleshooting section.

DISTORTED SOUND

The problem started out as a routine complaint of distorted sound. Replacing all of the sound and audio tubes, and adjusting the detector and IF transformers, failed to eliminate the distortion. This was quite surprising, since one of the push-pull output amplifiers and the detector tube had tested defective in a good tube tester.

A quick visual check of the chassis, cabinet and speaker hookups revealed that it would be much simpler to take cabinet and all to the shop. (Because of the nature of the trouble, it was necessary to take the speakers as well as the chassis. Connection for the four speakers, two on each side of the low-boy cabinet, were wired and soldered, thereby complicating their removal and reinstallation.)

Further analysis of the problem in the shop indicated that the audio distortion had at least two causes. The sound was mushy and garbled at low volume levels, while a rattling condition was noted at high volume settings. It also seemed that maximum volume wasn't loud enough—not for four speakers and a 10-watt amplifier.

Realignment of the IF and detector stages in accordance with the procedure outlined in the service literature failed to improve sound quality at all. Tapping the chassis near some of the components disclosed unusually high microphonic tendencies. The condition seemed to be worse when the areas around L_{11}, L_{14}, L_{15}, V_4 and V_6 (all shown in Figure 10) were tapped. The tubes were rechecked and the detector and output tubes previously found defective were now replaced.

As expected, this had little effect on the trouble.

The next step was to remove the TV chassis. Then the reverse side of the printed wiring board was carefully checked. Voltage readings were observed at key points while the three IF transformers (L_{11}, L_{14} and L_{15} in Figure 10) were tapped and twisted in several directions. At one point, it was possible to get the sound to cut out when exerting a slight force on the shield housing of L_{14}. After removing this shield, the dual-winding transformer was carefully removed from the printed board. A subsequent visual inspection revealed traces of excess solder, which was assumed to be shorting one of the secondary coil terminals to the grounded transformer shield.

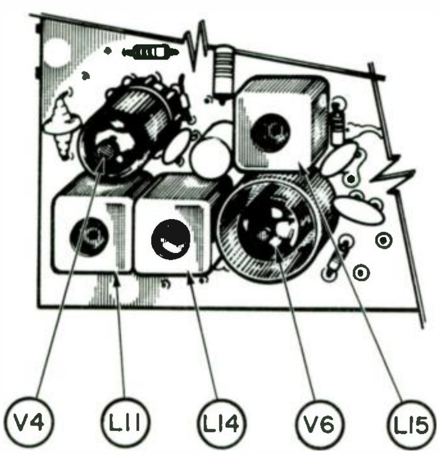


Figure 10 — Audio-IF and detector component section of a representative receiver.

A little heat from a miniature soldering iron caused the excess solder to be drawn to the terminals. (This same principle can be employed if you desire to remove a component from a printed board. Simply heat the lead of the component to be removed, being very careful not to heat the foil surface itself, and the solder will be drawn to the heat of the iron. A stiff brush is also useful for removing surface solder as it becomes molten. When most of the solder has been "worn away" in this manner, the remainder should be drawn to the heated lead, leaving it free from contact with the board.)

It was felt that since one of the IF transformers had revealed traces of excess solder, the others could bear investigation. Each of the shields was removed, and the extra solder was drawn back to the hot iron. Replacement of the shields and a touchup of the IF alignment cleared up the sound distortion at low volume levels.

Because one of the audio-output tubes had proved defective, the audio amplifier (located on a separate chassis) was given a quick check for leaky coupling capacitors, burnt resistors, etc. No defects were noted. This left only one possible source for the high-level rattling still present—the speakers themselves.

The four speakers were carefully removed and given the usual tests for rubbing voice coils and unbonded cone edges. No evidence of either type of defect was noted. The next step was to connect the amplifier output to the shop's speaker system—a 12″ coaxial unit enclosed in a bass reflex cabinet. There was no trace of the distortion, so the cause for the trouble was definitely isolated to the speakers—but they still didn't show signs of any defect that could cause the trouble. However, the speakers were connected to the audio amplifier and given a test in free air. This time the volume was slightly lower and fidelity was off a bit, but there wasn't a trace of the rattle.

Suspecting a rattle in the cabinet, a careful inch-by-inch check of the cabinet was started. Almost immediately, the cause was located—some loose wood on the cross member of the 6″ × 9″ speaker cutout. One layer of the plywood was loose and rattling. All the evidence indicated that the defect had been present before the set left the factory. However, after talking to the customer, it was concluded that the condition didn't actually develop until the set had been in operation for awhile.

The final solution to the problem included removal of all the loose wood chips and the application of a layer of wood glue to the plywood around the speaker cutout. In lieu of a suitable glue, a heavy coat of varnish can be used.

This experience served to emphasize that you should not be too hasty in making a decision to take only a part of a TV receiver into the shop for repairs when the trouble could be caused by a portion left at the home.

ELIMINATING TV BUZZ

When you ask any serviceman, "What gives you the most trouble in the TV sound section?" he will probably reply, "Buzz." This persistent symptom, much as it annoys the TV owner, is even more of a headache to the service profession. Besides being hard to localize, it also presents somewhat of a customer-relations problem. Many set owners seem willing to put up with buzz in the sound for a long time without calling for service, but when the set finally develops a more serious trouble, they are apt to think that the buzz should automatically be corrected along with the other repairs. On the serviceman's part, there is some tendency to shrug off buzz problems as being due to inherent design faults or poor signal transmission from stations. Regardless of these attitudes, buzz is usually the result of genuine circuit defects which can be cured by applying technical know-how.

Types of Buzz

In troubleshooting, a clear distinction must be made between "hum" and "buzz." Both of these effects are produced by low-frequency interference signals, but the similarity ends there. The smooth tone called "hum" is the result of a sine wave entering the audio section from the B+ or heater power supply, whereas "buzz" is a more rasping sound caused by a pulse signal.

These pulses can originate from two different sections of the receiver, and the first step in solving a buzz problem is determining what type of buzz is present.

If the interference can be heard even when no RF signal is applied to the receiver, the pulses are undoubtedly coming from the vertical-sweep section. You can verify this by simply turning the vertical hold control and listening for a slight change in the pitch of the buzz. Once you've recognized the sweep circuit as the interference source, a scope will help you find the undesired coupling path between the vertical and sound sections. You'll most often find a boost-filter or vertical-decoupling capacitor at fault, but an occasional case is due to a defective vertical-output transformer or improper lead dress.

If the trouble is present only when a station signal is being received, it is probably intercarrier sync buzz. This annoying sound ordinarily changes in intensity according to the content of the video signal, and its amplitude can also be varied by adjustment of the fine-tuning control. Intercarrier buzz is a tricky condition that defies analysis unless its basic underlying cause is plainly understood.

Sound Trouble in Video Circuits

The sound-IF signal in an intercarrier system is derived from mixing the sound and picture carriers at the video detector. Most of the modulation on this 4.5-MHz signal is FM sound information; however, it also picks up a certain amount of amplitude modulation (primarily sync pulses). The job of the sound IF and detector is to amplify and recover the frequency modulation while ignoring the amplitude variations. If something goes wrong with the AM-limiting function of the sound circuit, such as the amplitude ratio between picture and sound carriers, or the sync-pulse amplitude, a 60-cycle buzz will result.

Poor alignment or a faulty part in the sound section can either defeat limiting or attenuate the 4.5-MHz signal to a point where the normal sync pulses produce a noticeable buzz. The same symptom can also be caused by overloading of the video-IF or detector stages. Anything causing the vertical-sync pulses to be clipped or inverted ("sucked out") leaves gaps in the sound signal; these are effectively the same thing as amplitude modulation but cannot be removed by the limiting action of the sound system. Attenuation of the sound carrier, due to signal reflections reaching the antenna or to a poor response in the RF or video-IF stages, can also result in buzz.

Most picture-circuit troubles that lead to the sync-buzz symptom also cause the composite video waveform to develop visible defects; therefore, a scope check of the video-detector output signal is a good way to determine that such troubles are present. Obvious compression or distortion in this waveform is a warning to check for gassy IF tubes, loss of AGC bias, RF or IF misalignment, and similar troubles.

Sound-Circuit Troubleshooting

If you can determine with reasonable certainty that sync buzz is not due to a fault in the RF, IF, video, or AGC sections, turn your attention to the sound stages.

During the past several years, practically all TV manufacturers have adopted some type of quadrature detector circuit—particularly the 'DT6 version shown in Figure 11. Generally, one IF tube precedes the detector stage. It may be either a triode (as shown) or a pentode, but it is almost always a section of a multipurpose tube.

If an intermittent sync buzz is occurring, and you find low plate voltage on the IF tube, check R_2 in the circuit of Figure 11. An increase in value of this component will invariably cause a slight buzz in the audio output.

Should you find that the 'DT6 cathode voltage is about twice normal, make sure R_3 hasn't increased in value. If it is at fault, you may also find that most of the buzz can be eliminated by adjustment of quadrature coil L_2. Always replace the resistor, however, when you find it off value.

Another symptom to look for is low voltage on the screen (pin 6) of the 'DT6. Check to see if R_4 has increased in value; if this resistor goes up to about 1 meg, the sound output will drop considerably and you'll hear an overriding buzz. Cathode- and screen-bypass capacitors of this circuit can also give you trouble. If the buzz is fairly constant and cannot be tuned out by the quadrature coil, try a substitute for both C_4 and C_5 in Figure 11.

Generally speaking, adjustment of the quadrature-grid coil in the average 'DT6 circuit is not extremely critical as far as intercarrier buzz is concerned. A misadjustment *will* produce buzz, especially on strong input signals; however, if the slug setting is very

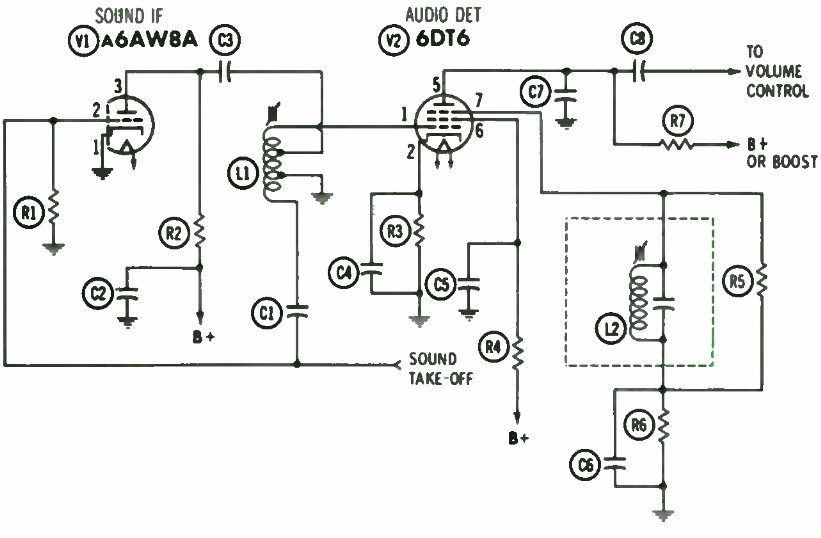
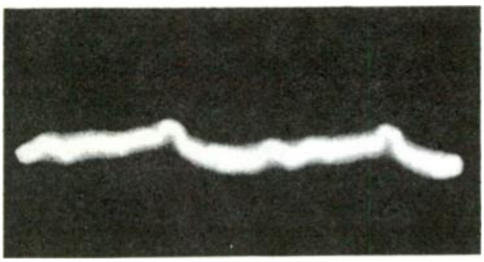


Figure 11 — Sound-IF and detector circuit of a typical TV receiver.

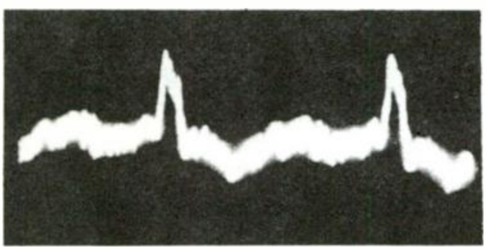
far off, the sound will also be considerably distorted. If the coil or one of its connections is open, you'll detect a buzz, but the sound will also be garbled and low in volume. Adjustment of the coil will, of course, have no effect.

Another component that can produce tricky symptoms is bypass capacitor C_6. If it changes value, buzz will develop and the sound will become distorted. However, you can usually compensate for the shortcomings of this capacitor by adjusting the quadrature coil. If C_6 opens completely, buzz will be heard, but the over-all output will be extremely reduced.

Buzz may be due to misalignment of the sound section, rather than to any specific component defect. Fortunately, a complete realignment of a typical quadrature detector and sound IF circuit is a simple three-step procedure which can be "played by ear," using a regular station transmission as a signal source. All slugs are merely tuned for maximum sound with minimum buzz.



A Normal background noise.



B Audible sync buzz (10V p-p).

Figure 12 — Buzz waveforms during a pause in sound modulation at a 30 hertz sweep rate.

It should be possible to reduce buzz practically to the vanishing point. A faint suggestion of pulses may still be apparent in the signal fed to the volume control during breaks in audio transmission, as shown in Figure 12A. This slight modulation can easily be tolerated, but an audible buzz soon appears if the pulses become stronger as illustrated in Figure 12B.

SUMMARY

The sound IF system of a television receiver is similar to that of an FM receiver. The IF frequency of the TV is 4.5 MHz rather than the 10.7 MHz used in FM radio receivers.

TV tube sets use the gated-beam FM detector tube and associated circuitry or a ratio detector circuit. The phase discriminator circuit is similar to the ratio detector circuit, principally in the arrangement of the diodes. Audio variations on the FM signal that are produced by conditions outside the transmitter or receiver are amplified to a minimum level. The variation in amplitude is not cut-off by the action of the limiter circuit.

The audio in a TV set can have the same troubles that affect an FM radio receiver. In addition the sound can have the unusual sound called buzz, that usually comes from the sync circuits.

TEST

Lesson Number 85

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-085-1.

1. **The intercarrier sound system should provide**
   A. amplification of the FM sound carrier, limiting, detection, and audio amplification.
   B. amplification of the FM sound carrier, detection, and audio amplification.
   C. amplification of the FM sound carrier, limiting, and detection.
   D. amplification of the FM sound carrier only.

2. **The quadrature tank circuit of a gated-beam tube follows the input frequency by**
   A. 180° degrees.
   4 B. 0° degrees.
   C. 90° degrees.
   D. a varying number of degrees.

3. **The gated-beam tube conducts plate current when:**
   A. only the first control grid is positive.
   5 B. both control grids are positive.
   C. either control grid is positive.
   D. none of the above.

4. **The phase relationship between the two oscillating tank voltages in a gated-beam tube is altered when**
   A. the sound carrier is shifted 4.5 MHz.
   6 B. the sound carrier is not modulated.
   C. the sound carrier is audio modulated.
   D. the sound carrier is frequency modulated.

5. **When the IF signal shifts below the center frequency, the voltages in the quadrature tank and in the input tank**
   A. quickly shift 180° apart.
   B. stay in the same relationship.
   6 C. move farther apart.
   D. move closer together.

6. **In Figure 5, there can be no accumulation of negative electrons or positive ions on the upper plate of C4**
   14 A. due to the mode of coupling to the center tap of L_2.
   B. because it is an electrolytic capacitor.
   C. because it will not pass AC.
   D. because it has a high voltage rating.

7. The diodes in a ratio detector circuit will conduct
- A. equal amounts of current when the modulating frequency is below the center frequency.
- B. equal amounts of current when the modulating frequency is above the center frequency.
- C. unequal amounts of current when the frequency varies.
- D. equal amounts of current under all conditions.

8. If the AM-limiting action of the sound circuit is lessened,
- A. a continuously variable pitch will be heard.
- 28 B. a 60 hertz buzz can be heard.
- C. a 60 hertz hum will always be heard.
- D. none of the above.

9. An intermittent sync buzz can be caused by
- A. a by-pass capacitor in the IF circuit that has become shorted.
- 29 B. a plate resistor in the IF circuit that has increased in value.
- C. a shorted IF coil.
- D. a short circuit of the power supply.

10. Low voltage on the screen of a gated-beam tube can cause buzz. If the resistors in the plate supply are not defective, the next components to be checked to eliminate buzz are the
- A. input to the IF stage.
- 29 B. the IF coils.
- C. by-pass capacitors.
- D. grounding connections.

Notes

Notes

Portions of this lesson from
TV Diagnosis and Repair
by PF REPORTER Editorial Staff
TV Video and Sound Circuits
by Thomas M. Adams
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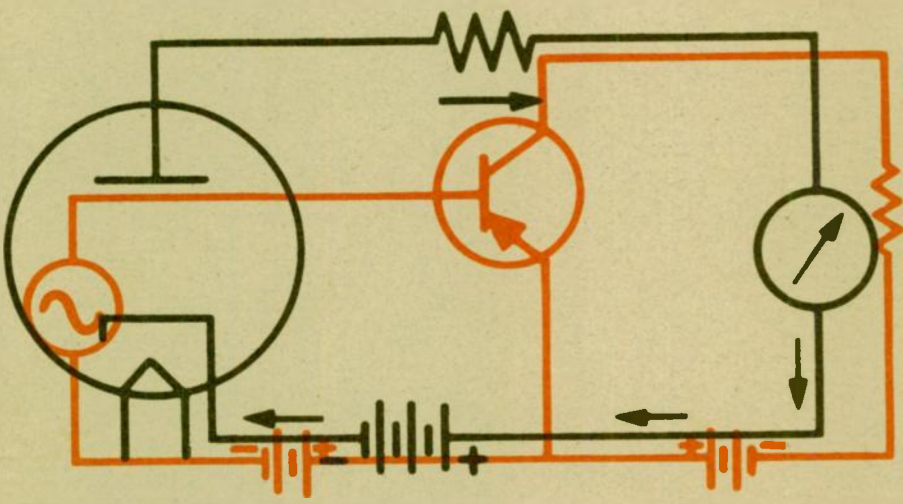
LESSON NO. 86

TELEVISION VIDEO SYSTEMS PART 1



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
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ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
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Contents

TELEVISION VIDEO SYSTEMS-PART 1

INTRODUCTION

In previous lessons we have studied the recovery of the transmitted television signal. The television signal induces an RF voltage into the television antenna. This voltage is coupled to the tuner by the transmission line. In the tuner, the signal is amplified and converted to IF. The composite video signal is further amplified and filtered in the IF strip.

The video signal must be separated from the IF and then amplified before it is applied to the picture tube. The video amplifier must be capable of amplifying a signal with a very wide bandwidth and this presents many design problems.

In this lesson, we will discuss video detection, video amplification, and the application of the recovered video signal to the picture tube of a television receiver. We will also discuss DC restorers and brightness control methods utilized in television receivers.

THE TELEVISION SIGNAL

Figure 1 shows some of the components of the typical television signal. The frequency-modulated (FM) sound carrier is shown in Figure 1A. This signal has constant amplitude and varies around a center frequency near the high end of the frequency band allocated to that particular channel. The center frequency for the audio carrier is 5.75 MHz above the low end of the band and .25 MHz below the high end of the band. The maximum deviation permitted above and below the center frequency is 25 kHz. The audio carrier is transmitted continuously, even in the absence of sound information.

Figure 1B shows the horizontal synchronizing signals. These signals are used to pulse-modulate the picture carrier, and they occur at a rate of 15,750 pulses per second. Actually, three different types of pulses are used to pulse-modulate the carrier. The horizontal sync pulses are interrupted at regular intervals by additional pulses which are necessary to provide vertical synchronizing information to the receiver. These additional pulses consist of equalizing pulses and a series of wider pulses which are generally referred to collectively as the serrated vertical pulse.

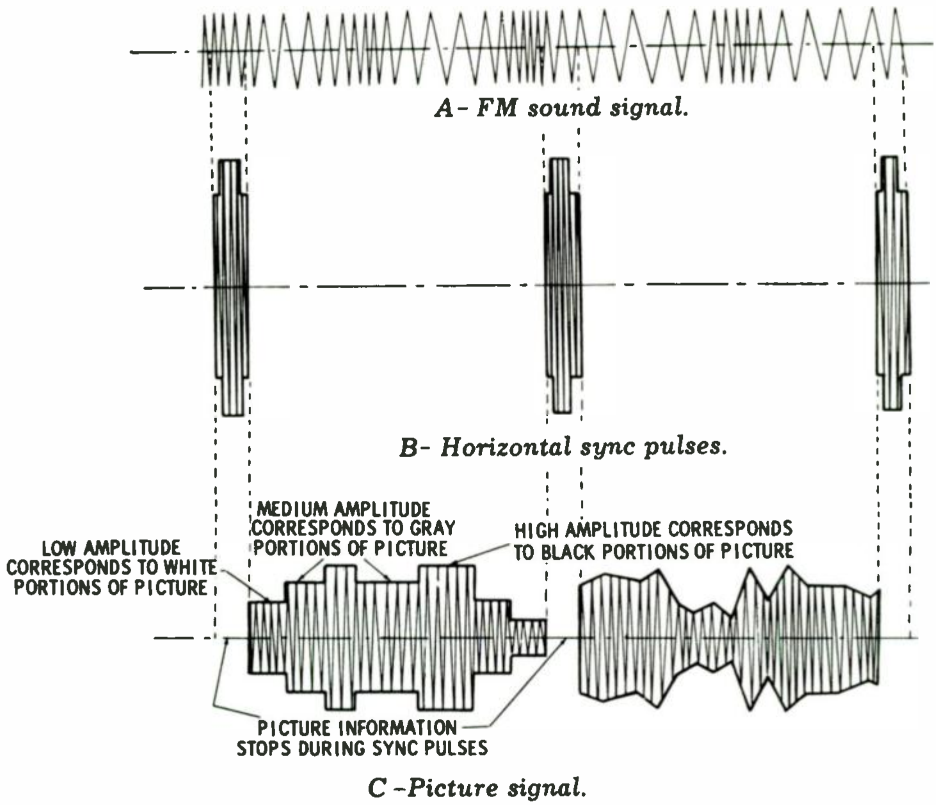


Figure 1 — Waveforms of the three types of intelligence which make up the composite video signal.

Each horizontal pulse is superimposed on a somewhat wider base, called a blanking pedestal. The blanking-pedestal amplitude is made higher than the highest portion of the picture waveform; therefore, it determines the "black level" of the video signal. Each horizontal sync pulse indicates the start of a new line of picture information; thus, you would expect 15,750 such lines to be traced out each second.

The pulses which convey the vertical synchronizing information must occur 60 times each second. This vertical sync pulse group is composed of six narrow equalizing pulses, six wide pulses, and six more narrow equalizing pulses, in that order. If they were allowed to continue, these eighteen pulses would occur at twice the rate of the horizontal sync pulses, or 31,500 times per second. Consequently, each such vertical sync-pulse group consumes the amount of time that would normally be devoted to nine lines of picture information. In addition, from nine to twelve horizontal sync pulses occur following the equalizing pulses but during the

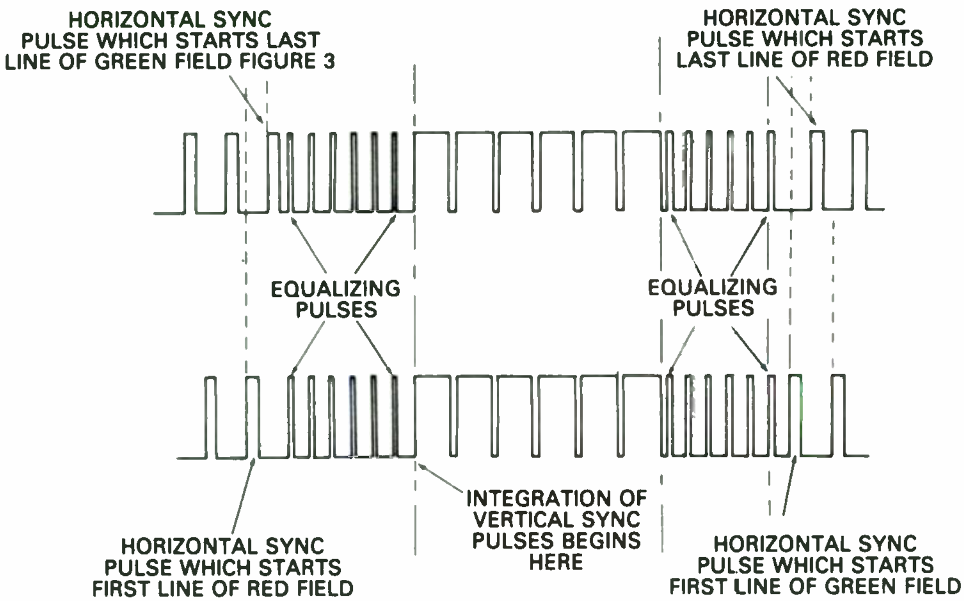


Figure 2 — Width and phase relationships of the three types of pulses in the composite video signal.

vertical blanking-pedestal time. Hence, there are several lines in each field when no picture information is transmitted.

The width and phase relationships of the three types of pulses for two successive fields of a picture are given in Figure 2. The process of integrating a vertical sync pulse begins once every 1/60 of a second when the wide pulses in the center of Figure 2 occur. In each line of Figure 2, the wide pulses are followed by six narrow, equalizing pulses. In the upper line, a wide space equal to one whole line of picture information is shown between the last equalizing pulse and the first horizontal sync pulse. In the lower line, however, only half of this amount of time elapses before the first horizontal sync pulse occurs. This is an essential part of the interlacing process, and it insures that the first line of one field will begin at the left edge of the screen, whereas the first line of the alternate field will begin in the center of the screen.

A new horizontal sync pulse occurs every 63.5 microseconds, since 15,750 of them occur every second. A single line of picture information lasts a somewhat shorter time, since each blanking pedestal consumes about 8 microseconds, and the picture line is not permitted to start until after the blanking pedestal has ended. One entire picture (known as a raster) is composed of 525 lines, and each raster is made up of two fields. Thus, each field has 262.5 lines, and a new field is initiated every 1/60 of a second by a vertical sync pulse. The horizontal synchronizing action must continue even during the vertical synchronizing action to maintain horizontal synchronization. Alternate fields are interlaced so that corresponding lines in successive fields are not overlaid on each other. Figure 3 shows the manner in which the picture lines are interlaced between successive fields. Figure 3 shows (solid blue) what the horizontal lines would look like during the vertical retrace period. We cannot see them, however, because they are blanked out during the entire vertical retrace action. In Figure 3 the picture lines of the first field are shown in solid red. Interlaced between these red lines are the picture lines of the second field (solid green). Both sets of lines must slant slightly downward from left to right. Each such line takes about 55 microseconds to complete itself. The retrace action, which takes only about 1 or 2 microseconds, connects the end point of one picture line to the beginning of the next line; therefore, the retrace lines are essentially horizontal. These retrace lines are shown in dotted black. First, all the lines represented in red in Figure 3 are traced. Then, after vertical retrace has occurred, the lines represented in green are traced.

The vertical retrace lines which follow the first (red) field are shown in dotted blue, and the vertical retrace lines which follow the second (green) field are shown in solid blue.

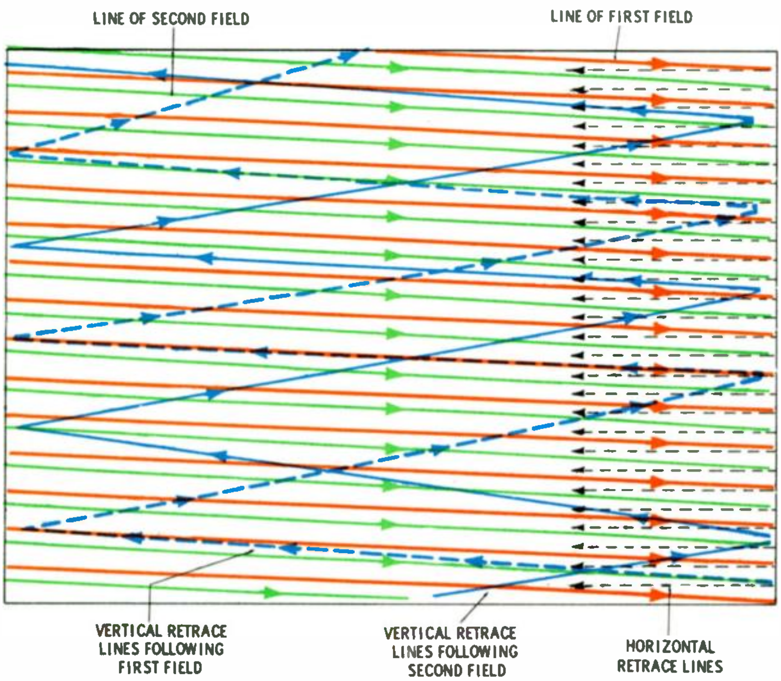


Figure 3 — Method of tracing a pattern on the TV screen.

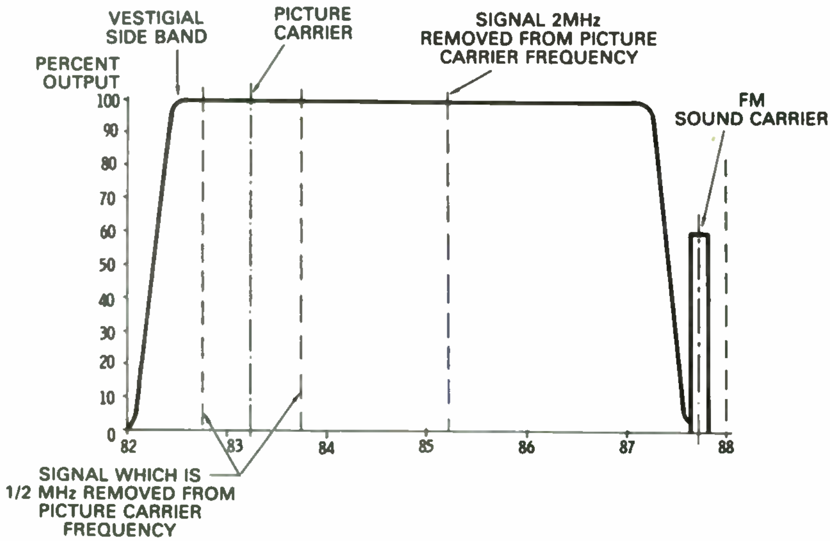
Figure 1C shows two successive lines of picture information. Dark areas in the picture lead to maximum amplitude of the video voltage, and light areas cause minimum amplitude. The two lines of video voltage shown in this illustration would be part of a single field. On the next successive field, alternate lines would be illuminated by the scanning beam and interlaced between the lines traced in the preceding field. Since each field is renewed 60 times a second, the individual lines cannot be discerned by the human eye, and an effect similar to that in motion pictures is achieved, i.e., continuous rather than intermittent movements.

The number of changes from light to dark during an individual line determine the bandwidth requirements of the television carrier. If the screen were divided into a checkerboard pattern with each small square just high enough to occupy one line of the picture, a carrier bandwidth of 4 MHz would be required. This can be computed by simple arithmetic. If the picture raster were perfectly square (which it is not), then a maximum of 525 lines would each contain the same number of small squares, alternating between black and white. The total number of alternations (from black to white and back again) required to present one entire field would be a maximum of 525 × 525/2, or approximately 137,800 cycles. Since there are 30 rasters presented each second, the total number of cycles per second would be 30 × 137,800, or about 4,130,000 cycles per second. The total number of individual picture elements, or squares, would be twice this figure, or about 8 million.

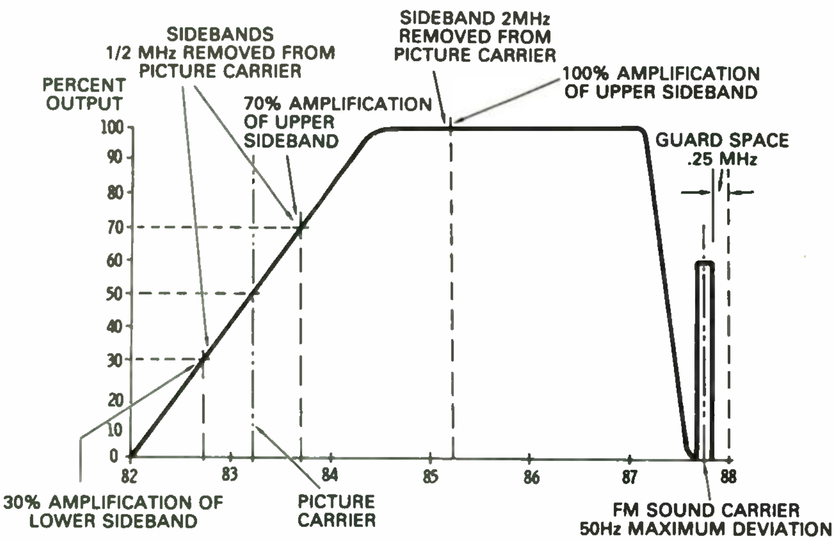
One important modification of these calculations should be made if one desires a more accurate figure. First, a television screen is not perfectly square. The width to height ratio, which is called the aspect ratio, is 4/3. Therefore we would require four thirds as many squares in our checkerboard as were indicated previously. Also, since some lines are sacrificed during the vertical retrace period which follows each field, approximately eighteen lines are lost per raster. But this does not significantly reduce the carrier bandwidth requirements, because during the approximately 55 microseconds which elapse during the scanning of each individual line, picture information will be occurring at the 4.13 MHz rate calculated previously, after modification by the aspect ratio. This modification would raise the sideband requirement to 4/3 × 4.13, or about 5.4 MHz. This amount of sideband can occur on either side of the carrier frequency.

The response of the television receiver should be such that all sideband frequencies in the carrier will be equally amplified. To accomplish this, the receiver response curve should approximate that of Figure 4B. The slope of the left edge of this response curve is arranged to pass through the zero point at the left edge of the channel; it also passes through the picture carrier (a center frequency) at the 50% response point. The picture carrier or center frequency is always located a distance of 1.25 MHz above the low end of each channel; therefore, for Channel 6 it is located at 83.25 MHz. The sloping portion of the response curve ends at 84.5 MHz (1.25 MHz above 83.25 MHz).

An example of what happens to a video signal which differs from the



A – Video signal.



B – Ideal receiver response.

Figure 4 — Bandwidth requirements (Channel 6) when vestigal-sideband transmission is employed.

picture carrier frequency by half a megahertz is shown in Figure 4. Figure 4A indicates that all of the upper sidebands and some of the lower sidebands of this signal are transmitted equally. Figure 4B, however, indicates that 30% of the total amplification in the receiver will be from the lower sideband, and 70% of the total amplification from the upper sideband.

An example of a video sideband which is 2 MHz from the picture carrier is also given in Figure 4. None of the lower sideband of this signal appears in the transmitter output of Figure 4A. Within the receiver, 100% of the total amplification of the signal is from the upper sideband.

Vestigial-sideband transmission offers several advantages over single-sideband transmission as the solution to the bandwidth requirements. If single sideband were used, very complex filter networks would be required at the transmitter to eliminate *all* lower sidebands. At the receiver end, elaborate and costly methods of generating and controlling a reference frequency equal to the picture-carrier frequency would be required, because the receiver would have no other means of distinguishing between the picture-carrier frequency and the sideband frequency. By transmitting the carrier and a portion of the lower sideband, the need for an independent local oscillator to reinsert the carrier is eliminated.

Vestigial-sideband operation implies that the bandwidth requirements are:

Lower sidebands	1.25 MHz
Upper sidebands	5.40 MHz
Guard spaces(approx.)	.70 MHz
FM carrier	.05 MHz
	7.40 MHz

However, the modern receiver does not begin to use all of the bandwidth indicated by the computations. Instead of allowing 5.4 MHz for the upper sidebands, only 4.0 MHz is allocated; this amount of band space has proved adequate to provide sufficient clarity and definition in the picture. When this is done, the sum of the four listed requirements is reduced to approximately 6 MHz, the maximum allowable width of a television channel.

THE VIDEO DETECTOR

Review of Basic AM Detection

Detection of an amplitude modulated signal is done with rectification and filtering. Any attempt to recover video from an amplitude modulated signal without rectifying it first results in the destruction of the RF carrier with its video counterpart, or serious distortion of the resultant video.

Once the signal is rectified, the gaps between RF peaks can be filled with a simple RC filter. This filter has a very short time constant and responds only to the high frequency RF fluctuations. The capacitor in the filter charges during the rise and discharges during the fall of the RF pulse. Figure 5 (A through D) illustrates how rectification of the carrier and filtering of the RF peaks causes recovery of the video portion of an amplitude modulated wave.

In Figure 5A, we show the modulated RF waveform. It is applied to L_1 of transformer T (Fig. 5B), which induces a similar voltage into L_2. Current flows in the forward direction through L_2, the diode, and R, developing a voltage drop across R, from which the output is taken.

Refer momentarily to Figure 5C; this particular illustration ignores the presence of the effects of C_2. The illustration 5C shows the presence of only positive RF pulses. Notice how they follow the amplitude variations of the modulation.

In Figure 5D, the effect of the filtering action of C_2 is shown. Capacitor C_2 functions as a smoothing device similar to a filter in a power supply. Its constants are chosen, however, to remove only the RF variations, not the video. Although the recovered video waveform at D looks somewhat ragged, it does approximate the original video closely enough to produce a good-quality picture.

Video Detectors

The video detector in a television receiver performs essentially the same function that the second detector in a superheterodyne amplitude-modulated radio receiver performs. It rectifies the signal (video and sync pulses) fed to it by the video IF system, removes the IF components, and feeds the remain-

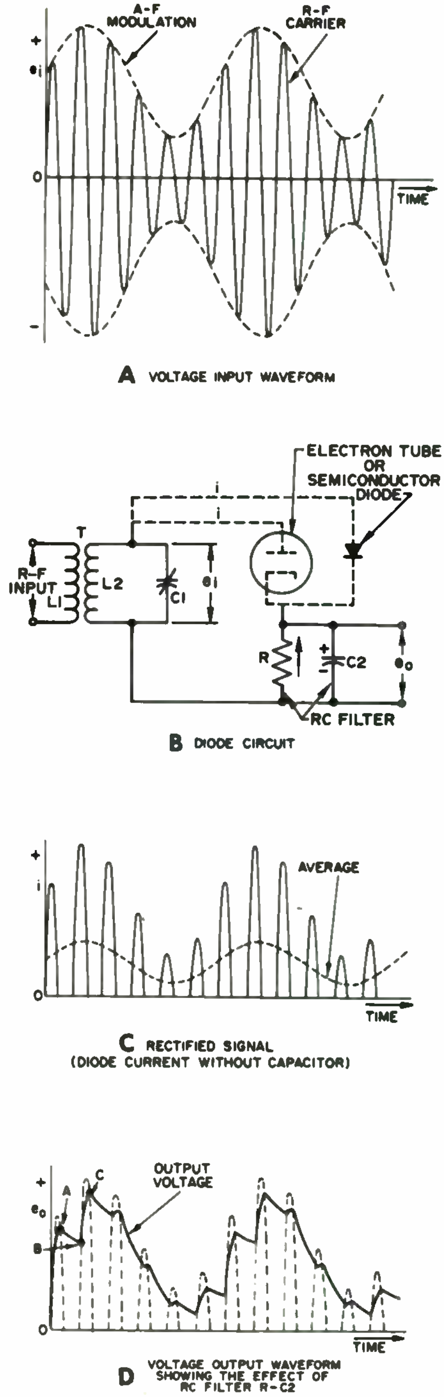


Figure 5 — Detection of an amplitude modulated signal.

ing signal and sync information to the video amplifier. Various circuit arrangements, employing either diode electron tubes or crystals, are used by the manufacturers of television receivers.

One type of diode detector is shown in Figure 6. Two methods of connecting the detector are shown. The output of V1 has a negative picture phase, and V2 has a positive picture phase.

In the circuit containing V1, the low amplitude positive-going picture signals correspond to the brighter portions of the picture and higher amplitudes correspond to progressively darker portions of the picture. This corresponds to the negative picture phase.

The low amplitude negative-going picture signals of V2 correspond to the brighter portions of the picture and higher amplitudes correspond to progressively darker portions of the picture. This corresponds to the positive picture phase.

The concept of negative picture phase may be made clearer from the following considerations. A video signal having a negative picture phase causes the cathode of the picture tube to be driven in a positive direction beyond cutoff during the blanking pulses. During the darker portions of the picture, the cathode is considerably in the positive direction, but not to cutoff. Consequently, few electrons reach the picture tube screen, and the screen is relatively dark. During the brighter portions of the picture, the cathode is driven only slightly in the positive direction and many electrons reach the picture tube screen. The screen is therefore relatively bright.

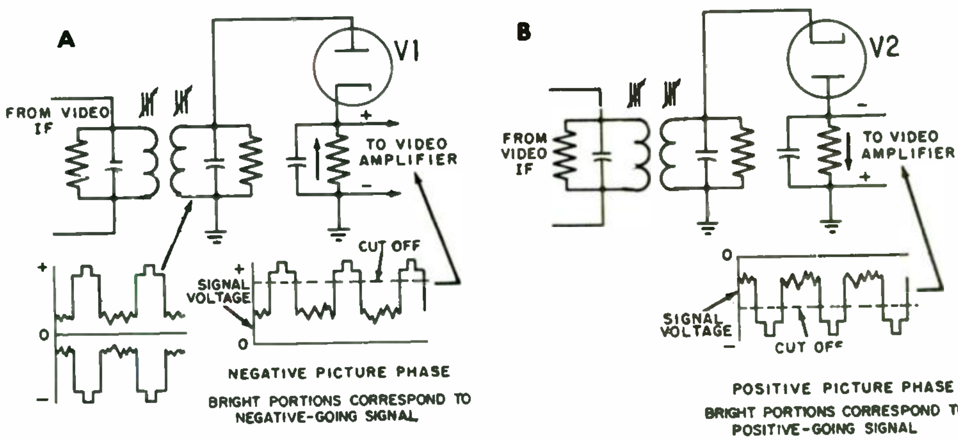


Figure 6 — Electron tube video detectors.

The concept of positive picture phase may be made clearer from the following considerations. A video signal having a positive picture phase causes the grid of the picture tube to be driven negative below cutoff during the blanking pulses. During the darker portions of the picture, the grid is driven considerably negative, but not to cutoff. Consequently, fewer electrons reach the picture tube screen, and the screen is relatively dark. During the brighter portions of the picture, the grid is driven only slightly negative, and many electrons reach the picture tube screen. The screen is, therefore, relatively bright.

In the United States, negative transmission is used; that is, the television signal is transmitted with the negative picture phase. In certain other countries, positive picture transmission is used.

The video signal may be applied to the grid or to the cathode of the picture tube. The element to which the signal is applied, and the number of amplifiers between the detector and the picture tube determine the polarity of the detector-output signal.

If there are an even number of video amplifying stages between the detector and the picture-tube grid, the detector output must be negative-going. In other words, an increase in IF carrier strength at the detector results in a more negative video signal with respect to ground.

If an odd number of video amplifying stages are employed (in most instances, this will be a single stage) and the video signal is applied to the grid of the picture tube, the detector must be connected as shown in Figure 6A. This circuit with the plate of the diode connected to the high side of the video coupling circuit produces a video output which becomes more positive as the video carrier strength is increased.

A typical video detection and amplifying system employing a video signal of negative polarity from the diode is shown in Figure 7. Load resistor R_2 has a value of 3,900 ohms and associated with it is

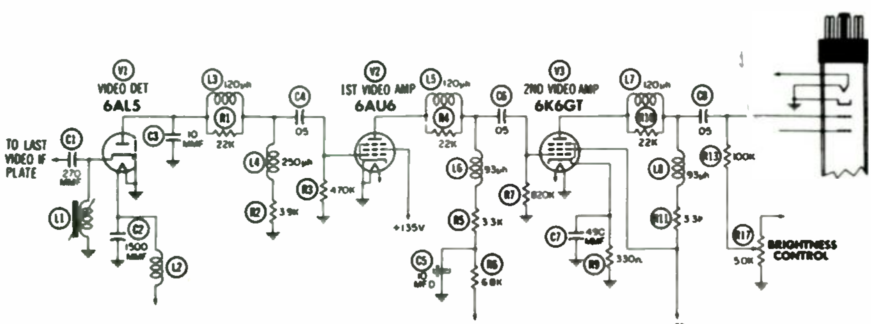


Figure 7 — Video detector of negative polarity feeding picture-tube grid through two video-amplifier stages.

a group of circuit elements, C_3, L_3, L_4, and R_1. These elements assist in producing a flat video response from 30 hertz to more than 4 megahertz.

The significant difference between a radio detector and a video detector is the value of the load resistor. In the second detector of a radio, a typical diode load varies from 0.5 to 2 megohms and maintains this high load resistance over the range of frequencies required for sound reproduction. In most instances, no frequencies higher than 5,000 hertz are involved. In the video detector, however, the capacitance of the diode and the capacitance to ground of its associated circuit prevent the use of a high diode load resistance, because flat response to at least 4 megahertz must be provided. At these high frequencies, the circuit reactance and tube capacitance would become lower than the load resistance, and thus bypass the high frequencies. For this reason, the load resistance is made a low value, and the compensating elements just discussed produce a resonant rise of circuit impedance at the high end of the video band. L_3 is a series-peaking choke and L_4 is a shunt-peaking choke. These compensating elements are employed in each video stage. (See L_5-L_6 and L_7-L_8 in Figure 7.) A more complete discussion of their function will be presented when video amplification is considered.

Figure 8 shows a video detection and amplification system employing the diode with its plate connected to the high side of the IF input circuit in order to produce a positive-going video signal. The polarity of the signal is inverted once by the single video-amplifier stage; thus, a more negative voltage is produced at the picture-tube control grid as the carrier strength increases. A combination of L_3 and C_4, together with the circuit capacitances, resonates at the high end of the video band and maintains a flat response from the detector.

In Figures 7 and 8, the video-output tube is coupled to the control

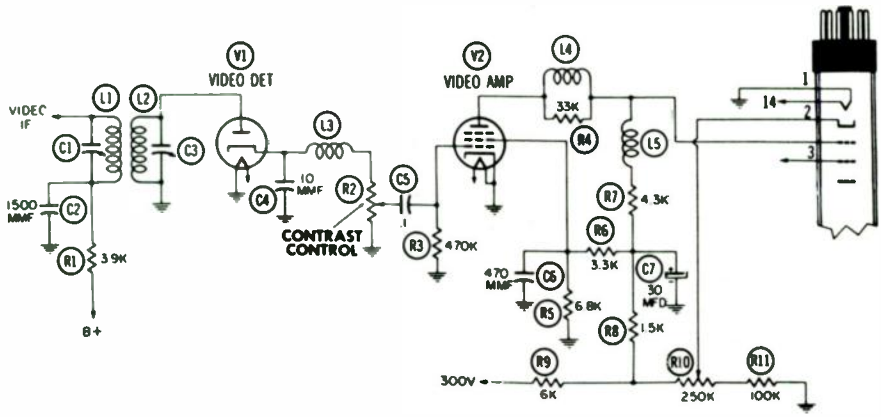


Figure 8 — Video detector of positive polarity feeding picture-tube grid through a single video-amplifier stage.

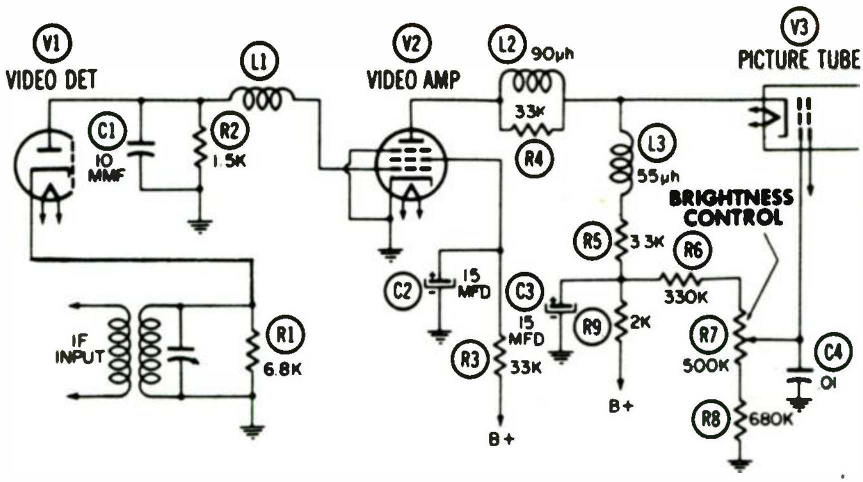


Figure 9 — A negative output detector feeding the cathode of the picture tube through a single DC amplifier.

grid of the picture tube. For circuit simplification in most receivers, the picture-tube input is inverted, and the video-output tube is coupled to the cathode rather than to the control grid. A positive-going rather than a negative-going signal must be fed to the picture-tube cathode. Figure 9 shows an example of a circuit employing a negative output detector V1 with a single-stage amplifier V2 feeding the cathode of picture tube V3.

The Crystal Diode Detector

Small fixed crystal rectifiers (Fig. 10) are being used extensively as a substitute for the vacuum tube diode. Figure 11 shows two typical applications of crystal detectors used as video demodulators. Figure 11A shows a load circuit consisting of resistor R_5 and high frequency-compensation network C_4, L_2, L_3, and R_4 connected in series with the diode. Figure 11B shows a shunt connection of similar elements.

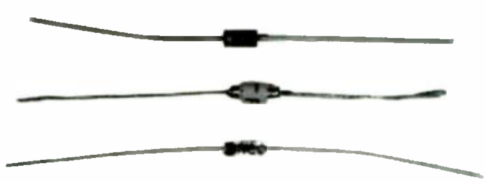
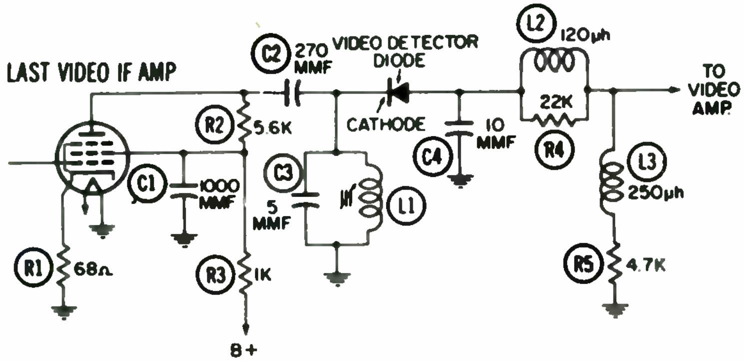
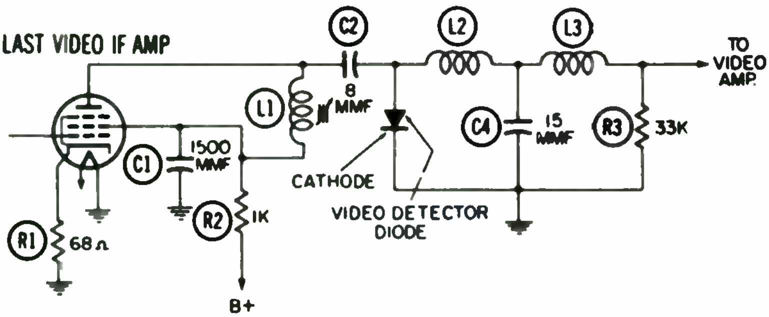


Figure 10 — Three types of fixed crystal detectors (actual size shown).

The crystal diode is recommended over the vacuum-tube type for several reasons: (1) lower dynamic resistance, (2) reduction of power consumption (no heater required), and (3) ease of mounting (no socket required). The lower capacitance and lower dynamic resistance of the crystal diode improve its performance as a video detector by providing higher rectification efficiency for a given bandwidth. Its improved linearity at low signal levels helps preserve highlights in the picture.



A- Crystal diode with series load.



B- Crystal diode with shunt load.

Figure 11 — The semiconductor crystal as a video detector.

VIDEO AMPLIFIERS

Video Amplifier Design Problems

After the video signal (containing the video information and the blanking and sync pulses) has been rectified in the second detector, it must be amplified in one or more video amplifiers before it is applied to the picture tube. Because a wide band of frequencies must be passed without discrimination by the video amplifiers, they must be carefully designed. Special high and low frequency compensating circuits must be used to extend the approximate range of frequencies passed from 30 Hz to 4 MHz. In other words, frequency distortion must be eliminated as much as possible.

The low frequency video components include the low frequency AC variations (represented on the picture screen as portions of the image that do not contain fine detail), the blanking pulses, and the sync pulses (vertical and horizontal). The high frequency video components are the high frequency AC variations that produce the fine detail on the picture screen. In addition to the low frequency and high frequency components in the transmitted signal, there is a zero frequency, or DC, component present.

If all of the frequency components are not properly amplified in the video amplifier section, a distorted image is produced. The distortion may appear as a lack of fine detail, a lack of image sharpness in the larger objects, or a lack of contrast.

In addition to frequency distortion, phase distortion must also be eliminated as much as possible. In effect, phase distortion means that certain components (frequencies) that make up complex waveforms are not passed by the amplifier in the same length of time that other frequencies are passed. For example, in resistance-coupled amplifiers, the coupling capacitor and the grid resistor, acting together, cause a phase shift that varies with the frequency.

Phase distortion may alter the background of the picture shown on the television screen; portions that should be white may be gray or even black. At the lower frequencies, excessive phase shift may cause larger objects to be blurred on the screen. At the higher frequencies, excessive phase shift causes the fine detail to be blurred.

Video amplifiers such as those used in modern television sets are designed to give essentially uniform amplification of all frequencies from 30 Hz to over 4 MHz. Audio-frequency amplifiers, on the other hand, are considered good if they have a relatively flat response between 30 and 15,000 Hz. Figure

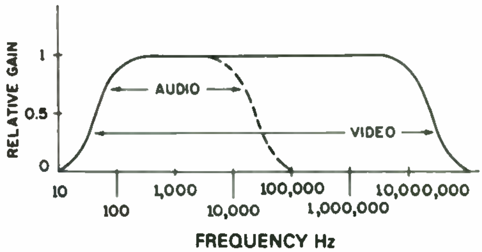


Figure 12 — Relative frequency response of audio and video amplifiers.

12 compares the responses of the two types of amplifiers.

It has been shown that resistance coupling gives the best response over a wide range, even at audio frequencies. This is especially significant in video amplifiers; however, to extend the range at both the low- and high-frequency ends, special compensation is necessary in video amplifiers.

Resistance-Capacitance Coupled Circuits

The RC coupled amplifier circuit shown in Figure 13 indicates the effects that must be overcome if the range is to be extended on both ends of the frequency spectrum.

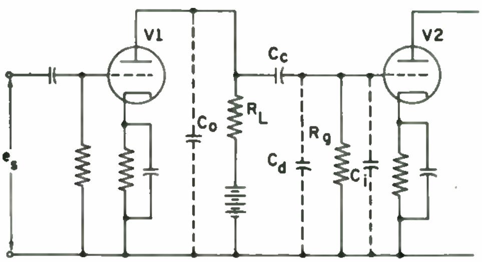


Figure 13 — RC coupled amplifier.

The high-frequency response is limited by the interelectrode output capacitance, C_o, the distributed wiring capacitance, C_d, and the input interelectrode capacitance, C_i. These three capacitances, acting in parallel, shunt the load, R_L, and reduce the output at the high frequencies.

The low-frequency response is limited by the reactance of the coupling capacitor, C_c. Thus at the lower frequencies the divider action of C_cR_g reduces the voltage available between the grid and cathode of V2.

It is obvious that the interelectrode capacitances of the tubes and the distributed capacitances of the wiring must be kept as low as practicable. Keeping the distributed capacitances low requires careful placement of the tubes in order to keep the leads as short as possible.

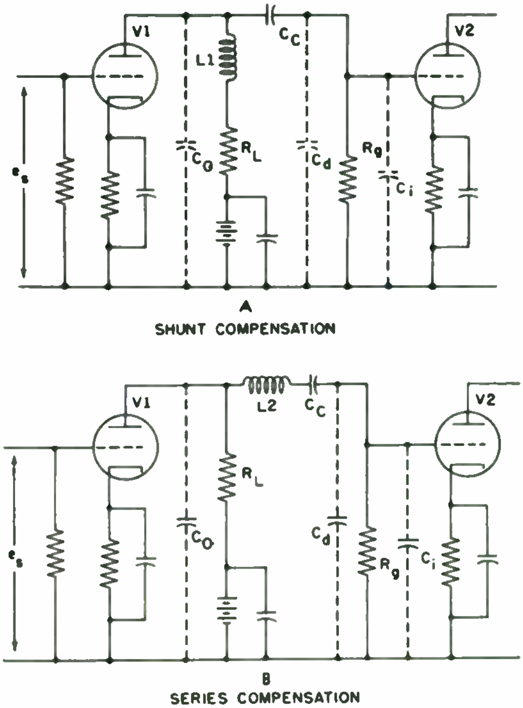


Figure 14 — High-frequency compensation.

High-Frequency Compensation

There are various methods of extending the range of a video amplifier at the high-frequency end of the range, but perhaps the simplest and most effective is the shunt-peaked method, shown in Figure 14A. As mentioned previously, the gain at high frequencies is reduced because the load is shunted by C_o, C_d, and C_i. These same values can be made to extend the range if a small inductor, L_1, is inserted in series with the load resistor, R_L, to form a parallel resonant circuit. If the value of L_1 is properly chosen so that the circuit will be in resonance at the point where the response curve begins to fall appreciably, the range can be extended. The value of L_1 is critical. If the value is not correct, the amplification may be increased before the point at which the response curve begins to fall, with resultant frequency distortion.

Series compensation may also be used to extend the range at the high-frequency end, as indicated in Figure 14B. In this instance, an inductance, L_2, of the proper value is added in series with the coupling capacitor, C_c, so that a series-resonant circuit is formed with the parallel combination of C_d and C_i. At resonance, increased current will flow through these capacitances and larger output voltage will be applied between the grid and cathode of V2.

The high-frequency peaking effect of shunt compensation in addition to the increased gain of series compensation may be obtained if both of these methods of compensation are used in the same coupling circuit. There are other factors, however, such as the transient response, which have to be considered in a network such as this.

Low-Frequency Compensation

At low frequencies, the distributed and interelectrode capacitances may be neglected but the reactance of the coupling capacitor becomes increasingly important. Since the reactance of this capacitor is

$$X_C = \frac{1}{2\pi f C_c}$$

it becomes appreciable at low frequencies. Consider a voltage divider made up of C_c and R_g (Fig. 15) in which the reactance of C_c is large, as it would be at low frequencies. More of the voltage would then appear across C_c and less would appear across R_g. Since the voltage gain in some practical applications must be maintained within 70 percent of the mid-frequency gain, this loss at low frequencies could not be tolerated.

The capacitance of C_c could be increased, but such a procedure would increase the stray capacitance and thus cut down the high-frequency gain.

Another factor that is perhaps more important than the loss of

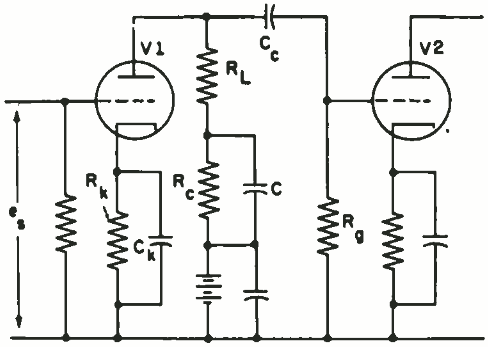


Figure 15 — Low-frequency compensation.

gain is the large shift in phase that occurs at these frequencies. If 10 stages of video amplification are used, a phase shift (lead) of about 2° is all that can be permitted for each stage.

The phase shift can be reduced by employing a large value of coupling capacitance and the largest permissible grid-leak resistance, but both of these expedients have their disadvantages also.

Amplifiers that do not have requirements as critical as video amplifiers may be made to operate satisfactorily by using large cathode and screen bypass capacitors and a coupling capacitor that is as large as practicable. Video amplifiers, however, require special compensation at the low frequencies.

Both the loss in gain and the increase in phase shift may be corrected by dividing the load resistance into two parts and bypassing one part with a capacitor. A circuit employing this method of low-frequency compensation is shown in Figure 15.

The load resistance is made up of two parts, R_L and R_c, of which R_c is bypassed by C. At the higher frequencies, the load is effectively R_L because R_c is bypassed by C, which has a low reactance at these frequencies. At low frequencies, however, C offers a high impedance and the load is effectively $R_L + R_c$. This effective load increase causes a greater proportion of the plate signal to appear as output and thus counteracts the normal drop at the low frequencies. Care must be used in selecting the values of R_c and C so that uniform gain can be extended into the lower frequencies beyond the point where the gain begins to fall off. Distortion will occur if the gain takes place before the curve begins to fall off.

Another component influencing low-frequency gain is the cathode-bypass capacitor. In order to prevent degeneration from occurring at the lower frequencies because of inadequate shunting, the capacitance of the cathode-bypass capacitor must be great enough to offer low impedance (with respect to the cathode resistor) at the lowest frequency to be amplified. Thus, in video amplifiers the capacitances of cathode bypass capacitors are many times those of comparable audio amplifiers.

High- and Low-Frequency Compensation in a Transistor Video Amplifier

Transistor video amplifiers have the same general characteristics that electron tube video amplifiers have, and utilize similar frequency compensating circuits. Figure 16 shows a 30 Hz to 4 MHz transistor video amplifier using both high- and low-frequency compensation. High-frequency compensation is provided by inductors L_1 and L_2. Resistor R_f and capacitor C_f provide low-frequency compensation. These circuits do not interfere with each other because they operate independently.

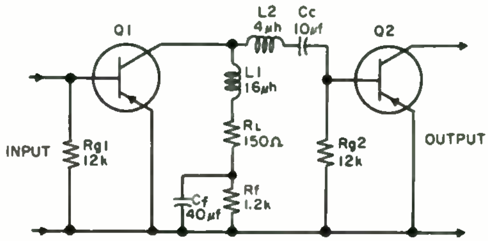


Figure 16 — Transistor video amplifier.

At low frequencies, the series reactance of inductor L_1 is very small and has little effect on the collector load impedance. The series reactance of inductor L_2 is also very small and has little effect on the input circuit to the second stage. At high frequencies, the reactance of C_f is very small and C_f can be considered a short circuit across resistor R_f. Resistor R_f has no effect on the collector load impedance at high frequencies, therefore, low-frequency compensating circuit R_fC_f has no effect at high frequencies.

DC RESTORERS

The DC restorer (or clamper) restores the DC component of a pulse waveform after this component has been removed by the passage of the waveform through the coupling capacitor in the video amplifier stage.

It is necessary to reinsert the correct DC component at the input of the television picture tube if the correct level of background illumination is to be maintained. Also, if the correct DC component is not reinserted, the blanking level will vary (instead of remaining constant, as it should), and retrace lines will appear on the screen during the time the blanking voltage is insufficient to cut off the picture tube during retrace.

The average brightness of one scanned line may differ widely from the average brightness of another scanned line, as indicated in Figure 17A.

The average DC component depends on the average brightness of a scanned line. A low DC component in the negative direction means that there exists a high level of brightness during that line; a high DC component in the negative direction means that there exists a low level of brightness during that line. The average DC component, therefore, establishes the blanking level.

Figure 17B illustrates what happens when the DC component is removed by the passage of the video signal through a coupling capacitor. Although the picture tube may be biased so that it is not driven in

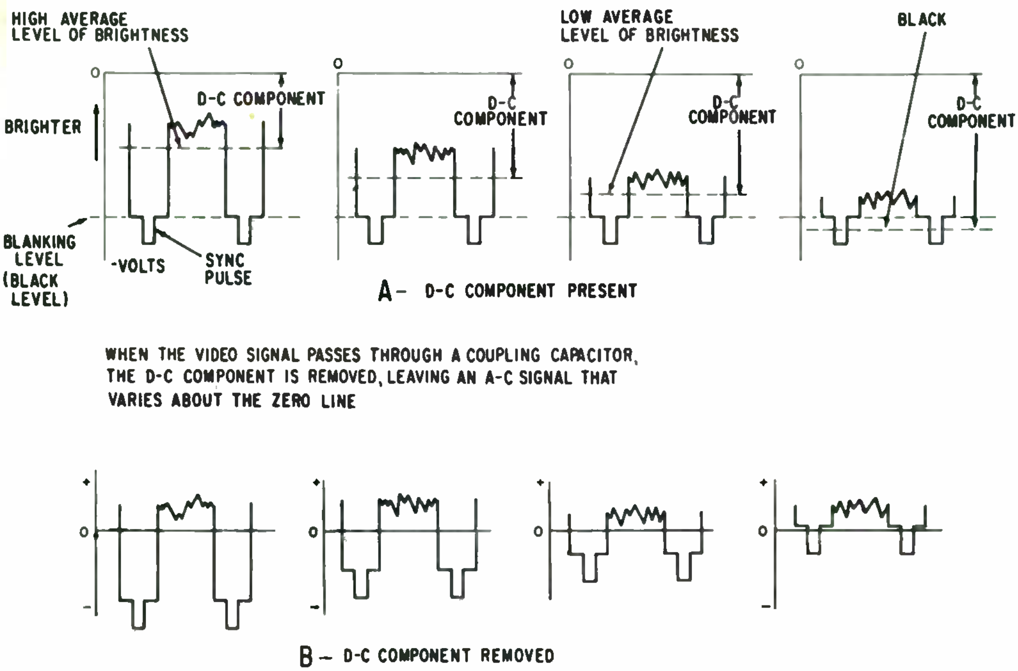


Figure 17 — Function of the DC component on the video signal.

a positive direction beyond a certain value, the blanking level varies and the retrace is often visible. The background brightness level also differs from that at the transmitter.

Simplified circuits of two types of DC restorers are shown in Figure 18. The function in each case is to restore the DC component that was lost when the video signal passed through the coupling capacitor of the video amplifier. DC restoration is accomplished by adding to the instantaneous AC signal enough DC voltage to bring the blanking voltage to the cutoff point.

The action of the DC diode restorer may be explained in the following manner: Without the diode, the input signal voltage appears as shown in Figure 17B. During the negative portion of the cycle (when the blanking and synchronizing pulses are active) the diode (Fig. 18A) conducts because its cathode is negative and its plate is positive. This action occurs because the self-induced voltage across L opposes the B supply voltage and exceeds the value between point B and ground. Capacitor C charges rapidly through the diode and has the polarity indicated. The amount of the charge (voltage across C) depends on the strength of the input signal.

During the positive portion of the signal, shown above the 0 line in Figure 17B, the diode cannot conduct, and C (Fig. 18A) discharges relatively slowly through R. A positive potential, which reduces the bias on the picture tube,

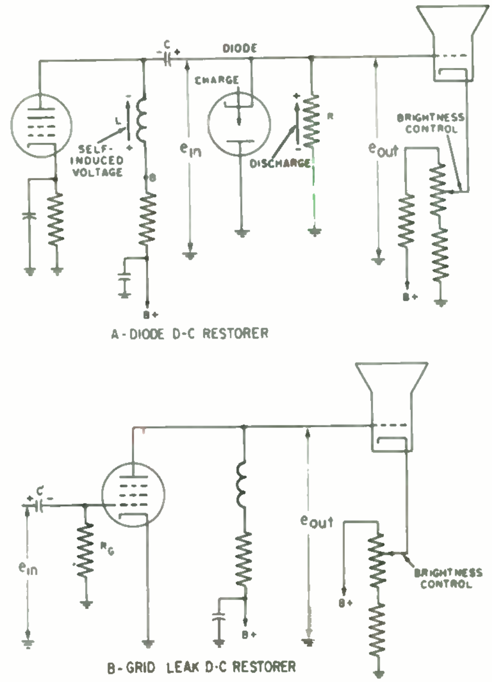


Figure 18 — Simplified circuits of DC restorers.

is thus applied between grid and cathode during the scan interval between the blanking pulses. During this interval, the diode is effectively an open circuit, and the video signal appears across R in series with the DC voltage supplied by C. The greater the input voltage, the less the net bias remaining on the grid of the picture tube and the higher the average brightness. Thus, the condition existing in Figure 17A is re-established.

A grid leak DC restorer circuit is shown in Figure 18B. The incoming video signal has a negative picture phase, and the DC component is missing; the output video signal has a positive picture phase, and the DC component is restored, or reinserted.

The action of the grid leak may be explained simply. There is no fixed bias on the tube, and the grid goes positive whenever a positive pulse is applied. Grid current flows, and C charges rapidly through the conducting grid circuit. If a large pulse is applied, a large amount of grid current flows and a large bias is developed. If a small pulse is applied, a small amount of grid current flows and a small bias is developed. These two actions tend to stabilize the plate current at the same level during the pulses of current; that is, the blanking pulses are lined up at the same level as they were before the DC component was removed. During the interval between blanking pulses, C discharges slowly through R_G.

It should be emphasized that the bias remains essentially constant (because of the long time constant of C and R_G) during the interval between blanking pulses. If this were not true, the DC component would be lost.

BRIGHTNESS CONTROL AND DC REINSERTION

Figure 19 shows a standard circuit diagram of an older-type TV receiver. It employs a principle known as DC reinsertion for adjusting the brightness (brilliance) of the picture tube when confronted with varying degrees of incoming signal strength. In simplest terms, the purpose of this circuit was to provide the picture tube with a

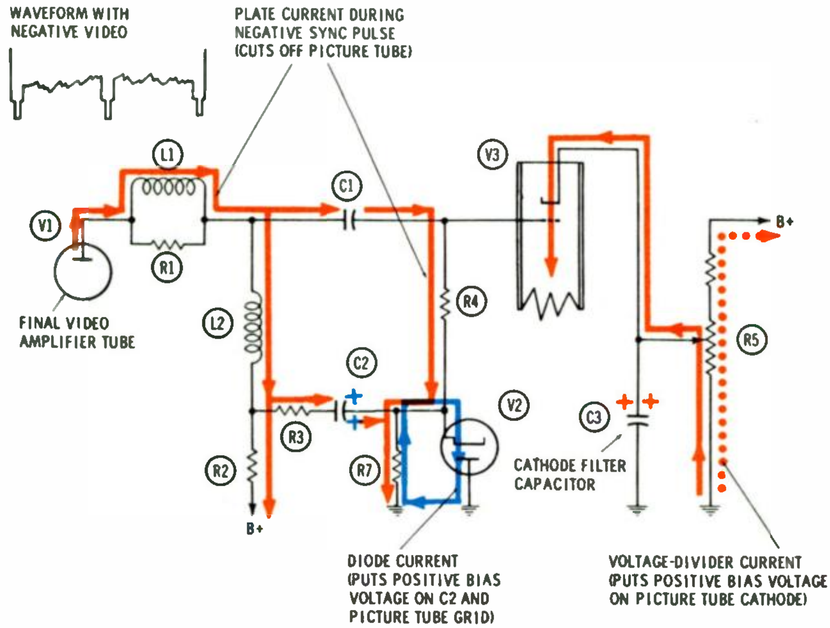


Figure 19 — A diode tube used for DC reinsertion.

value of operation grid-bias voltage which would equal the value of the pedestal or blanking voltage in the video signal itself. This gave assurance that any lesser value of video voltage would cause some electron flow through the picture tube and some degree of whiteness in the picture. While the principle of DC reinsertion using a diode tube is seldom encountered in modern receivers, an understanding of this function may help one to understand how it can now be omitted from receiver design.

In Figure 19, a video waveform having negative sync pulses is delivered at the output of V1. The plate current through this tube (solid red) will flow at its maximum rate when sync pulses are being received and amplified. As this plate current flows downward through the plate-load circuit (L_2 and R_2), it develops the voltage drop, which causes the plate voltage to become low when maximum current flows. As each pulsation of plate current (which represents a negative sync pulse) flows through the tube, it drives electrons onto coupling capacitor C_1 and downward through resistors R_4 and R_7 to ground. This action develops a negative voltage at the cathode of diode V2, causing electron current (solid blue) to flow through the diode from cathode to plate. The complete path for these electrons is through the diode from cathode to plate where they enter ground, then out of ground and upward through R_7 to the cathode.

This one-way flow of electron current through V2 creates an electron deficiency on the right-hand plate of C_2. This electron deficiency, which in reality is a positive voltage (indicated by the blue plus signs), is applied to the control grid of the picture tube as a biasing voltage. The frequency of the sync pulses is 15,750 hertz, but the time constant of the R_7 and C_2 combination is very long compared with the time of one cycle—perhaps a fiftieth or a hundredth of a second. Thus, the charge (voltage) formed on the right-hand plate of C_2 will be preserved for a hundred or so sync pulses.

The value of the positive voltage on the right-hand plate of C_2 depends on two factors: the strength of the sync pulses at this point, and the size of R_4. If R_4 had zero value (if it were a short circuit, in other words), the cathode of V2 would have the full value of the negative sync pulse applied each cycle. Then electrons would leave the cathode and cross the plate in such quantity that the electron deficiency created on C_2 would be a positive voltage exactly equal to the value of the sync pulse voltage. For example, if the negative sync pulse coming from the video amplifier has an amplitude of −50 volts, then C_2 would charge to +50 volts. This 50 volts would be applied to the control grid of the picture tube as a biasing voltage to establish a reference value from which the smaller video variations could be measured. The brightness control (variable resistor R_5) must be set so that a positive voltage will be applied to the cathode, ensuring that the negative sync pulses will cut off the picture tube. When this is done, any given amplitude of picture signal will always release the same quantity of electrons through the picture tube and thereby produce the same degree of whiteness on the picture-tube face. The foregoing can only be achieved if the varying video voltages carrying the picture information are measured from the same reference point, namely, a grid-cathode voltage that is equal to total darkness of the picture tube. Any value of grid voltage more positive than this blanking voltage will cause some illumination of the picture tube.

A single half-cycle of the video driving voltage (solid red) is shown flowing downward through R_4 and R_7 to ground. If this flow is large, a high value of negative voltage will be developed at the top of R_4 and at the control grid of the picture tube. This component of negative voltage acts in opposition to the positive biasing voltage on the right-hand plate of C_2; therefore, the amount of picture-tube current flowing at that particular instant will be reduced. This causes one small spot on the picture tube to be unilluminated, or to have only slight illumination; a black or gray spot results.

A half-cycle later, the driving current will be drawn upward through R_4 and R_7, developing a component of positive voltage which adds to the positive biasing voltage on C_2 and leads to a white or light gray spot on the picture tube.

A corollary function of equal importance which was provided by the DC reinsertion circuit was the cutting off of the picture tube during retrace actions. As explained previously, when the cathode-biasing voltage is properly adjusted by voltage-dividing resistor R_5, the driving current associated with the large negative sync pulse will flow downward through R_4 and R_7 in sufficient quantity to develop a negative cutoff voltage at the grid of the picture tube.

ELIMINATION OF DC REINSERTION

Very few receivers marketed in recent years include a special tube circuit for accomplishing the objective formerly known as DC reinsertion. This objective might be stated as an attempt to insure that the background light levels associated with various portions or elements of a picture are consistently measured or gauged from the same standard of light or darkness. This standard, called the black level, is determined by the blanking or pedestal level on which the sync pulse sits. This objective has not been realized in its entirety by the newer circuitry, but it has been attained to a satisfactory degree. Diagram 7 in your *Diagram Envelope* illustrates one typical example. The output waveform of video voltage from V1 is coupled eventually through C_{13} to the cathode of picture tube V2. The picture tube is cathode-driven, as are almost all picture tubes in modern receivers. The picture-tube driving current (solid blue) flows up and down through R_{10}, R_{11}, and R_{12} between C_{13} and ground. Downward excursions of this current develop a negative voltage at the upper terminal of R_{10} and at the cathode of the picture tube. This negative cathode voltage causes an increase in picture-tube current. The upward excursion of driving current through these resistors places a positive voltage on the cathode of V2 and restricts the amount of picture-tube current.

The largest amount of picture-tube current flows when the cathode is driven to its most negative (or least positive) voltage values. Much smaller quantities flow when the video voltage at the cathode has its higher positive values. Thus, positive excursions of video voltage tend to reduce the picture-tube current and cause dark or gray spots on the screen, while negative excursions cause white or light spots in the picture.

All of the picture-tube current must flow upward through R_{12}, R_{11}, and R_{10} before reaching the tube. In so doing, an additional component of positive biasing voltage is developed. This voltage must be added to the permanent biasing voltage created by the voltage-divider current flowing through brightness control R_{12}. In other words, the positive cathode voltage at the picture tube is the sum of two voltages, a fixed voltage of about +50 volts due to voltage-divider action in R_{12} and a variable amount of self-bias which always results when a tube plate current must flow through a resistive path before reaching the cathode.

As with all cathode voltages resulting from self-bias, the amount of this voltage must change when the amount of tube current changes. If the cathode is not bypassed by a filter capacitor, degeneration or loss of signal strength results. Whenever the signal causes an increase in plate current, the cathode voltage rises in the positive direction; this increase in cathode voltage, in turn, *reduces* the plate current. When the cathode resistor (or resistors) is bypassed by a filter capacitor, a means exists for smoothing out the cathode voltage so that instantaneous variations in plate current through these resistors will not cause instantaneous voltage variations at the cathode.

The length of time that a filter capacitor will hold or retain a voltage depends on the RC time constant of the combination. In Diagram 7, the total capacitive path which contributes to the filtering action at the cathode of V2 would include C_{13}, L_7, part of R_7, and C_{10}. C_{10} is much smaller than C_{13}, and the total capacitance of two capacitors in series must always be less than the capacitance of the smallest one. The time constant of R_{10}, R_{11}, and R_{12}, in combination with C_{13}, C_{10}, etc., will be approximately 25 microseconds or about half of the time duration of a single line of picture information.

When the background of a picture being received is predominantly gray or dark, the total picture tube current will be considerably less than for a light or white picture. Therefore, for the predominantly gray picture, the cathode will have a lower positive voltage on it. When a steep negative dip in the video signal occurs, denoting a white spot on the picture, it drives the cathode voltage from this lower base or average value. This causes the white spot to appear somewhat whiter than it should, and the lowered cathode voltage causes the gray background to be somewhat less gray than it actually is.

When a picture background is predominantly white, the total picture-tube current over a period of time is obviously larger than normal. This increases the positive self-bias on the picture tube. The first result is a slight decrease in the tube current which generates the whiteness, and a decrease in the shade of whiteness. A gray or dark object in the midst of this light background will appear darker (more gray), because a positive video pulsation of any size does not have as far to go to reach the total blackness or cutoff point, since it starts from a higher base, or higher cathode voltage.

It is emphasized that this circuit does not accomplish the same function as DC reinsertion in the older circuits. Elimination of DC reinsertion from modern receivers represents a compromise which was made in order to eliminate one additional tube from the receiver, thereby saving a small amount of cost. There is a definite loss in fidelity of the picture, because the varying shades of white and gray are not reproduced exactly as they appear in the studio. This loss in picture fidelity is rarely noticeable to the viewer, and the compromise must be considered to have passed the test of usage and customer acceptance.

SUMMARY

The video signal requires a bandwidth of 4 MHz to provide good picture quality. All the circuits that handle the video signal must pass this band of frequencies. If any portion of the video signal is attenuated, there is a corresponding loss in picture quality.

The video signal is separated from the IF by the video detector through the process of rectification. The video signal is amplified in the video amplifier and then applied to the picture tube. The video amplifier employs low- and high-frequency compensation to extend the frequency response to 4 MHz.

Television receivers employ DC-restorers to reinsert the DC component of the video signal that is lost by capacitance coupling of the video amplifier to the CRT. DC restoration is accomplished by adding to the instantaneous AC signal enough DC voltage to bring the blanking voltage to the cutoff point. In modern television receivers, the DC restorer is eliminated to streamline the receiver.

TEST

Lesson Number 86

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-086-1.

1. **What type of transmission is used for the television signal?**
   A. Single-sideband transmission.
   B. Double-sideband transmission.
   C. Suppressed-carrier transmission.
   – D. Vestigial-sideband transmission.

2. **In the television receiver, the video signal requires a bandwidth of**
   A. 5.75 MHz.
   – B. 4 MHz.
   C. 8 MHz.
   D. 15,750 Hz.

3. **The AM video signal is detected from the IF in the television receiver by the process of**
   A. differentiation in the video detector.
   B. heterodyning in the video detector.
   – C. rectification in the video detector.
   D. discrimination in the discriminator.

4. **If the video signal is applied to the cathode of the picture tube, the signal must be**
   A. an audio signal.
   12 – B. a positive-going signal.
   C. rectified by a crystal diode detector.
   D. capacitor-coupled to the cathode.

5. Video amplifiers such as those used in modern television sets are designed to give essentially uniform amplification of all frequencies from
A. 41.25 MHz to 45.75 MHz.
B. 82 MHz to 88 MHz.
14 C. 0 to 6 MHz.
—D. 30 Hz to 4 MHz.

6. Shunt-peaking and series-peaking coils are used in video amplifiers for
— A. high frequency compensation.
15 B. attenuation of the 4.5 MHz sound-IF.
C. low frequency compensation.
D. amplification of the 4.5 MHz sound-IF.

7. Low frequency compensation is accomplished in the video amplifier shown in Figure 15 by
A. using a larger value power supply fuse.
B. the use of cathode bias.
17 — C. capacitor C and resistor R_c.
D. capacitor C_k and resistor R_k.

8. The purpose of the DC restorer circuit is to
— A. reinsert the DC component of the video signal that is lost when the video signal passes through the coupling capacitor.
19 B. supply a pure DC voltage to the IF amplifiers to control the gain of the IF stages.
C. supply an automatic focus voltage to the focus anode.
D. filter the high voltage supplied to the second anode.

9. The DC restorer used in television receivers
A. is always a beam power tube.
17 B. increases the gain of the video amplifiers.
— C. restores the DC component of the pulsed video waveform.
D. removes the DC component of the pulsed video waveform.

10. To what element in the CRT is a video signal with a negative picture phase applied?
— A. the cathode.
B. The filament.
C. The focus anode.
D. The second anode.

Portions of this lesson from
TV Video and Sound Circuits
by Thomas M. Adams
Television Service Manual
by Robert G. Middleton
Courtesy of Howard W. Sams, Inc.

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"Serving America's Needs for Modern Vocational Training"

OPPORTUNITIES THROUGH PROGRESS

Engineering advances have opened up new avenues of service.

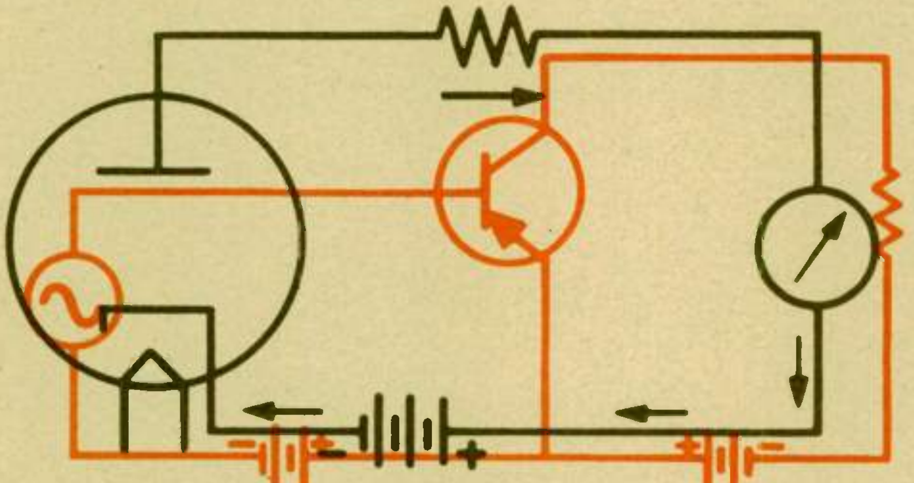
With each additional advancement comes an opportunity to learn something new and to broaden your capacity to earn.

"Solid state circuitry" is a good example of progress in the electronics field—inovations are constant and varied. Although older radio and TV sets are not equipped with transistors, almost all newer units incorporate some solid state circuitry. Servicing of products with these devices is another of the necessary phases of repair essential to success in your chosen field.

S. T. Christensen

LESSON NO. 87

REVIEW FILM OF LESSONS 83 THROUGH 86



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-087
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Reprinted October 1974

REVIEW FILM TEST

LESSON NUMBER 87

The ten questions enclosed are review questions of lessons 83, 84, 85, & 86 which you have just studied.

All ten are multiple choice questions, as in your regular lesson material.

Please rerun your Review Records and film before answering these questions.

You will be graded on your answers, as in the written lessons.

REMEMBER: YOU MUST COMPLETE AND MAIL IN ALL TESTS IN THE PROPER SEQUENCE IN ORDER FOR US TO SHIP YOUR KITS.

REVIEW FILM TEST

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-087-1

1. **Series filament systems**
   A. are never used in TV receivers.
   B. present a shock hazard.
   C. are used only in AM receivers.
   D. none of the above.

2. **The picture signal from the antenna is amplified**
   A. more than 150 db.
   B. about 2,000,000 times.
   C. about 70 db.
   D. less than 50,000 times.

3. **All VHF TV tuners have**
   A. an antenna impedance matching system.
   B. a high pass antenna filter.
   C. twelve channels.
   D. all of the above.

4. **The video IF amplifier**
   A. does not amplify the sound channel.
   B. only processes AM signals.
   C. amplifies video, sync, and FM sound.
   D. none of the above.

RC

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5. A video amplifier
   A. applies signals to a loudspeaker.
   — B. is compensated for wide bandwidth.
   C. cuts off rapidly below 200 hertz.
   D. has a peaked mid-band response.

6. Series and shunt peaking is used
   A. only in Hi-Fi audio systems.
   — B. mainly in video amplifiers.
   C. in UHF solid state tuners.
   D. in TV IF amplifiers.

7. In a TV signal
   A. video information is FM modulated.
   B. sync pulses are lower than black level.
   — C. black level has a higher voltage than white level.
   D. white level has the highest voltage.

8. The gated beam detector is easily identified because it
   A. uses a thyratron tube.
   B. is preceded by a limiter.
   C. uses a magnetron tube.
   — D. has a buzz control.

9. A contrast control
   — A. varies video voltage.
   B. changes picture tube bias.
   C. adjusts sync level.
   D. changes IF gain.

10. Video signals are fed to a picture tube's
   A. number three grid.
   B. anode.
   — C. cathode.
   D. accelerating grid.

Notes

"School Without Walls"
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MECHANICAL ABILITY?

A statement made quite often is, "I am handy with tools, therefore my mechanical ability is very good."

This statement is not always true. In tests conducted by U.S. Army psychologists, it was found that mechanical ability really meant "the ability to direct your hands with your head."

These psychologists found that merely being handy with tools was far less important than the ability or "know-how" for figuring out a problem—using good judgement in selecting the right tools for the job and the right knowledge of where, when, and how they should be used.

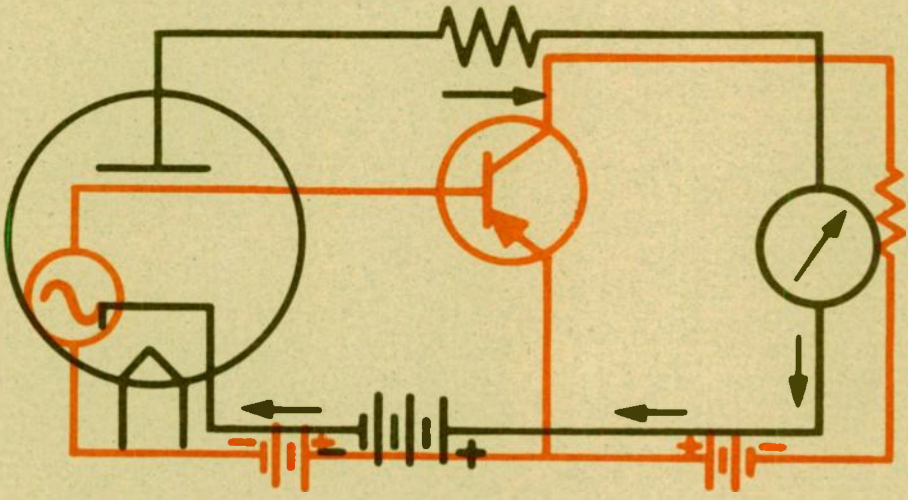
This proves my contention that the man who has the ambition and the desire for bettering himself can make a success in the Radio and TV Service business. However, he must develop the "know-how" and learn how to use this knowledge.

If you will apply yourself diligently, your ASI Training Course will give you this "know-how" and knowledge.

S. T. Christensen

LESSON NO. 88

TELEVISION VIDEO SYSTEMS PART 2



RADIO and TELEVISION SERVICE and REPAIR

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LESSON CODE
NO. 52-088
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Revised December, 1973

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Contents

TELEVISION VIDEO SYSTEMS PART 2

INTRODUCTION

The video circuitry in a television receiver performs four important functions:

1. The separation of the composite video signal from the video-IF, called video detection. An important side effect of video detection is the formation of the sound-IF of 4.5 MHz.
2. The amplification of the composite video signal, including the synchronizing pulses.
3. The separation of the composite video signal into its three component parts (sync pulses, video signal, and sound-IF) and the application of each signal to the appropriate circuitry.
4. The production and application of the biasing voltage to the cathode and grids of the CRT.

In this lesson, a careful analysis of a television receiver video circuitry is given. The video circuitry presented is typical of the present-day television receiver. A good understanding of its operation should provide the insight required for the analysis and repair of any monochrome television receiver. Diagram 7 in your *Diagram Envelope* will be used in the analysis of the video circuitry.

Because the sync pulses are separated after being amplified in the video amplifier, an analysis of a typical sync separation, noise cancellation and automatic gain control circuit will be included in this lesson. It will be necessary to maintain a clear understanding of the overall television receiver basics during this analysis.

THE TUBE TYPE VIDEO CIRCUIT

The video circuitry must detect the composite video signal, amplify it, separate the different signals in the composite video signal and apply these signals to the appropriate circuitry. Diagram 7 shows a typical tube type video circuit. This circuit is broken down into component circuits as the analysis progresses. Refer to Diagram 7 for the effect of each component circuit on the overall video circuit operation.

Details of Operation

The video signal makes its first appearance in a television receiver at the output end of the video detector (M1, in Figure 1). Either the diode section of a vacuum tube or a solid-state diode may be used to accomplish the detector functions. The cathode of M1 is the element on the left, and the anode is on the right (represented by a broad arrowhead). The direction of electron flow through any diode can only be from cathode to anode; therefore, the video signal current (solid blue) flows from left to right through M1 in a series of rapid pulsations. These pulsations occur at the video intermediate frequencies. The video current (dotted blue) is flowing back and forth between C_1 and L_8. These components are chosen to resonate across the video-IF band; the resulting current charges C_1 alternately to positive and negative voltage peaks. When the upper plate of C_1 is positive, M1 is prevented from conducting because its cathode is more positive than its anode. However, when the upper plate of C_1 is negative, as it is in the instantaneous picture of Figure 1, a pulsation of electron current will be driven through M1 from left to right. This action will repeat itself more than forty million times each second, since it will occur once during each cycle of the IF.

This unidirectional diode current delivers electrons to the upper plates of C_2 and C_3, and consequently builds up the negative voltage, known as the video voltage, on these capacitors. This video voltage will leak continuously to ground through inductors L_1, L_2, and L_3 and resistors R_1 and R_2. This continual drainage, or leakage, is essential to prevent the accumulation of so many electrons (negative voltage) on the upper plates of C_2 and C_3 that M1 and V1 would be biased so negatively that they would not conduct at all. The leakage process is regulated, or controlled, by the sizes of virtually all of the circuit components involved (C_2, C_3, C_4, L_1, L_2, L_3, R_1, and R_2). The amount of voltage stored on C_2 and C_3 will be proportional to the strength of the incoming IF signal.

The incoming signal at a television antenna is both amplitude and frequency modulated (at different frequencies within the allocated bandwidth). Since the video-IF signal which arrives at the video detector input is the same as the incoming signal in all respects except frequency, it is also modulated in amplitude as well as frequency. The voltage pool that appears on the upper plates of C_2 and C_3 must reflect or reproduce the amplitude modulation from the video-IF signal. This voltage must have its greatest negative value during those short periods (normally about 5 microseconds) when a synchronizing pulse is being received. These pulses, which are carried at the basic video-IF of 45.75 MHz, occur every 63.5 microseconds during the presentation (trace-out) of a single horizontal field of 262.5 horizontal lines of picture information on the cathode-ray tube.

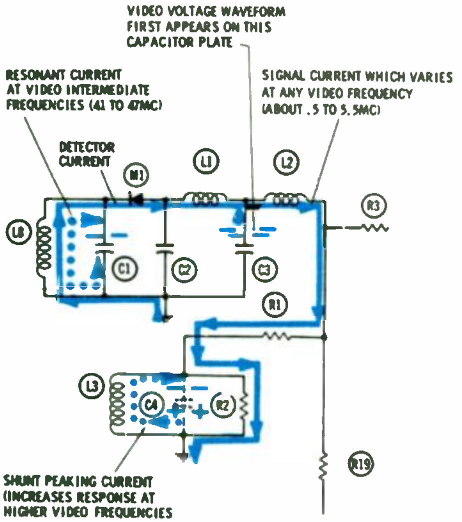


Figure 1 — The video detector.

Sync and Blanking Signals

The amplitude of the sync pulse which rides on top of the horizontal blanking pulse is not of particular importance in the video amplifier circuit. However, it must be faithfully reproduced so that it can be coupled to the sync separator stage. The entire blanking pulse interval, which includes the blanking and sync pulses, is of importance because this pulse must be coupled to the picture tube circuit to cut off the picture tube during the horizontal retrace period.

During the approximately 10-microsecond period when a horizontal blanking pulse (which includes the sync pulse) is being received, about 450 individual cycles of resonant IF current flow back and forth in the resonant tank (C_1 and L_8). This resonant current has its maximum strength during the approximately 5-microsecond period that the sync pulse is being received. Its value will be almost as great during the remainder of the blanking pulse. Each pulsation of electron current through M1 during these times also has maximum strength. Thus, an excess of electrons is delivered into storage on the upper plates of C_2 and C_3 during the time a pulse is being received. These electrons form a large negative voltage which we can identify as a horizontal sync and blanking pulse. This point marks the first appearance of the video sync pulse in the receiver.

As soon as the carrier signal which carries the pulse modulation is turned off, the resonant current flowing between C_1 and L_8 must disappear. In addition, the large pulsations of diode current through M1 also disappear. The accumulated electrons on C_2 and C_3 continue flowing to ground through L_1, L_2, R_1, etc.; but since no electrons are being *added* from diode M1, the negative voltage on C_2 and C_3 is discharged to ground (zero voltage) in relatively short order. This marks the end of the individual sync pulse.

Before considering the remaining components of the video signal (the picture and sound information), it will be worthwhile to discuss the action of the sync and blanking pulses from this point on. They are normally the most negative voltage applied to the control grid of V1; thus the amplifier plate current is reduced to a minimum value during this period. This reduction in grid voltage causes the expected sharp rise in plate voltage when the pulse starts. At the end of this same pulse (10 microseconds later) the control grid becomes less negative, the amplifier tube conducts correspondingly more current, and the plate voltage must drop as the increase in plate current flows through plate load resistor R6 toward the 255-volt power supply.

One rise and fall of this plate voltage becomes a positive sync pulse coupled directly to the sync-separator section of the receiver via R_5. Whereas the input sync pulse at the control grid may have an amplitude of a small fraction of a volt, the output pulse may be many volts in amplitude. This increase in amplitude is due to the amplifying properties of the tube. Amplification is accomplished because a small change in grid voltage releases (or withholds) a large flow of plate current electrons; these variations in plate current develop correspondingly large voltage changes across output load resistor R_6.

The positive blanking pulse is also coupled to the cathode of the picture tube (V2) via all of the components between the amplifier and the picture tube (i.e., C_9, C_{11}, R_7, L_7, R_9, C_{12}, and C_{13}). It is essential that current through the picture tube be completely cut off during the blanking pulse period. The application of the positive pulse to the picture-tube cathode helps to accomplish this objective. The picture-tube cathode is already biased with a positive voltage of perhaps 30 or 40 volts, whereas, the first control grid is connected to ground (0V) through R_{14}. Thus, any positive increase in cathode voltage increases the disparity between the cathode and grid voltages and thereby reduces or cuts off the flow of the picture-tube current.

The positive pulse voltage at the cathode is further aided in its function of cutting off the picture tube by a negative blanking pulse from the horizontal output transformer (not shown here). This blanking pulse current (shown in dotted green) is driven *downward* through grid resistor R_{14}, thereby creating a negative voltage at the control grid of the picture tube. This negative blanking voltage occurs in unison with the positive pulse at the cathode. Diagram 7 also shows the positive pulse current being drawn *upward* through R_{10}, R_{11}, and R_{12}. These two actions occur just prior to each sync pulse so that the plate current through the picture tube is cut off for about 10 microseconds. At the end of the pulse period, both currents reverse in direction, thus removing, or eliminating, the biasing conditions which cut off the electron beam through the picture tube. The picture tube is then ready to be turned on in accordance with the varying modulation caused by the picture information.

Noise Pulse Current

An additional current path is provided in this receiver for feeding noise pulse currents (when they occur) to a special noise-limiter circuit. A noise pulse current (shown in Fig. 2 in dotted green) leaves the detector output and flows downward to the noise limiter in the sync separator section of the receiver. In flowing through R_{19}, it develops a negative voltage at the top of this resistor which effectively cuts off all plate current through V1. Thus, the voltage at the plate of V1 will rise very quickly toward

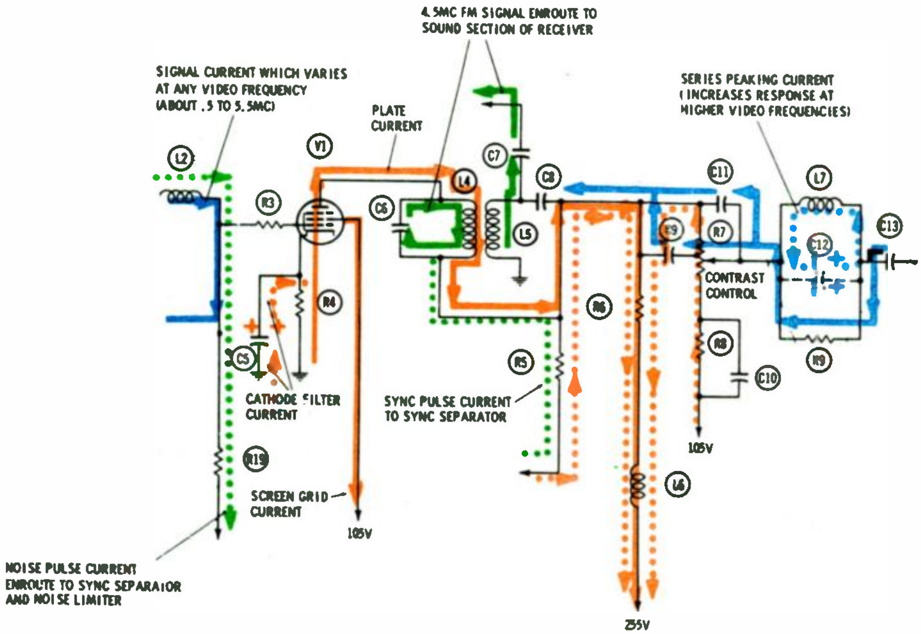


Figure 2 — The video amplifier.

the maximum plate supply voltage provided at the upper terminal of R_6. This rise in voltage is coupled to the cathode of the picture tube so that the picture tube cuts off for the duration of any such noise pulse. A noise pulse occurring during picture reception will, therefore, cause a dark spot or a dark streak in the picture; however, these spots or streaks are usually not noticeable because of their short duration. A pulse 1-microsecond wide would cut off the picture-tube beam for that period, which is approximately one-fiftieth, or 2%, of the time required to trace out a single line of picture information.

The Picture Signal

After a sync pulse and its pedestal voltage have passed, the strength of the resonant current in C_1 and L_8 decreases considerably; however, it will vary from cycle to cycle in accordance with the relative degree of whiteness desired at each particular spot in the single line of picture information being received. Thus, M1 will conduct varying amounts of electrons from cycle to cycle, and the accumulation of electrons on C_2 and C_3 will vary from cycle to cycle. This accumulation of electrons is the negative video voltage. It causes a pulsating DC to flow downward through R_1 and R_2 (and L_3) toward ground. The resulting voltage developed across these resistors by this pulsating current is the grid driving voltage for video amplifier V1.

Each small pulsation of video voltage is amplified considerably by the tube action causing large variations in the plate current flowing through load resistor R_6. These variations in plate current cause larger variations in the voltage at the upper terminal of this resistor. These variations, which are the amplified video voltage, are then coupled via C_9, C_{11}, etc., to the cathode of the picture tube.

The quantity of electrons in the electron beam of the picture tube is proportional, at any instant, to the amount of light, or whiteness, desired at that particular spot on the picture-tube face. The phosphorescent face of the picture tube always exhibits a degree of illumination proportional to the quantity of electrons striking it. Thus, a strong electron beam causes a bright spot (very white) on the picture-tube face. A weak beam causes a faint spot (gray rather than white) to appear on the picture tube screen.

The video signal is shown in solid blue in Diagram 7. In the detector portion of the circuit it is a unidirectional current flowing only from left to right through M1 and downward through R_1 and R_2 to ground. These electrons re-enter the detector circuit by flowing upward from ground into L_8.

In the circuit areas to the right of the video amplifier, the video signal has again become an alternating current; it flows in two directions through the entire coupling network (C_9, C_{11}, R_7, L_7, C_{12}, C_{13}, and R_9) and the cathode driving network (R_{10}, R_{11}, and R_{12}). At the instant shown in Diagram 7, video current is flowing upward and to the left through these networks, creating a positive signal voltage at the picture-tube cathode. This positive video voltage persists for as long as the picture information in that line is desired to be gray or black. (The more positive this voltage becomes, the darker the reproduced spot will be; conversely, the less positive the voltage, the lighter the spot becomes. Hence, all shades of gray can be reproduced.) When a white spot is desired in the picture, a near maximum negative video signal is required. When the video signal becomes negative, the electron currents in the coupling and driving networks reverse direction. Now the flow is to the right and downward. Thus a negative voltage is applied to the cathode, and the electron beam is increased, or turned up.

The video voltage is successfully transferred from the input circuit (the detector) to the output circuit (cathode of the picture tube) by means of pulsations in the plate current of the video amplifier tube (V1). This plate current is shown in solid red, but it is not an easy matter to draw a picture of these pulsations. All of the pulsations must eventually flow downward through R_6 toward the 255-volt power source. In doing so, the all-important voltage variations at the top of R_6 are developed. These voltage changes then drive electrons in and out of C_9 and C_{11}; these electrons become the new video signal current.

Shunt and Series Peaking

Two examples of resonant peaking being used to improve the response to higher video frequencies are shown in Diagram 7. L_3 is used as a *shunt peaker,* and L_7 is a *series peaker.* The principle involved in each instance is the same. There is a sufficient amount of inherent capacitance between the windings of any inductance to create a condition of resonance at some particular frequency. L_3 and L_7 are carefully wound during construction so as to possess both the desired amount of inductance and the necessary inherent capacitance. Thus resonance will occur near the high end of the video-frequency band (in the vicinity of 4 MHz). Any video signals near this frequency will excite an oscillation of electrons at its own frequency. Two such oscillations are shown in dotted blue; one is flowing upward through L_3 and charging inherent capacitance C_4 to a negative voltage. This negative voltage is in addition to the particular video voltage at that same frequency which set up the oscillation in the first place. The resonant voltage which will have a greater amplitude than the video voltage which excited it is applied to the control grid of V1 through R_1 and R_3. Therefore, greater amplification or response of the higher video frequencies will be provided by V1.

This process is called high-frequency compensation. It is made necessary by the fact that all circuit components, including amplifier tubes, have a certain amount of inherent, or built-in capacitance to ground. Since it is the nature of any capacitance to pass a high-frequency current more easily than a low-frequency current, the higher video frequencies are shunted to ground. It is necessary to compensate for this undesirable phenomenon by providing greater circuit response to the higher frequencies. R_2 and R_9 are placed in parallel with compensating inductors L_3 and L_7 for the purpose of broadening their response over a wider frequency band, even at the expense of considerable gain at their particular resonant frequencies.

The Audio Signal

The audio information carried by the television carrier signal is a frequency-modulated signal centered around a frequency of 4.5 MHz above the video carrier. This FM signal, which varies as much as 25 kHz on either side of the center frequency, is amplified only slightly in passing through the tuner and video-IF amplifier sections of the receiver. It is delivered to the detector input simultaneously with the synchronizing signals and the picture information.

Several important characteristics of the picture—synchronizing, and sound signals—their relative sizes (amplitudes), frequencies, and sequencing—are given in Figure 3. Line 1 of this illustration shows the audio signal; this signal is of relatively small amplitude, and the amplitude is constant or unchanging. Close inspection of this line will reveal that the frequency of this signal is constantly changing.

Line 2 of Figure 3 shows a typical single line of picture information. The individual cycles of electron oscillation (shown in blue) are occurring at the basic picture-carrier frequency or at any of the associated sideband frequencies. The modulation envelope has been drawn from peak to peak of the individual cycles. The sideband frequencies may extend upward to 4 MHz above the carriers, but they

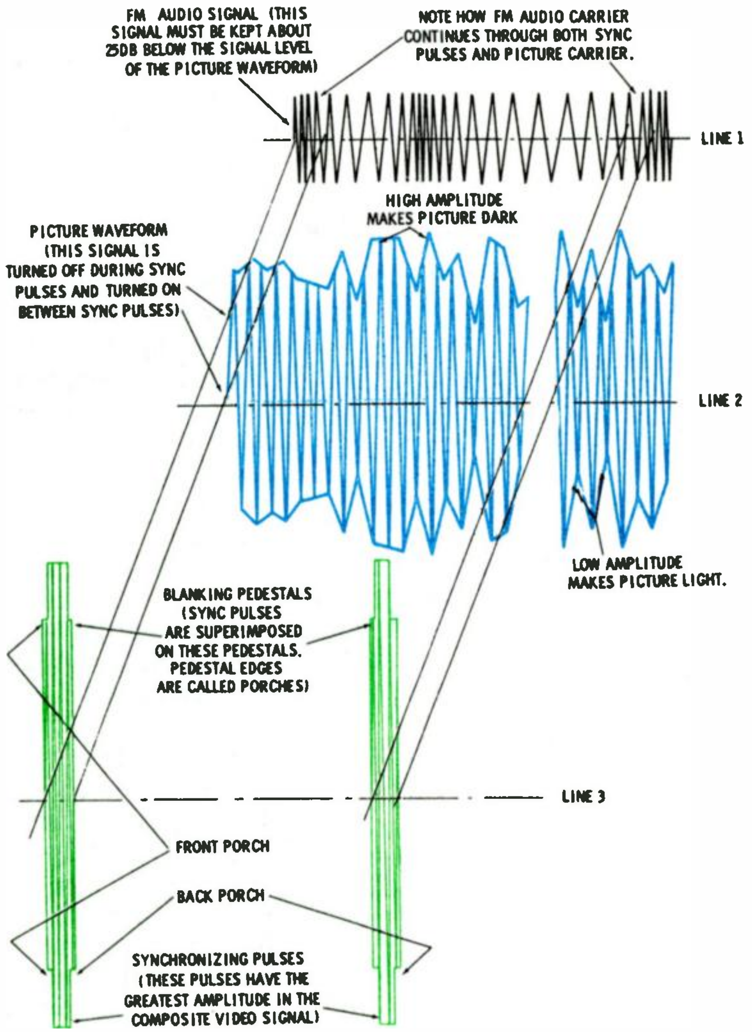


Figure 3 — Phase and amplitude relationships of the sync pulse, picture, and audio components of the composite video signal.

should stop short of the portion of the band reserved for the FM audio signal.

Line 3 of Figure 3 shows the IF carrier as it is modulated by the so-called "blanking pedestal" and a horizontal synchronizing signal. When the sync signal is being received, no picture information is being transmitted or received. The sync signal has a greater amplitude than even the strongest part of the picture signal. The strongest part of the picture signal is that part which completely turns off the cathode-ray tube and portrays a black portion of the picture. When the sync signal is made stronger than this, it assures that the cathode-ray tube will also be cut off during the period of each sync signal. Since the sync signal always coincides with the beam-retrace action, the greater strength of the sync pulse carrier assures that the electron beam through the picture tube will be turned off during retrace.

Be sure you can relate the waveforms of Figure 3 to the several currents and/or voltages depicted in Diagram 7. The individual cycles that make up the carrier waveforms in Lines 2 and 3 correspond to the electron current which flows back and forth between L_8 and C_1 as a resonant current. Each negative half-cycle of this carrier forces electron current to flow through detector M1 from left to right. The strength, or amplitude, of each of these half-cycles determines the *amount* of electron current which will be forced through the detector. This instantaneous signal strength will always be accurately reflected in the quantity of electrons accumulated in the voltage pool on the upper plates of C_2 and C_3. This accumulated voltage is sometimes referred to as the "detector" voltage, but it is also the video voltage which alternately provides synchronizing signals to the sync separator and picture signals to the cathode-ray tube.

The resonant current (shown in dotted blue) flows between C_1 and L_8 and contains the frequency-modulated audio signal carrier whose waveform is shown in Line 1 of Figure 3. Since this is a low-amplitude signal, it is always "masked" by the stronger sync and picture-carrier signals. This masking action is important because it insures that the electron voltage on C_2 and C_3 will always reflect or reproduce the amplitude or strength of the sync and picture carriers only. It must not be increased by any additional diode conduction resulting from the FM sound carrier. This is one of the reasons why the sound carrier is held at a much lower level than the lowest picture carrier strength (white level).

Each negative half-cycle of the sound carrier inevitably causes diode M1 to conduct some small amount of electrons, but since each half-cycle has the same strength as all other half-cycles, a small fixed component of negative voltage is added to the voltage on C_2 and C_3 and becomes, in effect, part of the bias voltage for V1.

While these actions are going on, additional pulsations of current flow through diode M1 at the video intermediate frequency of 45.75 MHz, as well as at each one of the video sidebands. Two very important mixing processes occur as a result of these simultaneous current actions. The FM intermediate frequency, which is centered around 41.25 MHz, mixes, or beats, with the picture-intermediate frequency of 45.75 MHz, producing a sound-IF signal centered around the new frequency of 4.5 MHz. Since the original FM sound signal had deviations of ± 25 kHz imposed on it, the new IF sound signal will also have these same deviations, so the sound-IF band will be from 4.475 to 4.525 MHz. The tuned plate circuit (C_6 and L_4 in Fig. 2) is resonant at this center frequency of 4.5 MHz. As the resonant tank current (solid green) flows up and down through L_4, it induces a companion current, flowing in two directions through L_5. This current drives electrons in and out of C_7 which couples this driving action to the sound-IF amplifiers.

The other important process that occurs in the video detector circuit involves the picture-intermediate frequency of 45.75 MHz and all of the video sidebands. These sidebands may extend as much as 4 MHz above the picture carrier. When the video-IF is removed, frequencies from zero to 4 MHz result. These frequencies become the video (picture) signal. They are amplified by V1 and pass downward through L_4 to an eventual junction with R_6, C_9, and C_{11}. At that point they are coupled to the cathode of the picture tube.

Voltage-Divider Currents

There is a total of five different voltage-divider currents which flow continuously in the circuit of Diagram 7. These currents are all essentially pure DC; they are almost always used to provide fixed values of positive voltage for application to the various electrodes of vacuum tubes. Such voltage values are usually called biasing voltages, meaning that they bias a tube electrode to a particular operating voltage. One of the virtues in identifying all of the voltage-divider currents in any circuit under study is the large number of circuit resistors which can be explained as *voltage-divider resistors.* The function they perform (providing reduced values of positive voltage for application to various tube electrodes) is technically a power-supply function. Normally, a power supply will provide only one or two values of high positive voltage, each having considerable current carrying capacity. The circuit designer can then construct voltage dividers at any point in the receiver where a particular value of voltage is needed.

The first of the voltage-divider currents has its origin in the sync-separator circuit (not shown). This current is drawn upward through R_5 and then downward through R_6 and L_6 to the 255-volt source. In addition to providing a low positive voltage at some point in the sync-separator circuit, it provides a higher value at the upper terminal of R_5; this voltage becomes the plate-supply voltage for video-output tube V1. The amount of this plate-supply voltage is also affected by the second voltage-divider current which flows upward through R_8 and R_7 and then downward through R_6 and L_6 to the 255-volt point. This current originates at a 105-volt tap in the power supply.

R_7 is the contrast control for the receiver. It can be used to vary the amount of output from the video amplifier that is actually coupled to the cathode of the picture tube. For example, if the variable tap on R_7 is positioned directly opposite the fixed tap that leads to C_9, the output signal is not required to flow through any portion of R_7 on its way to the picture tube. Thus, maximum gain is being attained from the amplifier. If, however, the variable tap is moved upward or downward on R_7, then the output signal which is being coupled through C_9 must also flow through a portion of R_7 and suffer some attenuation or loss. The entire video waveform will be proportionately attenuated by this adjustment. This attenuation tends to make dark spots or objects in the picture less dark and white spots or objects less white. Maximum contrast clearly implies achieving the maximum possible gain or output from the video output tube, thus providing a video voltage waveform with the largest possible swings between light and dark spots.

The video voltage is coupled to the picture tube through two parallel capacitive paths—C_9 and C_{11}. C_9 is the larger of the two; therefore, most of the signal flows through it. Whenever part of the contrast control (R_7) is interposed in the path through C_9, the total impedance of this path is increased so C_9 carries a smaller portion of the signal voltage and C_{11} carries a larger portion.

The third voltage-divider current flows upward from ground through R_{12} and R_{13} toward the 255-volt source. R_{12} is a variable resistor that serves as the brightness control, a front-panel operator adjustment which controls the bias on the picture tube. (A typical value provided by this variable resistor is 50 volts). The special relationship between this cathode-voltage value and the relative brightness of the picture tube will be discussed later.

The fourth voltage-divider current flows upward through R_{15} and downward through R_{16} to the same 255-volt source. The resulting voltage at the junction of the two resistors (about 50 volts) is applied to the screen grid of the picture tube. This voltage serves as an accelerating voltage to accelerate the plate-current stream of electrons flowing through the picture tube.

The final voltage-divider current flows from ground through R_{18} toward the high positive voltage known as B+ boost. In this receiver it has a value of +600 volts. R_{18} is another variable resistor which serves as a focus control. The voltage which is tapped from R_{18} is applied to one of the electrodes of the picture tube to concentrate (focus) the electron stream through the tube so that it will strike the face of the picture tube in as small a point or area as possible. A typical value for the focus electrode voltage in this receiver is 400 volts.

THE TRANSISTOR VIDEO AMPLIFIER AND OUTPUT STAGES

The video amplifier stages in transistor-TV sets do the same thing as in tube-type sets; they just look different. All of the same functions will still be there and in about the same places. Practically all of these circuits will use a two transistor video amplifier stage. The first transistor will often be connected as an emitter follower to match the input impedance to the high impedance output of the video detector. The low impedance output of the first video amplifier matches the low input impedance of the video output transistor.

A great many of these circuits will use direct coupling between the first video amplifier or driver and the video output transistor. Others will have AC coupling, with a blocking capacitor. Figure 4 shows a typical two transistor video amplifier stage. The DC coupling in this circuit, between the video output transistor and the CRT cathode, is made through diode X6, which is shunted by a 0.22-μF capacitor.

The video output transistor will be a higher voltage type, compared to other transistors in the video circuits. This is because this transistor must be able to develop a very large output voltage swing to drive the picture-tube cathode from full conduction to cutoff. Therefore, the video output transistor will not be a high power type, but a high voltage type. These stages are always biased to work in Class A, so that the signal can swing over a range of about twice the applied DC voltage, and give a distortion free output.

The collector voltage supply for this transistor is often taken from a boost supply tap on the flyback transformer, or from a higher voltage tap in the DC power supply. The supply voltage used will vary in different sets, but will be somewhere around 100 to 150 volts. In the example shown in Figure 4, the supply voltage is taken from the +130-volt boost source.

You will find series and shunt peaking coils used in transistor video amplifier stages, just as in tube-type sets, and for the same purpose. Peaking coils will often be shunted by resistors and bypassed by capacitors to improve the low-frequency response.

The sound IF signal is usually taken off at about midpoint in the video amplifier circuit. In Figure 4, a sound-takeoff transformer is used. The customary 4.5 MHz traps are used and are incorporated in the sound-takeoff transformer when one is used.

The video signal you see at the output stage may look just a little bit different than usual on a scope. Quite a few transistor video output stages take advantage of the fact that the signal for the sync separators, sound IF, and AGC stages is taken off after the first video amplifier stage. As a result, the designer can get quite a bit more gain out of the video output stage, often as much as 25 percent additional, simply by slightly clipping the sync side of the video signal. We do not have to amplify this portion of the signal, so the bias of the output transistor is shifted so that the sync tips fall on a part of the curve where they are actually clipped. Therefore, if you are checking the video signal on the CRT cathode, do not be surprised if the signal does not show the familiar 25 percent sync and 75 percent video amplitude relationship.

ANALYSIS OF SYNC SEPARATOR, NOISE CANCELER AND AGC CIRCUITS

The functions of sync separation, noise limitation or cancellation, and automatic control of receiver

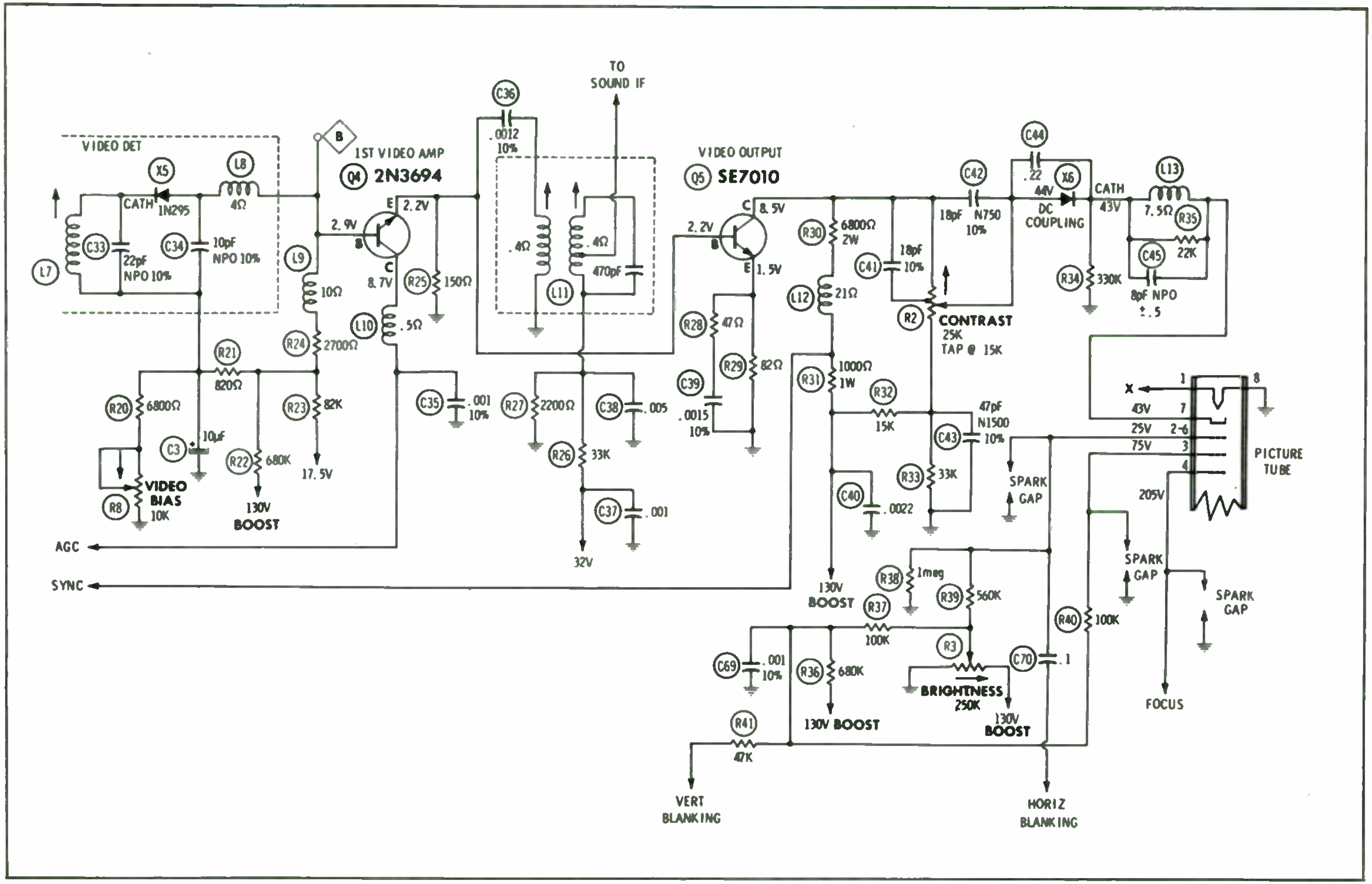


Figure 4 — Typical two-stage video amplifier.

gain are accomplished by closely related circuits in modern television receivers. These functions are interrelated within the circuit to the extent that no single one of them can be studied without encountering some feature of circuit design which has been provided to take care of a different function. Therefore, in this lesson, all three functions will be discussed. Figures 5 and 12 are identical circuit diagrams taken from a typical modern television receiver. In this circuit, each of the three functions is accomplished with a separate vacuum-tube circuit; therefore, each function can be studied independently of the others.

Sync Separator Operation

Of the three major functions (and countless minor functions) which are accomplished in the combination of circuits in Figures 5 and 11, the most important function is known as sync separation. The composite video waveform contains both the picture (video) information and the synchronizing signals, with the picture information being transmitted in a 58-microsecond period between each successive sync pulse. The function of the sync-separator is to separate the sync pulses from the picture information.

The sync pulses are always transmitted with higher amplitude than any of the picture information; therefore, the sync-separator tube must be biased so that it will conduct electrons only when driven by the high amplitude pulses. When the lower amplitude picture information is occurring, the tube is held below cut off and will not conduct.

This biasing is achieved by using a very high resistance in the grid circuit. In Figure 6 this resistor (R_{61}) is 8.2 megohms. Whenever the sync pulses from the video amplifier draw electron current upward through R_{61}, the control grid of V9 is made positive, and some grid leakage electrons will flow out of the tube via the control grid. This leakage current is shown in dotted red in Figure 6. Its complete path is from cathode to grid within the tube, then through R_{60} and R_{61} to ground, where the electrons have a ready return access to the cathode. Because of the large amount of resistance in their path to ground, electrons accumulate on the right hand plate of C_{44}. This accumulation of electrons constitutes a biasing voltage which is sufficiently negative to keep V9 cut off at all times except during the period when the high-amplitude sync pulses appear in the composite video waveform. Thus, only the pulses appear at the plate of the tube; the picture information has been removed. Because of the clipping action of removing the pulses from the composite video signal, this stage is often called a *sync clipper.*

In addition to separating the synchronizing pulses from the video information, the sync separator also serves to *separate* the horizontal and the vertical sync.

This function is accomplished in the network of resistors and capacitors in the plate circuit of V9. It is

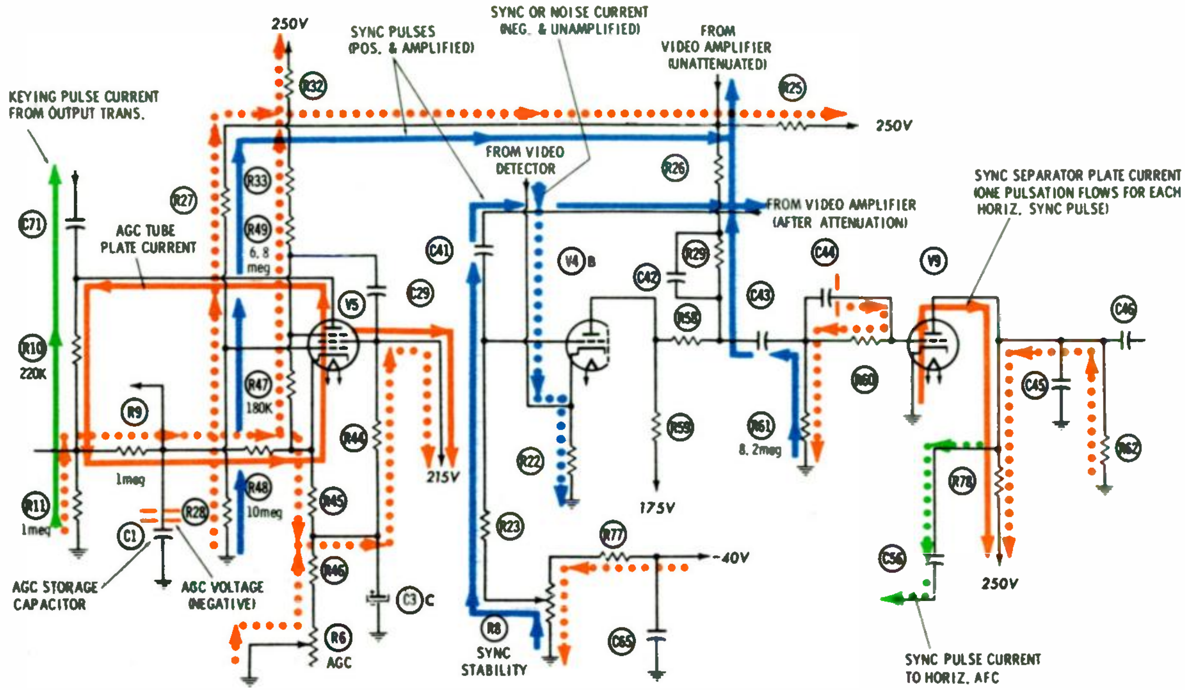


Figure 5 — Operation of AGC, noise canceler, and sync separator circuits—normal operating conditions.

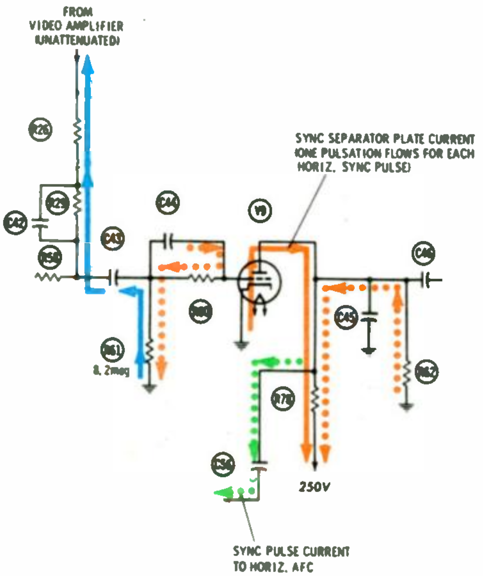


Figure 6 — The sync separator in normal operation.

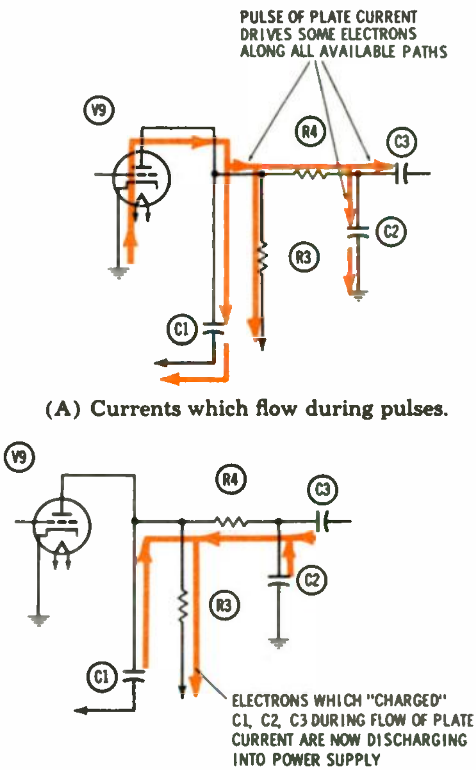
essentially a filtering problem, and a simple one at that. Figure 7 shows a simplified RC network which can accomplish this function.

Figure 7A shows the predominant electron currents which flow *during* the time duration of a sync pulse, and Figure 7B shows the predominant currents which flow in the period *between* pulses. Figure 8 shows the pertinent portions of the composite video waveform which relate to Figure 7.

The composite waveform contains a total of 15,750 synchronizing pulses. The leading edge of each one of these pulses constitutes a horizontal synchronizing signal, and each causes a single pulse of current to flow to the horizontal AFC circuit from the plate of V9. This is the current which is shown in dotted green in Figure 6.

These synchronizing pulses in the composite video waveform are alternately narrow and wide in accordance with the following sequence:

253 horizontal sync pulses, 5 microseconds wide.
6 equalizing pulses, about 1 microsecond wide.
6 wide pulses (about 55 to 60 microseconds wide), commonly called vertical pulses, although this title is misleading.
6 equalizing pulses.



(A) Currents which flow during pulses.

(B) Currents which flow between pulses.

Figure 7 — A typical circuit for passing high-frequency signals in one direction and low-frequency signals in another.

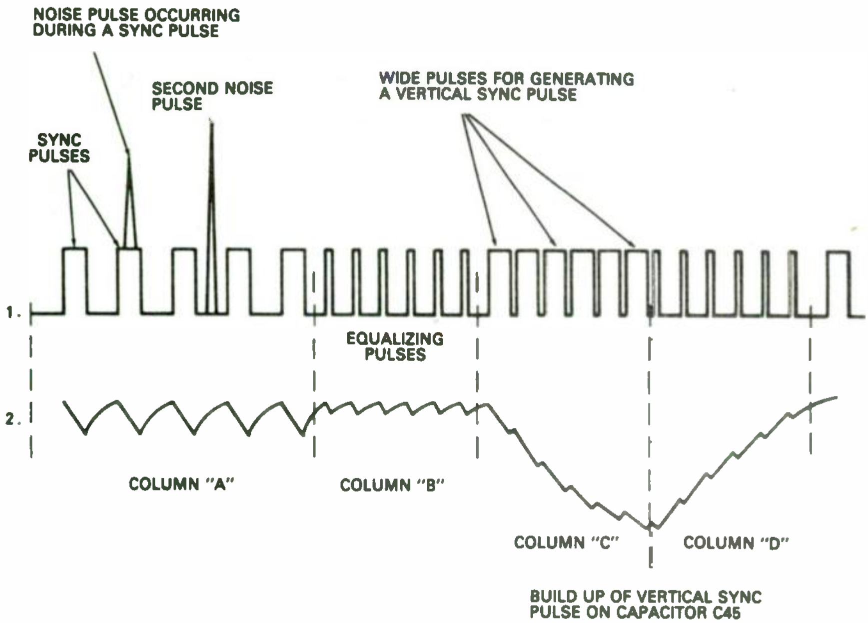


Figure 8 — Relationship between incoming sync pulses and the build-up of the vertical sync pulse.

This approximate sequence is repeated over and over again; each such sequence completes itself in one-sixtieth of a second. Figure 8 shows the relative spacings and widths of the various pulses. The leading edge of each pulse causes electron current to be drawn upward through the network composed of R_{26}, R_{29} and C_{42} in parallel, C_{43}, and R_{61} (Figure 6). The upward flow of electrons through R_{61} (shown in solid blue) makes the upper end of R_{61} positive with respect to the lower end. This constitutes a positive grid voltage for the sync separator tube (V9) and causes it to conduct electrons.

The sync pulse current from the video amplifier output circuit is shown in solid blue in Figure 6. The trailing edge of each pulse shown in Figure 8 will drive this electron current in the opposite direction, namely downward through R_{26}, R_{29}, C_{43}, and R_{61}. This downward flow of electrons through R_{61} develops a negative-grid driving voltage for tube V9; this, in turn, cuts off the flow of plate current through the tube.

Thus, during each one of the 253 *normal horizontal* sync pulses, this sync current flows upward through the RC network for about 5 microseconds, making the grid of V9 positive and causing plate current to flow through the tube. During the 58 microseconds which elapse between any two of these pulses, V9 does not conduct. The plate current which flows through V9 is shown in solid red in Figure 6.

In the simplified network of Figure 7A you can see the currents which flow whenever the sync separator tube is conducting plate current. The normal path for plate current is to flow from cathode to plate within the vacuum tube, then downward through the load resistor R_3 to the positive terminal of the power supply. However, R_3 is made large enough to act as a "dam" to the plate current electrons; therefore, electrons momentarily flow along any other available path. Thus, they flow into the upper plate of C_1, driving an equal number of electrons out of the lower plate toward the horizontal automatic frequency control (AFC) system. This action constitutes a negative sync pulse to the AFC system.

Some of these plate current electrons will also flow through the alternate path represented by R_4 and C_2. The size of R4 will determine *how many* electrons will flow through it during the period that V9 is conducting.

Normally, capacitor C_2 will have the full positive voltage of the power supply existing on its upper plate. This positive voltage will be lowered whenever any electrons from the plate current stream can get to it by flowing through R_4. Likewise, whenever the tube current is cut off (Fig. 7B), the current flowing through R_4 will reverse in direction, and electrons will be drawn away from the upper plate of C_2, causing the voltage at that point to rise toward the full positive value of the power supply voltage.

Line 2 of Figure 8 shows how the voltage on the upper plate of C_2 varies with time. Column A of this illustration represents almost an entire sixtieth of a second in time, although many pulses have been omitted for clarity. During this period, one complete field on the television screen will be traced out by the 253 horizontal scans of the electron beam, each scan being "triggered" by one of the horizontal pulses. During the five microsecond period of each pulse, plate current electrons will pour onto the upper plate of C_2 (Fig. 7A) sharply lowering its voltage. During the longer period between two successive pulses, electrons will slowly drain back through R_4 and downward through the plate load resistor to the power supply as shown in Figure 7B.

During the short periods of time represented by column B, C, and D in Figure 8, the charge-discharge curve of Line 2 will be modified as shown. The equalizing pulses last about one microsecond each, but they occur twice as frequently as the regular synchronizing pulses. Each equalizing pulse sends some electrons into R_4 and onto the upper plate of C_1. Each pulse of electrons flowing into C_1 causes an equal number to flow away from the lower plate of C_1; thus, they act as a negative synchronizing pulse for the horizontal AFC system. The manner in which this synchronizing action is accomplished will be discussed in a later lesson.

The necessary *vertical pulse* voltage which is required for either triggering or synchronizing the vertical oscillator system is generated 60 times each second, during the time period represented by Column C of Figure 8. The six long (or wide) pulses which occur during this time period are referred to as *serrations*, or *serrated vertical pulses*. Each of these long pulses lasts about 30 microseconds and is followed by a very short turn-off period—only a microsecond or two—before the next long pulse appears.

A sync-separator tube, such as V9, will conduct as long as a positive pulse voltage is applied to its grid. Consequently, the tube will conduct electrons almost continuously during the period represented by Column C—about 190 microseconds. The effect on the voltage on the upper plate of capacitor C_2 is shown graphically in Line 2. Electrons flow into C_2 from the tube as long as the tube is conducting, drastically reducing the normally high positive voltage which exists there. Usually, after three or four of these wide pulses have occurred, the voltage on C_2 will have been lowered enough so that the vertical oscillator can be triggered by what appears to it as a negative pulse of voltage. The manner in which this triggering occurs will be discussed in a later lesson.

The process of accumulating a charge of electrons on C_2 and thus reducing its positive voltage is called *integration*. There are many possible combinations of resistors and capacitors for achieving such an integration process, but they must all share two important characteristics in common. They must all possess:

1. A relatively low resistance charging path through which electrons can enter.
2. A relatively high resistance discharging path through which these same electrons must leave.

In Figure 7A you can see that the charging path for these electrons is through vacuum tube V9 (which is considered to be a low resistance) and R_4.

Figure 7B indicates the discharge path consists of resistor R_4 and the plate load resistance R_3. Thus, while the electrons must flow through R_4 while moving in either direction, they must flow through R_3 only when discharging to the power supply. Thus, it will always take much longer for any given quantity of electrons to discharge than to charge. Also, during the time period of Column C, only about 6 microseconds of time are available for the discharging process. These are the short intervals of time which separate the six wide serrated pulses. These circumstances enable us to build up or *integrate* a vertical pulse of voltage whenever the six serrated pulses occur in the composite video waveform.

The simplified circuit of Figure 7 can be easily compared with the portion of Figure 6, which performs the same functions of sync separation, and integration of a vertical pulse. Capacitor C_{56} couples each synchronizing pulse, including the narrow equalizing pulses and the wide serrated pulses, to the horizontal AFC system. During the 190 microseconds of time represented by Column C (Fig. 8) electrons pour almost continuously onto the upper plate of C_{45} (Fig. 6), reducing its positive voltage and integrating, or building up, a vertical triggering pulse. This triggering pulse is coupled directly into the vertical oscillator system via C_{46}. As electrons flow into C_{45} during the serrated pulse period (Column C), they also flow into the left hand plate of C_{46}, driving an equal quantity of electrons away from the other plate. Thus, a reduction in the positive voltage on C_{45} becomes a pulse of negative voltage to all circuit elements which may be connected to the right-hand plate of C_{46}.

A resistor comparable to R_4 in Figure 7 has been omitted from the circuit of Figure 6. In general, a circuit will function equally well without it. R_4 has been included in Figure 7 to illustrate the classic example of a combination *high-pass* and *low-pass* filter system. R_4 and C_1 constitute essentially a high-frequency filter system designed so that any high-frequency currents coming from the tube will have two alternate paths available to them—a high-resistance path through R_4 and a low-impedance path through C_1. Naturally, they will choose the low-impedance path.

To lower-frequency currents, the path through capacitor C_1 is not a low-impedance path, but rather a high-impedance path, because of the fact that the reactance (impedance) of any capacitor varies inversely with the frequency. Thus, to low-frequency currents the path through R_4 offers the least impedance or opposition to electron flow, and that is the path which they will travel.

Operation of the Noise-Canceler Circuit

The noise-canceler tube (V4B, Fig. 9) is normally nonconducting. This condition is achieved by connecting the control grid to a negative voltage source (approximately −20 volts). This voltage is provided by the voltage divider action of R_8 and R_{77}, through which a large quantity of grid leakage electrons from the horizontal-output tube (not shown) must discharge to ground. R_8 and R_{77} are actually the grid return resistors for the horizontal output tube.

Grid cut-off voltage for this tube (the triode portion of a 6EB8) is in the region of −2 or −3 volts with 175 volts applied to the plate, so the noise-canceler tube is biased well below the cut-off point. This tube (V4B) is simultaneously driven by two video voltages of opposite polarities. The cathode is connected directly to the video detector and, in fact, the cathode resistor (R_{22}) is also the video detector load resistor (not shown). Thus, the current shown in dotted blue in Figure 9 is a pulsating direct current, flowing continuously downward through R_{22} to ground. Each synchronizing pulse has the same amplitude and drives the cathode of V4B to a slight negative voltage but only a fraction of a volt, which is not enough to cause the tube to conduct.

At the same moment that this happens, the control grid of V4B is being driven by a synchronizing pulse current from the output circuit of the video amplifier. This pulse current is shown in solid blue. It is drawn upwards through R_8 and R_{23} and onto the lower plate of C_{41}. This places a substantial *positive* voltage at the control grid of V4B, but one which is not quite sufficient to overcome the permanent negative bias of −20 volts. Consequently, the normal effect of the negative grid bias and the two driving voltages (a positive one at the grid and a negative one at the cathode) will be that the noise-canceler tube does not conduct as a result of any sync pulse action.

It should be noted here that there are three different video signals which are applied to the circuits shown in Figure 5. A small amplitude negative signal is taken from the video detector and applied to the cathode of the noise canceler tube (V4B). This same signal is amplified many times by the video amplifier V4 (not shown here). This amplified signal is now positive; it is represented by the current shown in solid blue, being drawn upward through R_{61}, R_{29}, and R_{26}.

The third video signal, also positive, is also taken from the same video output circuit, but only after the signal has been passed through an attenuating network which reduces its amplitude. This third signal is represented by the solid blue current which is drawn upward through R_8 and R_{23}.

Figure 8 shows two unwanted noise pulses occurring during the time devoted to a horizontal field (Column A). The first one of these coincides with one of the syn-

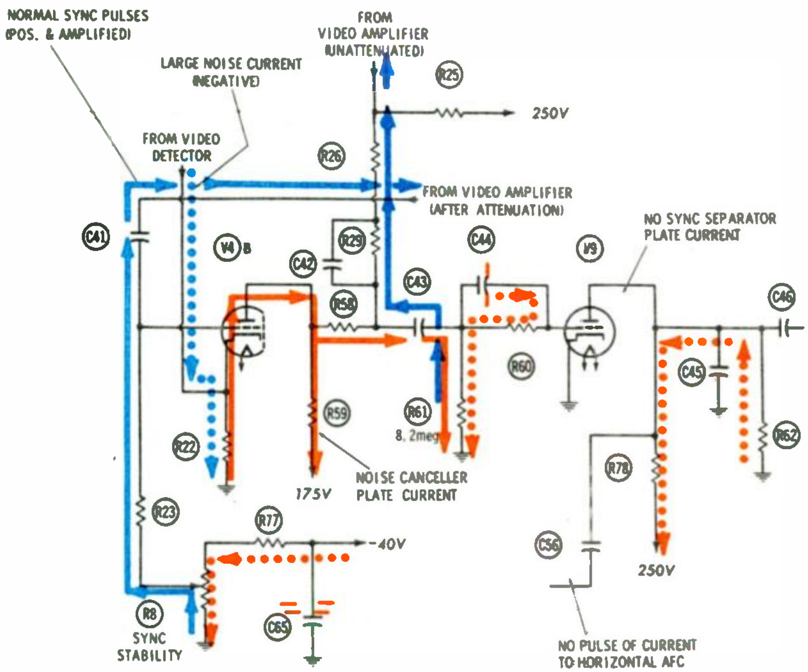


Figure 9 — Action of the noise canceler during a strong noise pulse.

chronizing pulses. A noise pulse such as this is usually of extremely short duration and also of much higher amplitude than the sync pulses. It is desirable that no such noise pulse be permitted to turn on the sync separator tube. The function of the noise-canceler tube is to prevent this from happening.

It should be obvious that a high amplitude noise pulse will increase the voltage output of the video detector. This will greatly increase the amount of electron current flowing downward through R_{22}, causing the voltage at the cathode of the noise-canceler tube (V4B) to become *more* negative. When a cathode voltage is made more negative, it has the same effect as making the control grid more positive, so the noise-canceler tube is brought closer to the point of conduction. Additionally, this same noise pulse will be inverted and amplified in the video amplifier, and the resultant noise pulse will be applied to the grid of V4B. This pulse current is the one shown in solid blue, flowing upward through R_{23} and R_8 in Figure 9. Since it has considerably greater amplitude than the normal sync pulse, there is no question that the canceler tube will conduct electrons from cathode to plate. The noise canceler plate current is shown in solid red in Figure 9.

Several important events occur as a result of this. Perhaps the most important result is that the sudden flood of electrons reaching the junction of R_{58} and R_{59} from the plate of V4B will drive an electron current through R_{58}, C_{43} and R_{61} toward ground. This downward flow of current through R_{61} develops a negative voltage at the upper end of R_{61}, which counteracts the positive voltage being developed at the same point by the sync-pulse current from the video amplifier. The net result is that the sync separator tube (V9) is prevented from conducting its normal pulse of plate current during this particular sync pulse. It is thus unable to deliver its usual sync pulse current to the horizontal AFC system. As we shall see later, the absence of an occasional synchronizing pulse imposes no hardship on the AFC system.

A second result of plate current flowing through the noise-canceler tube is that it partially dampens or decreases the voltage output of the video detector. It should be remembered that cathode resistor R_{22} is also part of the load circuit for the video detector. When the noise-canceler plate current (shown in solid red in Figure 9) flows upward through R_{22}, it develops a positive voltage at the upper terminal of R_{22}. This voltage completely nullifies the negative voltage developed there by the noise current from the video detector. The resulting effect is that of reducing the strength of the noise pulse *before* it is applied to the video amplifier.

In the case of the second noise pulse (Figure 8) it is even more important that the sync-separator tube not be permitted to conduct while it is occurring, because it would send a spurious sync pulse to the horizontal AFC system. This could result in triggering the horizontal oscillator at the wrong moment, thus destroying several lines of picture information before proper synchronizing can be restored. The noise-canceler tube (V4B) operates in essentially the same fashion as described previously. A positive noise pulse current from the video amplifier flows upward through R_8 and R_{23}, driving the grid of V4B positive. A negative noise pulse current from the video detector flows downward through R_{22}, making the cathode of V4B negative. These two actions combine to make V4B conduct, and the resulting noise-canceler plate current drives some current downward through R_{61}, the grid resistor for V9, overcoming the positive voltage developed across R_{61} by the unattenuated noise current from the video amplifier. This assures that the sync-separator tube (V9) will be held in a cut-off, or nonconducting, condition for the duration of the noise pulse.

Sync Stabilization

Most modern receivers have a variable adjustment, usually a variable resistor, which provides a function known as sync *stabilizing.* This adjustment is primarily useful in fringe areas far removed from a transmitting station. Also, in industrial areas the various types of man made electrical noises (arc welding, ignition systems, etc.) will provide greater competition with the synchronizing pulses. The situation becomes most troublesome when some decrease in received signal strength causes the sync pulses to be of approximately the same amplitude as a large variety of noise pulses which otherwise would not be strong enough to trigger the horizontal AFC system.

Adjustment of the variable tap on R_8 has two independent effects on the operation of noise-canceler tube V4B. Moving the tap closer to ground applies a *lesser negative voltage* to the control grid. This enables the canceler tube to be turned on by *weaker* noise signals than would normally be the case. This is the adjustment which would be made in a fringe area. It is desired to set this variable resistor so that a normal sync pulse, driving the two sync currents through R_{23} and R_{22}, respectively, will not be quite strong enough to cause V4B to conduct, but that any noise pulse of greater amplitude than a sync pulse will cause it to conduct.

Automatic Gain Control (AGC) Operation

The AGC circuit constructed around tube V5 is a fairly typical one for television receivers in that it requires the simultaneous application of two separate signal voltages before the tube will conduct electrons. A normal positive sync pulse is applied directly from the video amplifier output to the control grid of the tube. At the same time, a high voltage positive pulse, known as a *keying* pulse, is applied to the plate of the same tube. Either one of these actions occurring by itself is insufficient to cause the AGC tube to conduct. When they occur together, the tube conducts strongly. This is a noise protection feature, because the keying pulse comes from the horizontal oscillator and occurs only once each cycle during the retrace period. The sync pulses occur only during the retrace period. Thus, any noise pulse current flowing through R_{28} and R_{27} at any other time than during retrace will not cause the AGC tube to conduct.

V5 is initially biased by several voltage divider currents. In Figure 10, the cathode is biased at +50 volts, the control grid at +40 volts, the screen grid at +215 volts, the suppressor grid at +50 volts, and the plate at the very low value of +4 volts. The fact that the cathode is 10 volts more positive than the control grid prevents the tube (a remote cut-off 6DT6A pentode in this case) from conducting under these biasing conditions.

When a sync pulse occurs in the composite video waveform, the current shown in solid blue is drawn up through R_{28} and R_{27}. Since R_{27} is about twice the size of R_{28}, approximately one third of the total sync pulse voltage from the video amplifier will be developed across R_{28} and applied as a driving voltage to the control grid of V5. This is sufficient to overcome the existing negative grid to cathode bias of 10 volts so that the grid will allow electrons to flow on through the tube. If no additional positive voltage is applied to the plate, these electrons will be attracted to the positive voltages on the screen and suppressor grids (+215 and +50 volts, respectively), and will exit from the tube via those grids. Very few of these electrons get through both grids and reach the tube plate, which has only about +4 volts applied to it by voltage divider R_{11}, R_9, R_{48}, R_{47}, R_{49}, etc.

When the positive pulse from the video amplifier is caused by a genuine sync pulse rather than a spurious noise signal, it occurs at the same time as the retrace action which is generated within the horizontal oscillator. This retrace action induces a sharp pulse of current in a special winding of the horizontal output transformer. The polarity of this winding must be so arranged that the resulting pulse of current flows in such a direction through resistors R_{11} and R_{10} as will make the plate of V5 more positive. In other words, this keying current, which is shown in solid green in Figure 10 must flow *upward* through R_{11} and R_{10}.

This action places an instantaneous positive voltage of several hundred volts on the plate of the AGC tube, causing plate current to flow. This plate current is shown in solid red in Figure 10. Its complete path is from cathode to plate within the tube, then through R_{10}, R_9, and R_{48} back to the cathode of the tube. Because of the large resistive value of R_{48} (10 megohms) most of these plate current electrons temporarily accumulate on the upper plate of the AGC storage capacitor (C1) and then leak through R_{48} at a slow rate towards the 250 volt power supply source. The electrons accumulated on the storage capacitor constitute the negative AGC voltage which is usually applied to the control grids of the RF stage in the tuner, and the early IF stages.

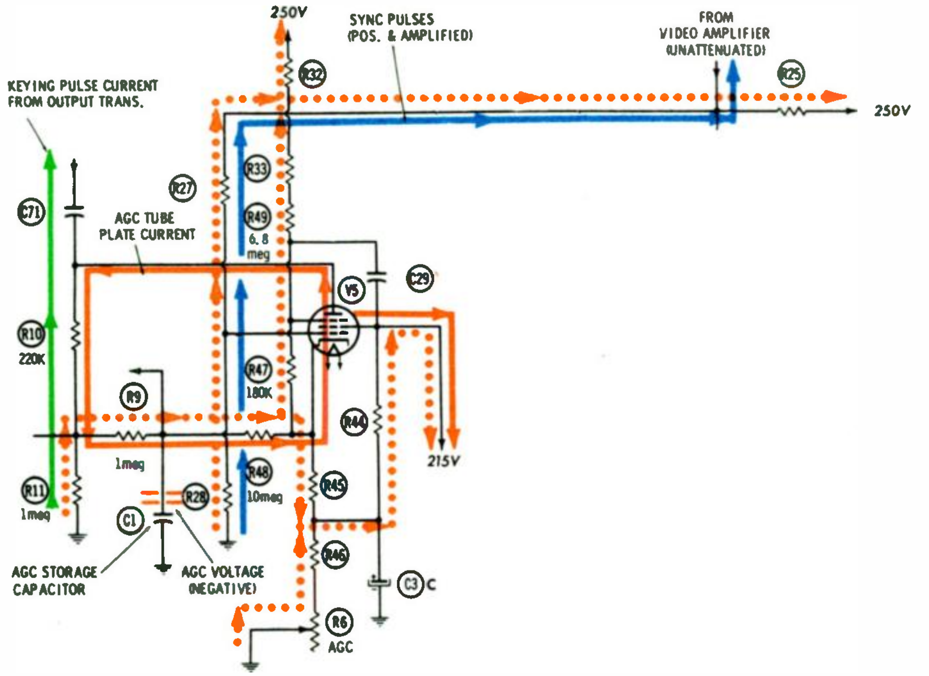


Figure 10 — AGC circuit in normal operation.

It is desirable to have the AGC voltage become *more* negative when the signal strength *increases* and *less* negative when the signal strength *decreases*. This will naturally occur, because a strong sync pulse will draw *more* electron current up through R28, making the control grid of V5 more positive and causing more plate current to flow through the tube. This *increases* the accumulation of electrons on the AGC storage capacitor. On the other hand, a weakened sync pulse, characteristic of a weakened signal strength, will make the control grid of V5 less positive. This reduces the amount of plate current flowing through the AGC tube, and thus reduces the number of electrons which can flow into temporary storage on the storage capacitor. Thus, the AGC voltage becomes less negative during a period of reduced signal strength.

As is the case with all AGC systems, either in TV systems or in FM or AM radio, the upper plate of the AGC storage capacitor is a scene of constant restless activity. Electrons flow into this point once during each synchronizing pulse, coming from the plate current of the AGC tube. These electrons accumulate on the upper plate of the storage capacitor and constitute the negative AGC voltage. Finally, electrons drain continuously away from this point, flowing through the large resistor (R_{48}) toward the cathode of the AGC tube, or to the 250-volt power-supply source.

All AGC systems share certain essential characteristics in common. The most important characteristic is that the AGC storage capacitor is a very large capacitor, and that the prime AGC resistor (R_{48} in this case) is a very large resistor. These conditions give us assurance that the AGC voltage on the AGC storage capacitor will not decrease or discharge significantly during the periods between pulses, and also that this voltage will not increase significantly when sync pulses are occurring. The voltage on the upper plate of the storage capacitor may be compared to a giant "pool" of electrons. Electrons come into this pool during each sync pulse, but the number coming in during each pulse is insignificantly small in comparison with the number already stored there, so that the negative AGC voltage will not be increased by this action. Also, electrons flow out of this pool continuously through the 10 megohm resistor (R_{48}), but the quantity which can escape by this route is also insignificantly small in comparison with the number which are stored there so that the negative AGC voltage will not be decreased by this action.

These relationships are governed by what is known as Coulomb's law, which relates the size of a capacitor to the quantity of electrons (or positive ions) stored in it and the resulting negative (or positive) voltage. In mathematical form, this law is stated as follows:

$$Q = C \times E$$

where,

Q is the quantity of stored electrons (or ions) measured in coulombs,
C is the size of the capacitor in farads,
E is the voltage across the capacitor in volts.

During periods of stable signal strength, a balance is found and maintained between the electrons which flow into the storage capacitor *during* the sync pulses and those which flow out in the periods *between* the sync pulses. A stable negative voltage of several volts will exist on the capacitor. This voltage is applied to the RF amplifier and some of the IF amplifier control grids.

If the signal strength should fade due to atmospheric conditions or anomalous propagation, the AGC tube conducts fewer electrons during each sync pulse, as explained previously, upsetting this condition of balance or equilibrium. More electrons flow away from the storage point in the period between pulses than are flowing in during the pulses; this inevitably reduces the negative voltage stored on the capacitor. The resulting reduced negative bias on the RF amplifier control grids will cause those tubes to provide greater amplification of the incoming signal, thus largely offsetting the reduction in signal strength. When an unwanted increase in signal strength occurs, an opposite set of conditions will prevail.

Figures 5 and 11 differ in certain important details. Figure 5 depicts normal operating conditions, when positive sync pulses are applied to

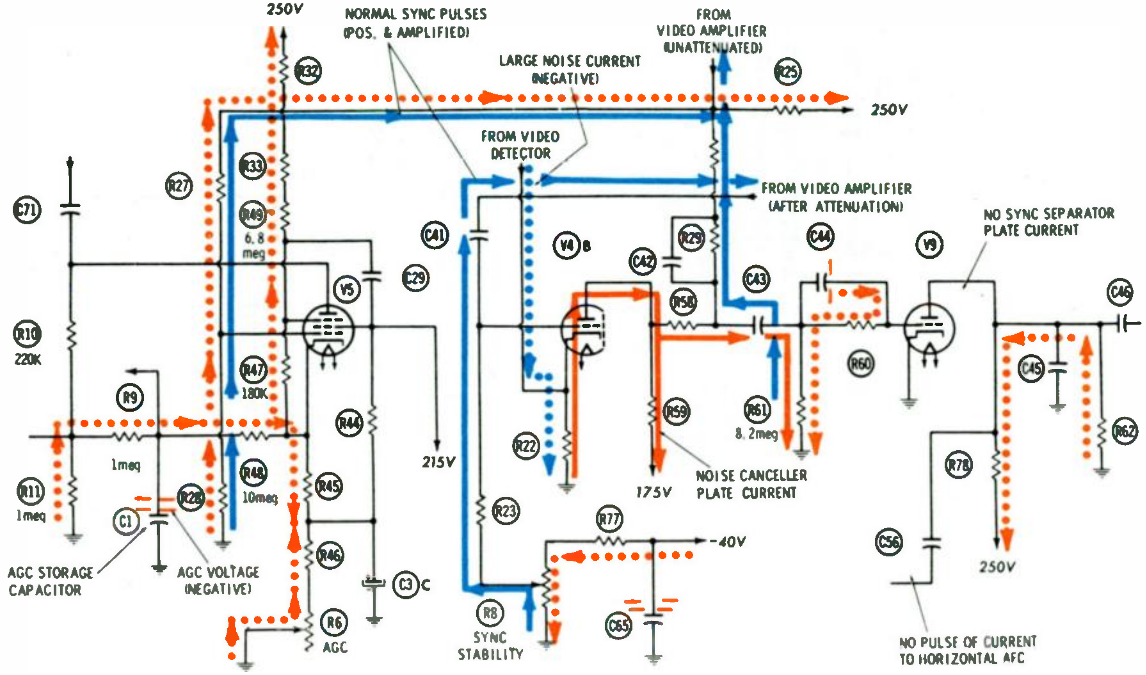


Figure 11 — Operation of AGC, noise canceler, and sync separator circuits—strong noise pulse being received.

the control grids of both AGC tube V5 and noise-canceler tube V4B. While this is happening, a positive keying pulse is applied to the plate of AGC tube V5 so that it will conduct. (It conducts only during the short periods when sync pulses are occurring.)

V4B has this positive driving voltage applied to its grid, and also a negative driving voltage applied to its cathode. This results from the negative sync pulse current (shown in dotted blue) which flows downward through R_{22}. However, these two driving voltages are not sufficient to cause V4B to conduct because of the fixed negative bias applied to the grid from voltage divider network R_8 and R_{77}.

Figure 11 depicts abnormal operating conditions when a strong noise pulse is being received. The strength of such a pulse causes a stronger positive signal at the grid, and a stronger negative signal at the cathode of V4B. Together, these two signals will overcome the fixed negative bias applied from R_8, so that the noise tube will conduct plate current.

This noise pulse can occur at any time. If it occurs in the period between sync pulses, the AGC tube will be prevented from conducting by the absence of a "keying" pulse (shown in solid green) from the horizontal output transformer. This keying pulse occurs *only* during the horizontal retrace period, which coincides with the sync pulse arrivals. This is the condition depicted in Figure 5.

If the noise pulse arrives or occurs simultaneously with the sync pulses, the plate of AGC tube V5 will be unable to distinguish a noise pulse from a sync pulse, and the amount of plate current through V5 will be increased.

When a signal fade occurs, the strength of the individual sync pulses decreases. The electron current, drawn upward through R_{28} and R_{27} (shown in solid blue) is proportional in quantity to the strength of the sync pulses.

An increase in signal strength would have the opposite effect. The current drawn up through R_{28} would be increased, and the positive biasing voltage developed at the top of R_{28} would be increased accordingly.

SUMMARY

In the video circuit of Diagram 7, the video signal is detected, amplified, and applied to the picture tube. The AM video signal is detected from the video-IF by the detector circuit which includes diode M1. The video signal is coupled to the video amplifier (V1) where it is amplified. In the detector, a 4.5 MHz beat frequency is formed when the 41.25 MHz audio-IF and the 45.75 MHz video-IF are heterodyned. This 4.5 MHz signal is the sound-IF, which is amplified in the video amplifier and then separated by the tuned circuit of C_6 and L_4 which couples the sound-IF to L_5, where it is applied to the audio circuit.

The sync pulses are applied to the sync separator through resistor R_5. The video signal is applied through the contrast control and the series peaking circuit to the cathode of the picture tube. This is cathode drive and is the commonly used method of applying the video signal to the picture tube.

The sync separator, noise-canceler and AGC circuits shown in Figure 5 perform their functions in conjunction with the video signal. The sync pulses are applied to the grid of the sync separator (V9). The sync pulses are separated and shaped by the resistors and capacitors in the output of V9.

This circuit also incorporates a noise canceler circuit that will prevent the sync separator from conducting during a noise pulse, which would produce an erroneous sync signal. V4B is normally cut-off, but is driven into conduction by a noise pulse. When V4B conducts, it produces a negative bias across R_{61} to keep V9 cut-off. This prevents a noise pulse from causing an erroneous sync signal to be coupled to the deflection circuits.

The AGC circuit is of the keyed type. This prevents an AGC voltage from being produced by a noise pulse. The keyed AGC circuit requires a positive horizontal output pulse before it can be *keyed* into operation. The actions of all three circuits should decrease the effects of a noise pulse on the receiver operation.

TEST

Lesson Number 88

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-088-1.

1. **The purpose of coils L_3 and L_7 in Diagram 7 is to**
   A. provide shunt and series peaking to increase the high frequency response of the video amplifier.
   B. provide shunt and series peaking to increase the gain of the video amplifier.
   C. provide shunt and series peaking to increase the low frequency response of the video amplifier.
   D. provide coupling for the input and output of the video amplifier.

2. **The tuned plate circuit of C_6 and L_4 in Diagram 7 is resonant at**
   A. 41.25 MHz.
   B. 45.75 MHz.
   C. 4.5 MHz.
   D. 25 MHz.

3. **A noise pulse applied to the video circuit of Diagram 7 will**
   A. have no effect on the video circuitry.
   B. drive tube V1 into saturation thereby producing a bright spot on the CRT screen.
   C. cut-off tube V1 thereby causing a bright spot to be produced on the CRT screen.
   D. cut-off tube V1 thereby causing a dark spot to be produced on the CRT screen.

4. **In the video circuitry of Diagram 7, the contrast control (R_7) controls the**
   A. amplitude of the sync pulses that are applied to the sync separator.
   B. amplitude of the video signal that is actually coupled to the cathode of the picture tube.
   C. amplitude of the voltage applied to the screen grid of the picture tube.
   D. amplitude of the noise pulse applied to the noise canceler circuit.

5. In Figure 6, the component that is used to integrate the vertical sync pulse is

A. R78.
B. R26.
C. C45.
D. R29.

6. During the reception of a noise pulse, the noise canceler tube (V4B) in Figure 9

A. cuts off, developing a *negative bias* across R61 thereby cutting off the sync separator (V9).
B. conducts, developing a *negative bias* voltage which is applied to the cathode of the video amplifier.
C. conducts, developing a *positive bias* across R61 thereby cutting off the sync separator (V9).
D. conducts, developing a *negative bias* across R61 thereby cutting-off the sync separator (V9).

7. The function of sync stabilization is accomplished in Figure 5 by

A. R6.
B. R8.
C. R47.
D. R49.

8. In Figure 5 the AGC tube V5 is keyed into conducting by a

A. keying pulse from the horizontal output system.
B. keying pulse from the vertical output system.
C. high level noise pulse.
D. positive polarity noise pulse.

9. The component in Figure 5 that stores the AGC voltage is capacitor

A. C71.
B. C41.
C. C65.
D. C1.

10. The negative AGC voltage that is developed in Figure 10 is applied to the

A. video amplifier.
B. RF and IF amplifiers.
C. sync separator.
D. horizontal output system.

Notes

Notes

Notes

Portions of this lesson from
TV Sync & Deflection Circuits
by Thomas M. Adams
Transistor TV Servicing Made Easy
by Jack Darr
TV Video and Sound Circuits
by Thomas M. Adams
Courtesy of Howard W. Sams Co., Inc.

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When you learn the proper service procedures, you are learning to expand your services to another vital area of repair.

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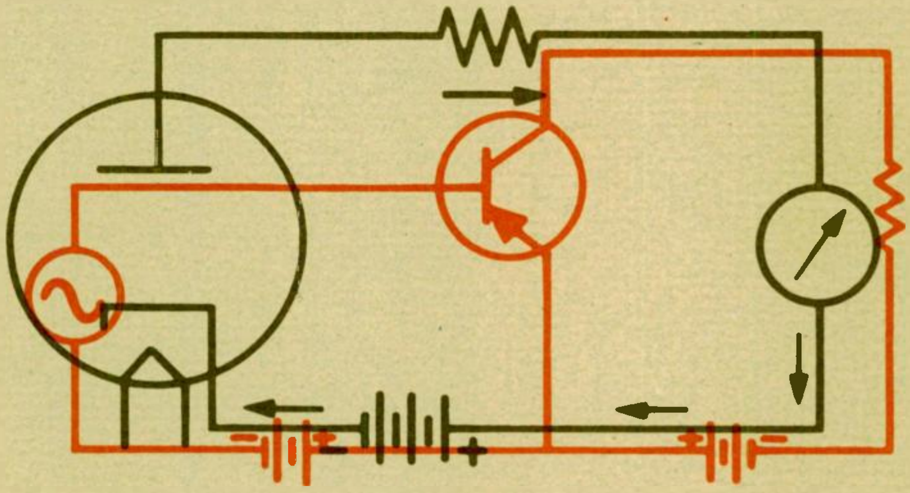
With this kind of efficient, speedy service, you will earn more money and a better reputation.

S. T. Christensen

LESSON NO. 89

CATHODE RAY TUBES AND SYNC CIRCUITS



RADIO and TELEVISION SERVICE and REPAIR

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Contents

CATHODE RAY TUBES AND SYNC CIRCUITS

INTRODUCTION

The televised picture is broken up into individual elements instead of the entire picture being transmitted simultaneously. A process called interlaced scanning is employed to break up the picture for transmission. In this system, 525 horizontal lines are scanned across the picture. All odd-numbered lines are scanned first, then the beam returns to the top of the picture and the even-numbered lines are scanned. Thus, two fields of 262½ lines each are interleaved to form the complete picture or frame (525 lines).

The horizontal lines are scanned at a rate of 15,750 per second. Each field of 262½ lines is repeated 60 times per second, and 30 complete pictures consisting of 60 interlaced fields or 525 horizontal lines are transmitted per second. Because the picture tube continues to glow for a period after the beam strikes it and because the persistence of vision of the human eye makes it sensitive only to changes which occur at a rate of 1/16th of a second or slower, we see the complete picture without flicker.

In addition to the picture or video signals, blanking signals to black out the beam during retrace when the beam returns from the right to the left of the screen and from the bottom to the top of the screen are also transmitted. Sync signals, which keep the receiver deflection circuits in step with the transmitter are situated on top of the blanking signal.

Negative modulation is employed for the picture signal; that is, an increase in the light intensity of the televised scene causes a decrease in the radiated power. Conversely, a decrease in the light intensity causes an increase in the radiated power. The primary reason for adopting negative transmission is that any noise pulse present with the signal will usually cause an increase in the signal strength. With negative transmission, noise will be produced as a black spot, whereas, with positive transmission it would appear as a bright flash of light. The black spots are far less annoying. Also, blanking and sync pulses must be transmitted as black; therefore, with negative transmission, they will appear at the maximum amplitude, assuring proper synchronization even at low signal strength.

Oscillators within the TV set drive the sweep amplifiers which, in turn, cause the electron beam to move across the cathode-ray tube in step with the televised picture elements. Synchronization pulses are broadcast on the televised signal to start and stop these oscillators at the proper times. In this lesson you will learn how the cathode-ray tube operates and how the beam is deflected. You will also be introduced to the circuitry that develops and amplifies the signal that controls the sweep of the beam.

CATHODE-RAY TUBE

The cathode-ray tube (CRT) is a type of electron tube in which electrons emitted from the cathode are shaped into a narrow beam and accelerated to a high velocity before striking a phosphor-coated viewing screen. The screen fluoresces or glows at the point where the electron beam strikes and thus provides a visual representation of voltage or current waveforms. (The CATHODE-RAY OSCILLOSCOPE is a test instrument which uses the cathode-ray tube). Scenes and waveforms can be positioned on the screen so they appear stationary in the same location, provided the motion of the electron beam is kept in step with generated synchronizing pulses.

In addition to TV sets the CRT is also used as the visual indicating device for radar, sonar, radio direction finders and Loran.

The beam of electrons has practically no weight or inertia but follows a straight line unless diverted by an electric or a magnetic field. Cathode-ray tubes are of two types according to the method of deflecting the electron beam—(1) electrostatic, and (2) electromagnetic. Almost all types of test-instrument oscilloscopes use the electrostatic type of CRT because of the need for high sweep frequencies in both the vertical and horizontal directions. Certain radar, sonar, and TV sets use electromagnetic type CRTs. Focusing or narrowing of the beam is achieved by either electrostatic or electromagnetic methods. Electrostatic deflection bends the beam by an electric field produced by a deflection voltage between parallel plates inside the CRT. Electromagnetic deflection bends the beam by means of a magnetic field produced by a deflection current in a coil around the neck of the tube.

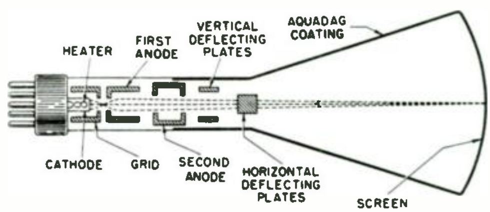


Figure 1 — Construction of cathode-ray tube using electrostatic deflection and focusing.

An electrostatic type of CRT is illustrated in Figure 1. The cathode, when heated by its enclosed filament, releases free electrons. A cylindrical grid surrounds the cathode and controls the beam intensity as electrons pass through the end opening of the grid. The control is achieved by varying the negative voltage on the grid and is called INTENSITY or BRIGHTNESS CONTROL. After leaving the grid, the electron stream passes through two or more cylindrical focusing anodes which narrows the beam. The first anode concentrates the free electrons and the second anode increases their speed. The entire assembly is called the *electron gun.* The electrons emerge from the electron gun at high speed.

The grid helps to narrow the beam but cannot focus it to a sharp point on the viewing screen. The two anodes aid in the focusing action, as shown in Figure 2.

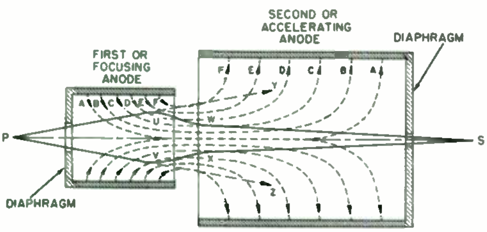


Figure 2 — Electrostatic focusing.

Both cylindrical anodes are positive with respect to the cathode but the second anode is positive with respect to the first anode. Thus, an electric field is established between the anodes as shown in Figure 2. The electrons which are emitted from the cathode are attracted by the first anode. Some of the electrons pass through the hole in the end of the first anode and into the field between the two anodes. The purpose of the diaphragm is to prevent all electrons except those making a small angle with the axis of the beam from passing through the hole in the diaphragm. This serves to keep the beam narrow. The electrons entering the curved electric field between the anodes are subjected to inward-directed forces thereby focusing the beam. As the beam passes parallel to the lines of force, the electrons are accelerated to a very high speed. Thus, the net result of the forces influencing the beam of electrons is a high speed, inward-directed beam converging at point S on the screen. The repelling force of like charges tends to scatter the electrons but they are accelerated to such a high speed that the scattering action is not effective in defocusing the beam. Nevertheless the mutual repulsion between electrons in relation to the speed of the electrons determines the sharpness with which a beam may be focused on the screen. The diaphragm on the accelerating anode is used to stop all wide angle electrons from hitting the screen.

The focus of the electrostatic type of cathode-ray tube is generally controlled by varying the voltage between the first anode and the cathode. This voltage varies the force exerted on the electrons and tends to narrow the beam. Thus, if the screen is observed when the first anode voltage is varied, the beam may be brought to a bright, sharp spot.

Focusing in early electromagnetic cathode-ray tubes was achieved by a coil or ring magnet encircling the outside neck of the tube. The entire assembly could be moved along the neck to initially focus the beam. The usual method of control with a focus coil after it was in the proper position, was to vary the current flowing through the coil with a variable resistor. The term "focus control" is derived from this function. Current TV sets nearly all use internal focus elements.

Without lateral deflection, the electron gun produces only one spot of light on the viewing screen. With deflection, the trace of the spot forms a line of light across the screen. The electrostatic-type of cathode-ray tube uses two pairs of deflection plates mounted at right angles to each other, as shown in Figure 3. The vertical deflection plates (YY') deflect the beam vertically and the horizontal deflection plates (XX') deflect it horizontally. Both pairs usually function simultaneously. The beam is attracted by the positive plate and repelled by the negative plate as the electrons pass between them. One plate of each pair may be grounded. To deflect the beam a positive or negative voltage is applied between the other plate and ground, thus establishing an electric field between the plates. The deflecting force varies with the deflection voltage across the plates and with the field intensity.

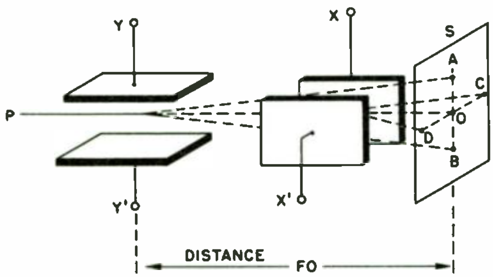


Figure 3 — Deflection plates for electrostatic cathode-ray tube.

If plate Y is positive with respect to Y' the beam is deflected upward, striking the screen at A. If plate Y is negative with respect to Y' the beam is deflected downward, striking the screen at B. If there is no deflection voltage across the plates, the beam will strike the screen at 0. The amount of deflection varies with the deflection voltage across the plates. Note the relationship between length of line and voltage. This characteristic makes the CRT practical as a scope to serve as a voltmeter because the length of line (so produced) is a measure of the applied voltage.

Another practical use of the scope is for determining polarity. If plate X is positive with respect to X' the beam will be deflected horizontally, and will strike the screen at C. If X is negative with respect to X' the beam will strike the screen at D. Both pairs of plates are mounted near the output end of the electron gun, with the vertical deflection plates farthest from the screen. Two centering controls (horizontal and vertical) enable the operator to move the spot as he desires, to any place on the screen. Each control customarily consists of a variable resistor that serves as a voltage divider to enable the centering action.

The deflection angle of the electron beam is the total angle through which the beam may be moved or diverted. A cathode-ray tube with a 50° deflection angle can deflect the beam at any angle that equals (or is less than) 25° from the center line.

The length of time that the screen glows, or fluoresces, at the point where the electron beam strikes depends on the material of the phosphor coating on the screen, and is known as *screen persistence.* Some cathode-ray tubes have a long persistence screen and others have a short one, depending on their use.

All fluorescent materials have some phosphorescence, or afterglow, but the duration of the afterglow varies with the material, as well as with the amount of energy in the beam causing the emission of light. For oscilloscopes that are to be used for observing nonrepeating phenomena or periodic phenomena that occur at a low repetition ratio, a screen material on which the image will linger is desirable. Where the image changes rapidly, prolonged afterglow is a disadvantage, because it may cause confusion on the screen.

The eye retains an image for about one-sixteenth of a second. Thus in a motion picture, the illusion of motion is created by a series of still pictures flashed on the screen so rapidly that the eye cannot follow them as separate pictures. On the TV screen, the picture is reproduced as a series of lines with the varying shades being produced as a result of the intensity of the electron beam as it traces a line of the scene.

ELECTROMAGNETIC DEFLECTION

When a very large screen is used and correspondingly large deflections are required, it is not practical to use electrostatic deflection. The extent of deflection desired would require greater spacing between the deflection plates and, consequently, unusually high signal voltages would be necessary. It is simpler to obtain large deflections in a relatively short tube by means of magnetic fields. In addition, with magnetic deflection, it is easier to obtain the special types of sweep required by television picture tubes.

It should be noted that both the electrostatic and electromagnetic deflection systems have their advantages and disadvantages. The electrostatic deflection systems are used when high sweep frequencies are needed (as in oscilloscopes). The electromagnetic systems have the disadvantages of frequency limitations and high weight and large size.

The common method of obtaining electromagnetic deflection is to use two pairs of electromagnets around the neck of the CRT. This simplifies the construction of the tube since no internal deflection plates are required. Instead of applying a signal voltage across deflection plates, the final signal amplifiers send a strong signal current through the electromagnets. The amount of current varies to follow the scene that is being scanned, and thus the electron beam deflection is always in step with the portion of the scene being televised.

Figure 4 illustrates a simplified typical deflection amplifier for producing a horizontal time base using magnetic deflection. The input signal is a trapezoidal waveform of voltage as shown in the illustration.

The input is applied through coupling capacitor C_1 to the grid of V1, which is operated as a Class A stage with fixed bias. Sufficient negative bias is applied to prevent the grid from going positive with maximum signal input. V1 is a pentode or a beam power type, in order to obtain the power amplification required to furnish current to the deflection coil (This coil may require from 50 to 100 milliamperes (or more) of current for maximum beam deflection.)

The output of V1 is applied to the deflection coil, which in the illustration is represented by an inductance, L_1, with a resistance, R_2, in series with it. R_2 is shown as a dotted resistance because it is actually a part of L_1. The output voltage waveform at the plate of V1 is trapezoidal; when this waveform is applied to the series R-L circuit (deflection coil), the voltage waveform appearing across the resistance is resolved to a sawtooth shape, while that appearing across the inductance is resolved to a square-wave shape.

The square wave of voltage across the inductance causes a sawtooth wave of current through it, which is the required waveform for producing a horizontal time base deflection on the screen of the cathode-ray tube. The development of the sawtooth current waveform from the trapezoidal voltage input waveform is shown in Figure 5.

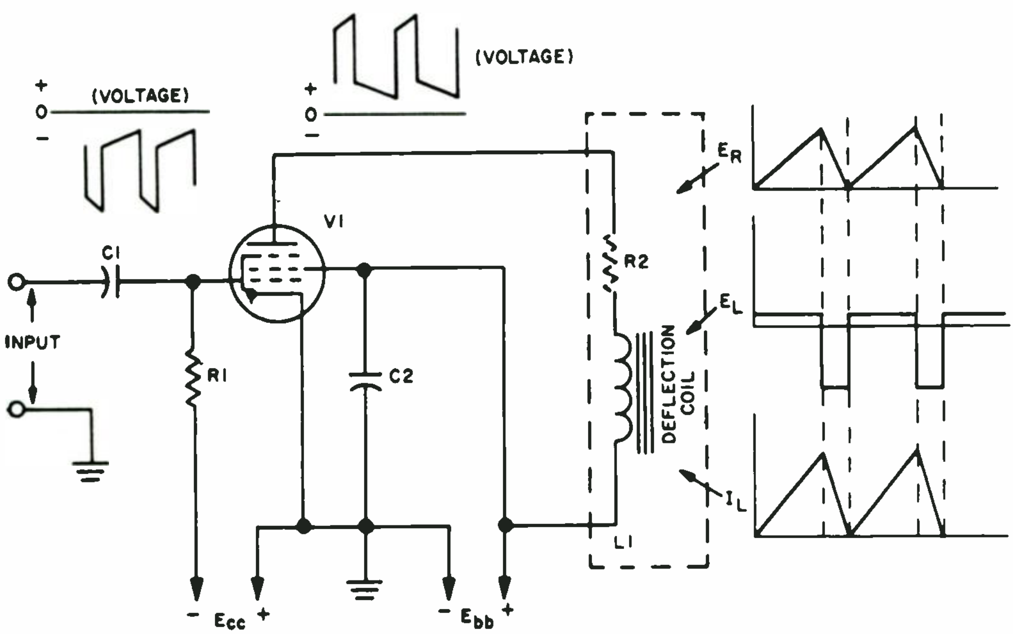


Figure 4 — Electromagnetic deflection amplifier.

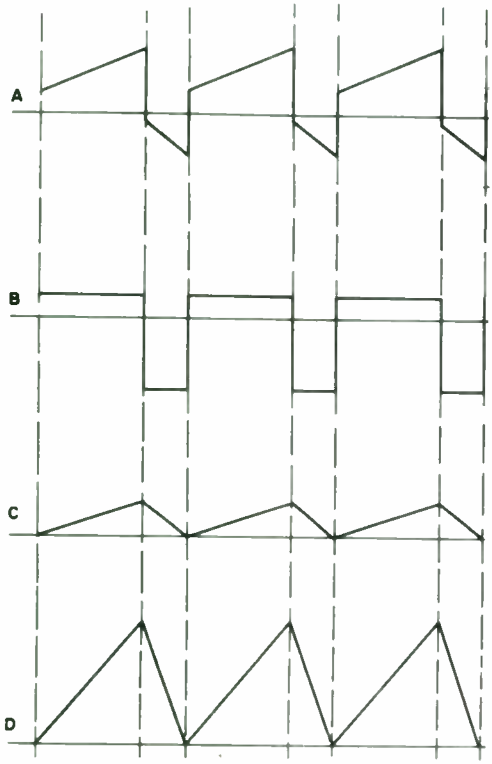


Figure 5 — Development of sawtooth current waveform.

The trapezoidal voltage input waveform to the grid of amplifier V1 is shown in (A); the differentiated voltage which appears across the inductance is shown at (B); the integrated voltage which appears across the resistance (of the coil) is shown at (C); the current through the deflection coil, which is the composite result of waveforms (B) plus (C) is shown at (D).

When the conduction of the tube is interrupted at the end of the positive square wave, V1 is cut off, and the current decays rapidly to zero. This rapid decay is due to a change in the time constant of the circuit between the rise and fall of the current.

During the rise of current, the circuit time constant (L/R) is long. The resistance is composed of cathode resistor R_2 and the low value of plate resistance of V1. During the decay of current, the time constant is made short, as a result of the increase in the value of plate resistance when V1 stops conducting. With the shortened time constant, the current decays rapidly.

The sudden decay in current flowing in the deflection coils when the tube stops conducting causes a counter EMF in the coil, which opposes the current decay. In addition, the circuit may be shock excited into oscillation by the sudden change in value of current. Although the oscillations gradually die out, they may continue into the following sweep, especially if the circuit Q is high. This condition may result in a nonlinear start of the buildup of current in the coil, and therefore a nonlinear sweep, as shown in Figure 6B.

These oscillations can be eliminated, or damped out, by lowering the Q of the circuit by means of a resistor shunted across the coil. This wastes some of the deflection current, however. A more satisfactory method incorporates the use of a damping diode shunted across the deflection coil, as shown in Figure 6 (C), where diode V2 acts to damp out the oscillation.

The current through V1 is increasing during the rise of the sawtooth current wave shown in (B), to provide the sweep deflection. The voltage at the plate of V1 is lower than the plate supply voltage by

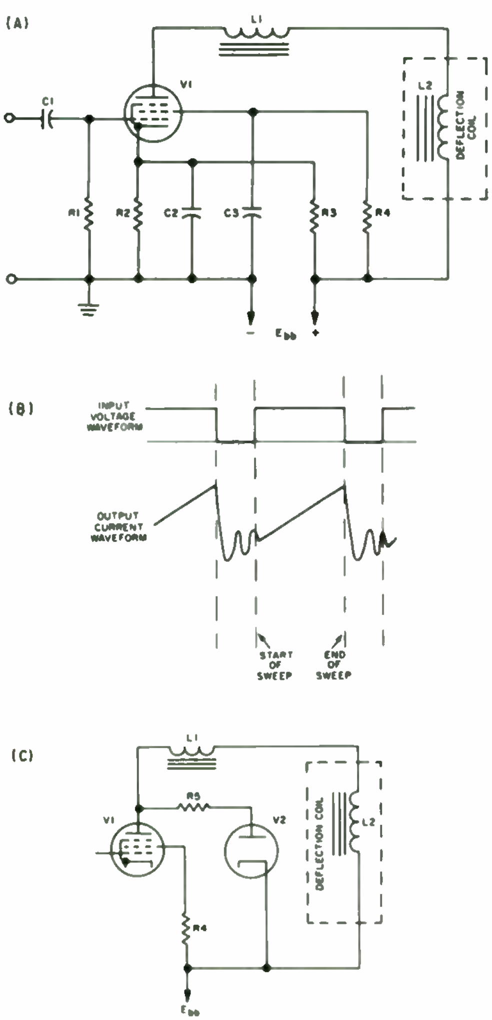


Figure 6 — Deflection amplifier, square wave input.

the amount of voltage drop in the deflection coil and inductor. The cathode of damping diode V2 is therefore more positive than its plate, and the diode will not conduct.

When the current through V1 falls to zero at the end of the sawtooth current wave, the voltage at the plate tends to rise above the plate supply voltage due to the fact that the CEMF (generated by the inductance) adds to the plate supply voltage. When this condition is reached, damping diode V2 conducts, and any oscillations are dissipated in resistor R_5.

Balanced output (push-pull) circuits, when used, usually operate by means of a phase inverter circuit fed from a single ended source. In some radar deflection circuitry, the two outputs obtained by means of a phase inverter are separately amplified by individual single ended deflection amplifiers, and then applied to the two separate windings of a split winding deflection yoke. Push-pull tube circuits are rarely used in TV sets, for horizontal and vertical sweep.

TV PICTURE TUBE

The basic operation of the picture tube is the same as for any other tube. That is, a filament (heater) heats the cathode which emits electrons—the same as any tube. These electrons are attracted by the accelerating anodes which have B+ voltage on them and by the second anode which has the high voltage connected to it. However, instead of striking these elements, the electrons travel to the face of the tube and strike the screen. The screen is coated with a fluorescent material which glows when struck by the electrons. This is the lighted portion you see on the screen.

The magnetic field from the focusing devices concentrates all the electrons in the beam so they strike the screen at one point. A magnetic

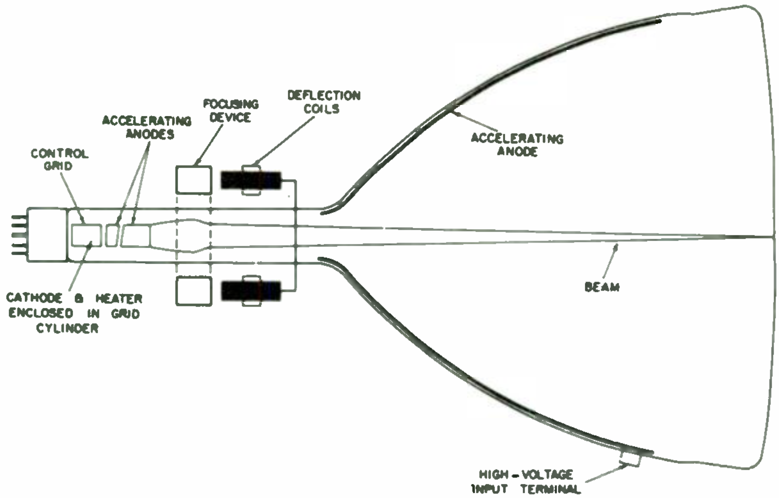


Figure 7 — A magnetically-controlled cathode-ray tube.

focusing device, connected around the neck of the tube is shown in Figure 7. In many receivers, however, this function is accomplished by another element within the picture tube.

The horizontal and vertical deflection currents are applied to the deflection coils shown on the neck of the tube. These currents, flowing through the coils, cause a magnetic field to be produced which acts upon the electron beam in the tube. These vertical deflection currents cause the beam to be deflected upward or downward from the center of the screen. This deflection is at the 60-hertz rate. At the same time, the horizontal deflection currents cause the beam to be deflected to the left and right at the 15,750-hertz rate.

Thus, the beam is caused to scan across the face of the tube from left to right and from top to bottom, in step with the beam at the transmitter.

The video signal is applied to the grid or cathode. The element which has no signal applied to it is connected to a constant voltage source. As the video signal varies, fewer or more electrons are allowed to pass. When more electrons pass, the beam produces a brighter spot on the particular spot being scanned at that instant on the screen. When fewer electrons pass, less electrons strike the screen; hence, a darker spot will be produced at that instant.

The vertical and horizontal oscillators within the set *generate* a deflection signal—only the timing of these signals is controlled by the sync pulses. Thus, when no video signal is being applied to the grid or cathode of the picture tube, the deflection currents will still flow in the deflection coils and the beam will still be deflected back and forth and up and down on the screen. The only difference is that the electrons striking the screen will not form alternate lighter and darker areas.

Instead, a constant brightness pattern will be produced. This series of horizontal lines across the tube screen is called the *raster* and is present whether a picture is being produced or not.

POWER SUPPLIES

Two separate power supplies, plus an additional voltage source derived from the damper circuit are used in television receivers.

Low-Voltage Supply

The low-voltage power supply provides the voltage necessary for operation of practically every tube or transistor in the TV receiver. This circuit is much like the power supply of a radio or amplifier. It takes the AC from the line, rectifies it, and supplies the DC voltages necessary to operate the TV receiver. Because of added complexity, the TV power supply must be capable of supplying a much higher current than a radio. In addition, the voltage is usually stepped up to a higher value in a TV receiver. Typical B+ voltages in tube type TV receivers range from 125 to 300 volts.

Because all circuits do not require the same operating voltages, a voltage divider is usually connected at the output of the power supply. The different circuits are then connected to the points which supply the proper operating voltages.

In addition to the B+ voltages, the low-voltage supply (in tube type receivers) also furnishes the filament voltage necessary to heat the tubes to the proper operating point and, in some receivers, furnishes negative bias voltages.

High-Voltage Supply

In addition to the B+ voltages, a much higher voltage (15,000 to 23,000 volts) is needed for proper operation of the picture tube. This voltage is obtained from the horizontal deflection circuit. The pulse from the horizontal output stage is stepped up by the horizontal output and high-voltage transformer to a very high value. Then this pulse is rectified by the high-voltage rectifier to provide the high DC voltage. Since very little current is necessary, this high voltage can be obtained from the horizontal output stage without placing too much strain on the stage. Nevertheless, the horizontal output stage is the highest powered stage in the receiver.

Boost Voltage

Another voltage, called the boost voltage, is obtained from the damper stage. The normal damper action of suppressing the pulses in the horizontal output stage results in a voltage higher than the normal B+ being developed in the circuit. This voltage is filtered and put to work in the receiver. In all modern TV receivers, the boost voltage is employed as the B+ for the horizontal output tube. In addition, it may also be applied to the vertical output, horizontal oscillator, picture tube, and other stages of the receiver.

SYNC SEPARATION

In order for a televised scene to be reproduced in proper sequence, something must instruct the sweep circuits when to begin and end a sequence. To do so the station
4 transmits synchronization signals (commonly called sync pulses). These pulses lock in the horizontal and vertical oscillator so that they know when to either begin or end a line, a field or a frame.

If these pulses are to be made available to the sweep oscillators they must first be removed from the video waveform. It is the job of the sync clipper to recover these pulses.

Sync clipping is also associated with sync separation and may be accomplished with diodes, triodes,
5 or transistors. Pentodes may also be used along with the special tubes used in a gated sync separation circuit. All of these systems have been used in various recent sets.

Diode Sync-Separation

Figure 8 shows three diode sync-separation circuits. The input signal of each circuit is the composite video signal, and the output is a pulse signal that represents the sync pulses.

In Figure 8A the video signal is coupled to the plate (anode) of the diode. The output signal is developed across a resistor in the cathode circuit. In order that the diode can be kept at cutoff until sync-pulse time, the plate (anode) is connected

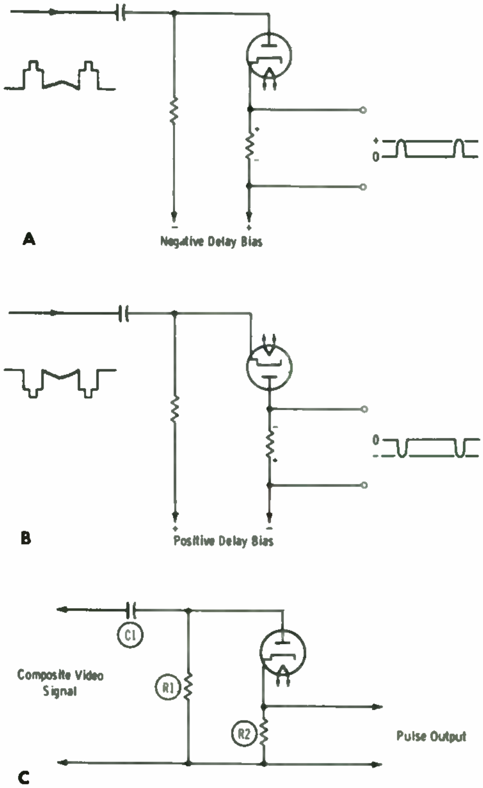


Figure 8 — Diode sync-separation circuits.
A. Positive sync pulses with delay bias on diode
B. Negative sync pulses
C. Positive sync pulses with self-biased diode

to a negative delay-bias source. When the highly positive sync pulses come along, the delay bias is overridden and the diode is allowed to conduct. During this time, a voltage is developed across the cathode resistor in the polarity shown. The output taken across the cathode resistor is in the form of positive pulses.

Figure 8B is an inverted version of the same circuit. In this circuit the video signal is coupled to the cathode and the output signal is developed at the plate. Cutoff is accomplished by a positive delay bias applied to the cathode. The input signal is of opposite polarity to that applied to the diode in Figure 8A. The sync pulses are highly negative. When the sync pulse comes along, the positive delay bias is overridden and the diode conducts.

The circuit in Figure 8C is similar in operation to the one in Figure 8A, except that the bias required for delay of the diode action to the correct point is obtained from the charge placed upon C_1 during diode conduction. The time-constant used in bias circuit R_1-C_1 is long compared to the horizontal and vertical scanning times. Thus, the diode can be biased automatically by the video signal to the proper point, so that the sync pulses are clipped from the signal.

Triode Sync Separation

In many present day receivers either triode-tubes or transistors are used for sync separation. With these devices amplification is attained along with separation.

The circuit of Figure 9A uses grid rectification of the video signal to bias the control grid, so that plate-current cutoff occurs at the desired pedestal level. This action is similar to the one just discussed for the diode circuit in Figure 8C. Two additional actions are found in this circuit:

1. The sync pulses are large enough to drive the grid positive, and the lowered grid resistance limits the input signal by loading.

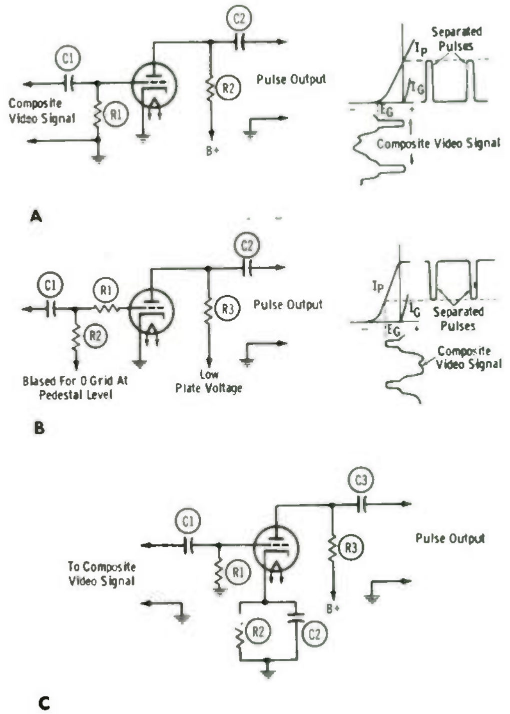


Figure 9 — Triode sync-separation circuits
A. Grid cutoff by signal rectification
B. Separation by positive grid and plate-current saturation.
C. Cathode-bias circuit.

2. Some amplification of the sync pulse occurs because of the amplifying properties of the triode.

In Figure 9B the operating conditions are quite different from those of the circuit in Figure 9A. The tube is biased from an external voltage source, through resistors R_1 and R_2, until it just starts to draw grid current at the black or pedestal level. The input signal is inverted in polarity from that of the preceding example. The sync-pulse portion of the video-input signal is the most negative. The plate voltage is made so low that the plate current is saturated at a near zero grid voltage. The portion of the video-input signal which is more positive than the desired clipping level lies in the saturation region and produces no further rise in plate current. For this reason, limiting or leveling occurs at this saturation point. The negative grid voltage from the sync-pulse portion of the input signal causes a drop in plate current, as shown in the waveform drawings of Figure 9B. So that the circuit action can be better illustrated, the amplitude of the sync input pulses has been limited in the drawing. If their amplitude were extended to beyond the grid cutoff point, limiting would also occur because of plate-current cutoff, and the output pulses would still be uniform but larger in size. Series resistor R_1 in the grid circuit limits the amount of grid current that can conduct over any one frame. This limiting prevents a long-time blocking condition from developing because of an excessive charge on capacitor C_1.

The circuit in Figure 9C employs cathode bias to establish the correct operating point for plate-circuit separation of the sync pulses. The values chosen for resistor R_2 and capacitor C_2 are determined by the following considerations:

1. The resistor must have such a value that the plate-current pulses above the clipping level will produce a voltage drop equal to the required operating grid bias. For high-mu tubes, this resistor will be around 10,000 ohms.
2. The value of capacitor C_2 must be high enough to maintain constant bias voltage throughout at least one vertical blanking period and yet low enough that it can change its charge as the average background lighting of the scene changes.

Pentode Sync-Separation Circuits

Figure 10 illustrates the use of a sharp cutoff pentode as a combination sync separator and limiting amplifier. Plate-current saturation is assured by operating both the screen and plate at extremely low voltages. This low voltage is accomplished with dividing networks. The screen network consists of resistors R_3 and R_4. With a B+ voltage of 340 volts, the screen is held at the extremely low voltage of 3.2 volts. The plate-supply network

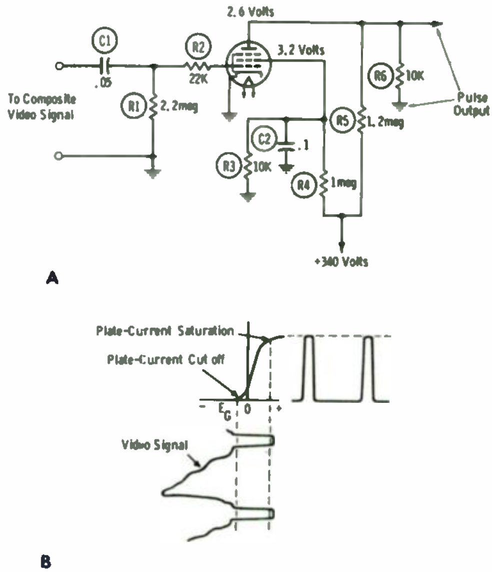


Figure 10 — Pentode sync-separating circuit that incorporates leveling or limiting.
A. Schematic B. Input and output waveforms.

of resistors R_5 and R_6 maintains the plate at 2.6 volts. Plate-current saturation occurs just after the grid voltage goes positive, as shown in the diagram in Figure 10B. The grid circuit network, resistors R_2 and R_1 with capacitor C_1, establishes the operating point of the circuit by grid-circuit rectification of the video signal. This rectification assures plate-current cutoff just above the pedestal or black region. You can see from the drawings that the synchronizing pulses are clipped at both ends, and limiting occurs. Because a pentode under these conditions exhibits very low voltage gain, a circuit of this type must either be operated at a high signal level or be followed with sync amplifiers.

Series grid resistor R_2 has a function similar to that of resistor R_1 in the positive grid triode of Figure 9B. However, R_2 in Figure 10A has an additional function. In the absence of resistor R_2, sharp noise pulses (such as those due to motor-car ignition, whose amplitude might be higher than that of the sync pulses) would cause an excessive bias voltage on C_1 and result in blocking. Loss of synchronization would occur while the tube was blocked.

Cathode-Follower Used with Sync-Separation Circuits

Figure 11 shows a circuit which employs a cathode-follower ahead of a sync separator. The cathode-follower tube (V1) operates on the linear portion of the curve. This is due to the balance of the bias across resistor R_3 and the voltage from the plate supply produced by network R_1 and R_2. A net negative voltage of −2 volts appears between grid and cathode.

Cathode-follower tube V1 functions both as video output and sync takeoff. The video output for the picture-tube cathode is taken directly from cathode load resistor R_3 through capacitor C_5. This same load resistor feeds a triode (sync separator and DC restorer) tube V2 through the network of C_2, R_4, R_5, and C_3. The combination of R_5 and C_3 filters the high-frequency components of the video signal.

Sync pulses are taken from the plate of triode V2, the operation of which is similar to the circuit in Figure 9C. The DC bias voltage across network R_6-C_4 is used to restore the average component of the picture signal responsible for the average light of the televised scene. This DC component has been lost in passing through video-amplifier stages.

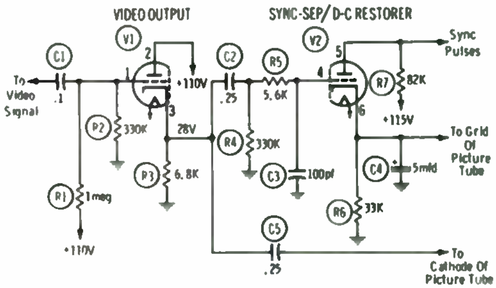


Figure 11 — Cathode-follower used with sync-separator.

Gated Sync-Separation Circuits

The sync separators which have been described have one feature in common—the output signal is low in amplitude. Additional stages of amplification (and sometimes clipping) are needed to produce a sync signal of sufficient amplitude to trigger the sweep oscillators. A simpler type of separator circuit, called the gated sync separator, has been developed. This circuit eliminates the extra amplifier stages because its tube is usually a pentagrid, which supplies many times more gain than a triode.

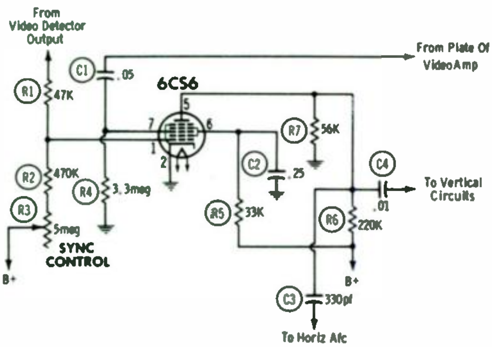


Figure 12 — Schematic of a gated-sync circuit.

The schematic of one type of gated circuit is presented in Figure 12. This circuit is primarily designed to stabilize sync operation in weak and noisy signal areas, and operates as follows:

The composite video signal is sampled from the plate circuit of the video amplifier and fed to the grid (pin 7) of the 6CS6 tube through capacitor C_1. The positive-going signal on pin 7 is of high amplitude and causes the grid to draw current; therefore, capacitor C_1 charges to approximately the blanking level of the composite video signal. The bias developed on pin 7 permits the tube to conduct only on signal peaks which are greater in amplitude than the blanking level. This condition allows only the horizontal- and vertical-sync pulses to appear in the plate circuit.

A noise-cancellation action is provided along with this sync-separation action. A fixed bias is developed on the grid (pin 1) of the 6CS6 tube by resistors R_1, R_2, and sync control R_3. The bias is set by adjusting the sync control, so that the tips of the sync pulses will fall near the cutoff point of the tube.

When part of the composite video signal containing negative-going sync pulses from the video-detector output is impressed on the grid (pin 1) through resistor R_1, any noise pulse of sufficient amplitude will cancel the effect of a simultaneous positive pulse on pin 7 by cutting off the tube and will not be present in the plate circuit of the stage. Noise pulses on pin 1 during the sync-pulse interval will also cut off the tube; but since the noise pulses usually have a shorter time duration than the sync pulses, the stability of the vertical and horizontal oscillators will not be affected.

Another circuit is built around one tube which does triple duty as a sync separator, AGC amplifier, and noise inverter. The most unusual feature of this circuit is that the inverter removes noise pulses from the AGC signal as well as from the sync signal. The AGC amplifier circuit will be described in a later chapter.

A unique tube, the 6BU8, has been used in this circuit (Fig. 13). The tube might be called a "Siamese-twin" pentode. The cathode, the first control grid, and the screen grid are common to both sections of the tube. Outside the screen grid, there is a second control grid, which is split into two distinct sections; and there are two separate plates in line with these two control grids. The currents in the two plate circuits can be controlled simultaneously by the first control grid or separately by the pair of second control grids.

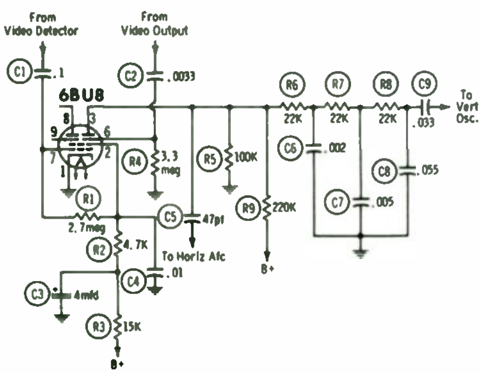


Figure 13 — The 6BU8 gated-separator circuit.

The cathode is grounded, so that variations in the plate current of one section of the tube will not be coupled to the other section. The sync-separator output is taken from the plate connected to pin 3, and the AGC output is obtained from the other plate. The first control grid (pin 7) is employed as a noise inverter.

A composite video signal containing positive-going sync pulses is coupled from the video-amplifier plate through C_2 to one of the second control grids (pin 6) of the 6BU8 tube. Grid-leak bias is developed by C_2 and R_4. Plate current in the right-hand section of the 6BU8 is cut off, unless a sync pulse is on the grid. The waveform of plate voltage measured at pin 3 of the 6BU8 is typical of the output of a sync separator. Negative-going sync pulses are developed at this plate. They are applied to the horizontal-AFC tube and vertical oscillator without further amplfication. The vertical oscillator used with this circuit is a multivibrator and requires a negative sync pulse for proper triggering.

The first control grid of the 6BU8 tube receives a composite video signal from the video-detector output. This signal has the same waveform as the sync input signal on pin 6, but is opposite in polarity. One might assume that the two signals would cancel each other. Actually, the signal on the first grid has such a small amplitude that it has only a slight degenerative effect on the output of the tube. The action of the first grid becomes important only when noise is in the input signals.

The first control grid is biased so that the tips of the negative-going sync pulses will almost drive the grid into cutoff. Noise pulses in the composite video signal sometimes have a greater amplitude than the sync pulses. When one of these bursts of noise reaches the first control grid, the grid voltage is driven below cutoff, and all conduction within the 6BU8 tube ceases momentarily. At the same instant, a positive noise pulse appears at the second control grid, but the temporary interruption of plate current prevents a corresponding pulse from developing at the plate.

If the noise inverter were not in the circuit, strong noise pulses would get into the output signal of the sync separator. They would tend to cause random triggering of the sweep oscillators, and unstable synchronization would result.

SYNC-PULSE AMPLIFICATION, CLIPPING, AND SHAPING

Many television receivers employ more than one circuit to separate the sync pulses from the video signal. Additional stages are introduced to (1) invert the phase of the pulses (when not of the proper polarity to control the scanning oscillator), (2) clip the pulse width (for more reliable scanning control), (3) amplify the pulse (if it is not strong enough for control), and (4) level the pulse (to take care of variations in the video signal and minimize the effect of interfering noise pulses).

There has been little standardization in naming those stages, and we find the following descriptive titles in the service literature of various manufacturers: "sync clipper," "pulse stripper," "sync amplifier," "sync inverter," "sync leveler," "sync limiter," "pulse limiter," and "clamper." The various actions are self-explanatory; but it should be noted that, even though a stage is labeled as a sync amplifier, it is usually so biased that either cutoff or saturation contributes leveling or clipping as well as the desired voltage amplification.

At present, most tube-type receivers employ a single triode stage to perform sync-separating functions. A typical circuit is shown in Figure 14. In some instances, a noise canceller is incorporated ahead of the sync separator to reduce sharp noise spikes which, if allowed to remain, could cause false triggering of the sweep oscillators.

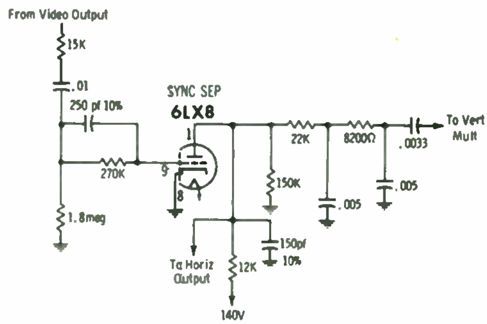


Figure 14 — Typical sync-separator circuit employed in modern tube-type receivers.

In solid-state television receivers, the transistor sync-separator is usually followed by either a sync amplifier or a sync phase-inverter stage. In some cases the phase inverter also serves as an amplifier or vice versa depending on which circuit configuration is employed. Figure 15 shows a typical arrangement of sync separator and phase inverter. Here, the sync section is designed to supply a push-pull output to a balanced-AFC circuit. In order to do this the last stage in the sync section is arranged as a phase inverter. Positive-going sync pulses are developed at the emitter and negative-going pulses are developed at the collector. In other words, transistor Q2 operates as a phase splitter for the horizontal

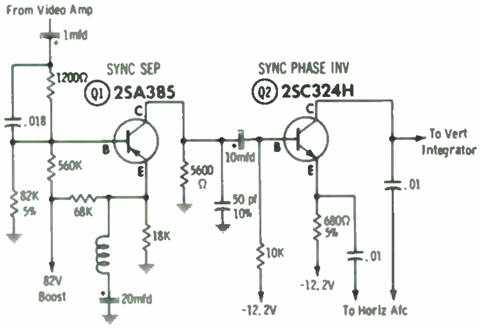


Figure 15 — Typical solid-state sync configuration using separator and phase inverter.

sync pulses. The circuit itself is a combination common-emitter and emitter-follower.

Another arrangement involves the use of sync amplifiers (or combination amplifiers and inverters) ahead of the sync separator rather than following. A circuit such as this is shown in Figure 16.

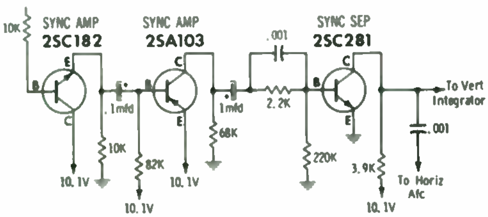


Figure 16 — Sync system providing amplification prior to sync-separation stage.

SORTING OF THE INDIVIDUAL HORIZONTAL AND VERTICAL PULSES

In the foregoing description of the various methods of separating the synchronizing pulses from the composite video signal, only the narrow horizontal pulses were mentioned. The longer vertical pulses are clipped from the signal in the same separation process.

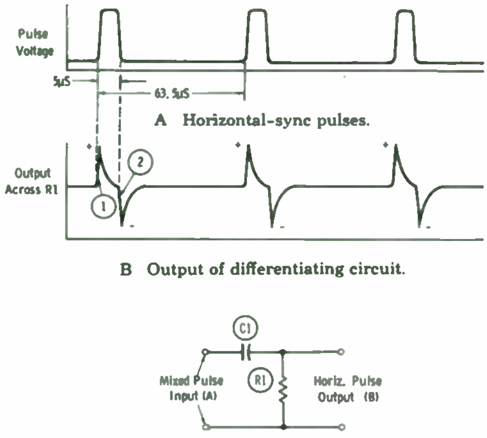
After the sync pulses have been removed from the video signal, the vertical pulses must be sorted from the horizontal pulses; and each one must be fed to its respective deflection-scanning system. Since the horizontal and vertical pulses are equal in amplitude, the methods of separation for clipping them from the video signal cannot be used to distinguish between them. They do, however, differ in time duration. It is on this basis that sorting is accomplished.

Several times, we have mentioned differentiating networks for removing horizontal pulses and integrating networks for the vertical pulse acceptance. We will now consider the action of such systems in greater detail.

Horizontal-Pulse Separation

The horizontal pulses of the transmitted signal are approximately five microseconds in duration. These pulses are impressed on a circuit of the type shown in Figure 17, which is known as an RC differentiating circuit.

Differentiation means the breaking down of a quantity into a number of small parts. The pulses in Figure 17A are made into smaller parts, as shown in Figure 17B, by the action of the circuit in Figure 17C. The circuit consists of a capacitive and resistive combination in which the capacitor is in series with the separated pulse input and the resistor is shunted across the output. The time constant of this circuit is made short compared with the duration of a horizontal-sync



A Horizontal-sync pulses.

B Output of differentiating circuit.

C RC circuit for horizontal separation.

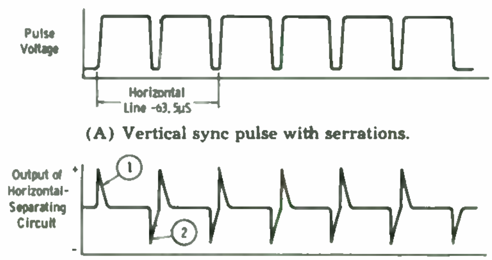
Figure 17 — Horizontal-pulse separation, or differentiation.

pulse. The sync pulse is held between 4 and 5 microseconds, and the time constant of the horizontal differentiating circuit is made between 1 and 2 microseconds. As described and illustrated previously (an RC circuit in which the time constant is short compared with the duration of the applied squarewave pulse), the capacitor is completely discharged. A sharp pip of voltage occurs across the resistor at both the leading and trailing edges of the applied square-wave pulse.

The amplitude of the pip is determined not only by the amplitude of the square wave but by the steepness of the edge of the square wave. For this reason, the FCC limits the allowable slope of the leading and trailing edges. These slopes must not occupy more than 0.4 percent of the horizontal-line scanning interval of 63.5 microseconds.

The voltage pip due to the leading edge of the horizontal-synchronizing square wave is shown as a positive pip at (1) in Figure 17B. The pip due to the trailing edge of the horizontal pulse is shown as a negative voltage at (2). The leading-edge pulses are the ones which control the horizontal-scanning oscillator. The negative pulses are rejected by cutoff or saturation of one or more stages of the sync system.

When the longer duration, vertical synchronizing pulses arrive, the differentiating circuit acts as shown in Figure 18. Here again, a positive pip occurs at the leading edge of each vertical pulse, and a negative pip occurs at the trailing edge. The leading-edge pulses continue to control the horizontal oscillator during vertical retrace. In this instance, however, two pulses occur during a horizontal line-scanning interval. Only the first of these pulses is used to control the horizontal oscillator. The second pulse cannot cause lock-in, since it occurs while the oscillator is insensitive to tripping.

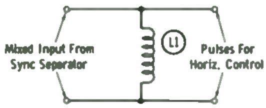


(A) Vertical sync pulse with serrations.

(B) Output of horizontal-differentiating circuit.

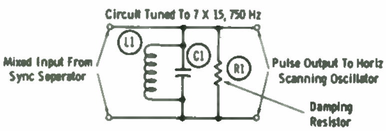
Figure 18 — Action of horizontal-differentiating circuit on vertical-sync signal.

The horizontal pulses can be separated by other means than the RC differentiating circuit just described. Figure 19 shows two types



A Differentiation by self-inductance.

B Differentiation by mutual inductance (transformer action).



C Horizontal separation by tuned-circuit action (one-half cycle of ringing employed).

Figure 19 — Other methods of horizontal sync-pulse separation.

of differentiating circuits which employ inductance and a third type which uses the properties of a resonant circuit. The inductance of the circuit in Figure 19A is connected in series with the plate circuit of a tube which has been biased to clip the sync pulses from the video signal. The waveform of the sync-pulse plate current consists of steep slopes which correspond to very rapid changes of current. The voltage across the inductance is proportional to the rate of change of the current through it. Thus, at the leading and trailing edges of each plate-current pulse, a high voltage is produced across the inductor. This voltage is the same form shown for the RC type of differentiator. If the pulses are of proper polarity and sufficient amplitude, they can be applied directly to the scanning generator by a capacitor connected to the plate end of the inductor. If the polarity is incorrect, phase reversal can be accomplished by an amplifier stage or by a transformer as shown in Figure 19B. When a transformer is used, secondary L_2 may be connected so that the output voltage pulses have opposite polarity to those across primary L_1. The secondary can be connected directly to the grid circuit of the horizontal-scanning generator.

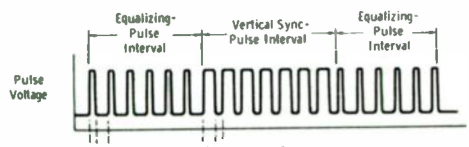
The circuit shown in Figure 19C operates quite differently from the two just described. The resonant circuit, consisting of L_1 and C_1, is tuned to approximately seven times the horizontal-line frequency of 15,750 Hz, or 110 kHz. The separated sync pulses are impressed across the circuit and shock-excite it into oscillation at its resonant frequency. The oscillation is quickly damped out by parallel resistor R_1. Only the first half-cycle of voltage across the circuit is used to control the horizontal-scanning oscillator. This corresponds to a pulse duration of approximately 5 microseconds. Several advantages can be cited for this method of horizontal-sync discrimination:

1. An extremely simple pulse-separation and oscillator-control system can be used. The circuit can be connected directly in the plate return of the sync-separator tube and coupled directly to the scanning oscillator because pulse shaping is performed by the resonant action.

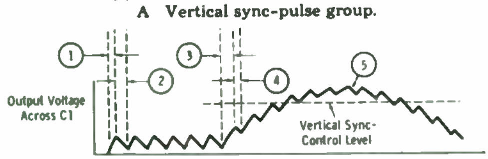
2. This method is relatively immune to excitation by static or ignition noise because such pulses would have to be of the proper time duration (5 microseconds) and repetition rate (15,750 Hz) to produce ringing. The probability of such coincidence is slight.

Vertical-Pulse Separation

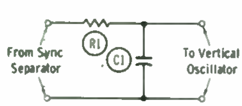
In the description of vertical-scanning systems, we mentioned integrating networks for segregating the long-time vertical field pulses from the sharp horizontal line pulses. We will now consider the means of sorting these vertical field-scanning pulses from the composite scanning pulses and of using them to control the vertical-oscillator timing.



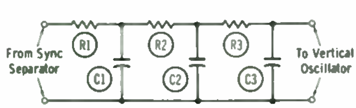
A Vertical sync-pulse group.



B Output of integrating circuit.



C Integrating circuit.



D Cascade integrating circuit.

Figure 20 — Vertical-pulse separation by integration.

The integrating action which sorts the vertical pulses from the complex video signal is exactly opposite from the differentiation process for separating the horizontal pulses. Integration means the addition of a number of small elements to form a whole. Figure 20C shows an integrating circuit. It is the opposite of the differentiation circuit in Figure 17. The resistor is in series with the input, and the capacitor is connected across the output. The time constant of the combination is much longer than that employed for sorting the horizontal pulses. This time constant is made approximately equal to the duration of a horizontal pulse. Consequently, the charge accumulated by the capacitor because of a horizontal pulse is small and will decay rapidly. This action is shown in Figure 20B. During the time shown at (1), the equalizing pulses produce only a small voltage across the capacitor. This voltage decays to near zero in the interval between pulses, as shown at (2). The much longer vertical-synchronizing pulses produce a greater charge in the capacitor during period (3). This charge does not completely decay during the short serration interval (4). Consequently, each vertical pulse adds an element of charge to the capacitor, and the voltage continues to build up during the interval of vertical pulses. The dotted line in Figure 20B indicates the level at which this voltage becomes large enough to trigger the vertical-scanning oscillator. This point usually occurs after two or three vertical pulses have charged the capacitor.

The vertical-integrating network is seldom the two-element type shown in Figure 20C, but is usually a cascade network, as shown in Figure 20D. The resultant time constant of this network is smaller than that of any of the individual branches (R_1-C_1, R_2-C_2, or R_3-C_3).

The overall time constant calculation is the same as for resistors in parallel. For the three-branch circuit in Figure 20D with T_1 for the time constant $R_1 \times C_1$, T_2 for $R_2 \times C_2$, and T_3 for $R_3 \times C_3$, the effective circuit time constant (T) will be

$$\frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2} + \frac{1}{T_3}$$

Individual time constants for a three-branch circuit in a modern receiver are 30 to 60 microseconds. The effective overall circuit time constants are, therefore, between 10 and 20 microseconds.

The reasons for using cascaded integrating circuits are:

1. To prevent erratic control of vertical retrace by random noise or static pulses. Before such pulses could control the vertical oscillator, they would have to be comparable in duration and spacing to the vertical-sync pulses.

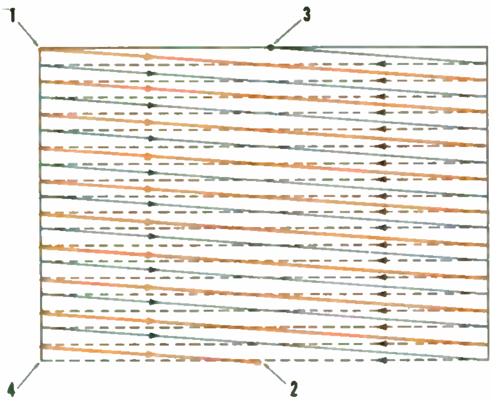
2. To smooth out the contour of the rising voltage wave (shown in the interval 3 to 5 of Figure 20B) across the output capacitor. The action is similar to that of the familiar resistance-capacitance, power-supply filter system in which the ripple is reduced by successive stages.

Because of this smoothing action, an individual horizontal pulse cannot cause pairing of lines during retrace. The sections of the cascade network are usually not made with equal time constants. This unbalance prevents accidental triggering by noise pulses.

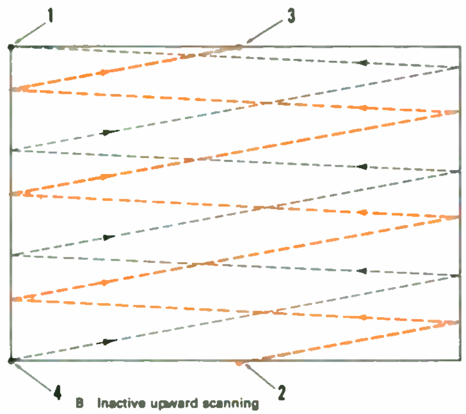
THE FUNCTION OF VERTICAL-EQUALIZING PULSES

In earlier lessons we discussed interlaced scanning, which prevents flicker of the image. For simplicity, the retrace from bottom to top of the picture was shown as a straight line or single jump. Actually, the horizontal oscillator must be kept in step with the transmitter during vertical retrace, which lasts from 1250 to 1400 microseconds (20 to 22 horizontal lines). Figure 21A shows a simplified version of the downward scanning in which nine and one-half lines have been drawn to represent each field. Actually, a field consists of $262^1/_2$ lines, less the lines lost during retrace. The first field, which starts at the upper left-hand corner (Point 1) and ends at the bottom center of the picture (Point 2), is shown by heavy lines. The second, or interlaced field, starts at the top center (Point 3) and ends at the lower left-hand corner (Point 4), and is shown by light lines. During vertical retrace, when the picture is blanked out, the beam moves upward under the combined action of both the vertical- and the horizontal-deflection systems. This is represented in simplified form by the diagram in Figure 21B. Here, three lines represent the twenty to twenty-two lines actually required during vertical retrace. Again, a heavy dotted line represents the retrace of field No. 1, and a light dotted line the retrace of field No. 2.

The dual functions of producing vertical retrace at the proper instant and of keeping the horizontal oscillator in synchronism are controlled by the equalizing and vertical pulses shown in Figures 22A and B. The vertical sync signal for the retrace of field No. 1 differs from that of field No. 2 by the spacing between the last horizontal pulse and the first equalizing pulse. In Figure 22A for field No. 1, this space (a) consists of only one-half of a horizontal line, since field No. 1 ends at the middle of the last line, as shown at Point 2 of Figure 21A. In Figure 22B for field No. 2, the space (b) between the last horizontal pulse and the first equalizing pulse consists of an entire horizontal line. Vertical blanking starts at the leading edge of the equalizing pulses. Thus, the successive field blanking time is accurately set up by the signal.



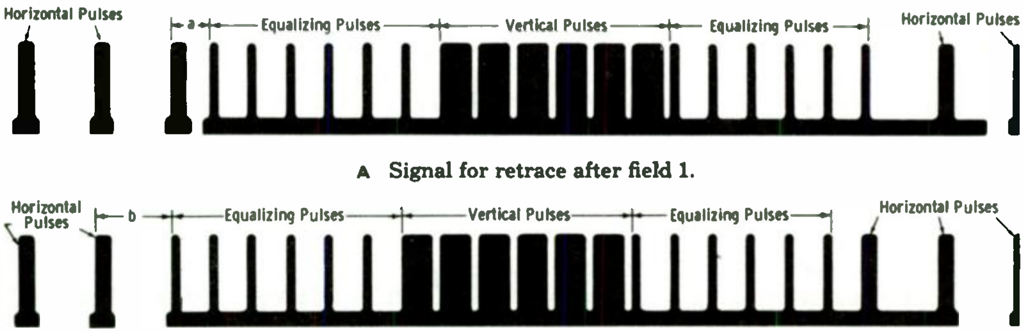
A Active downward scanning



B Inactive upward scanning (vertical retrace)

Figure 21 — Simplified illustration of interlaced scanning.

Even though retrace blanking is accurately established, vertical retrace may not take place at the proper instant unless the critical charge on the integrating capacitor occurs at exactly the same point for each successive vertical-sync signal. How the equalizing pulses assure this condition is shown in Figure 23. At (1) is shown the composition of a vertical-sync signal which would follow field No. 1 if the equalizing pulses were not present.



A Signal for retrace after field 1.

B Signal for retrace after field 2.

Figure 22 — Vertical-sync signals for retrace on alternate fields.

This signal input to the integrating circuit would charge the capacitor as shown by dotted line (1) on the charge curves of Figure 23. This curve crosses the sync-control level at time X.

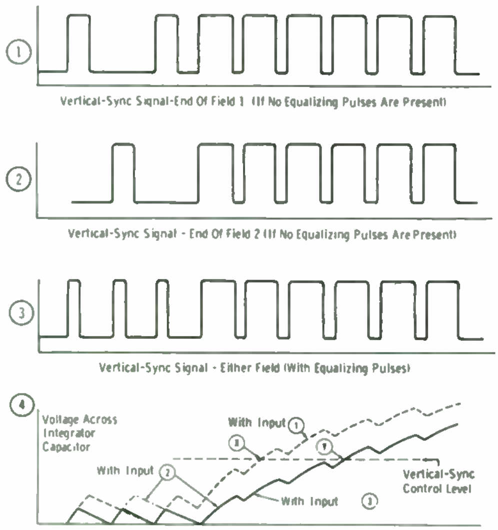
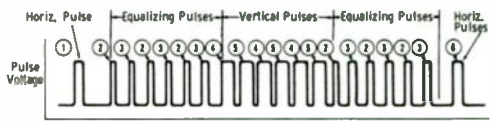


Figure 23 — Action of vertical-integrating circuit for alternate fields (with and without equalizing pulses).

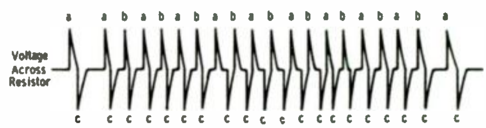
The vertical signal, without equalizing pulses, for retrace at the end of field No. 2, would be as shown at (2) in Figure 23. On the charge curves, the critical sync-control level would be reached at time Y, which is so much later than time X that proper interlace would not occur. When equalizing pulses are employed as shown at (3), the critical firing point for the vertical oscillator is at time Y for both fields. Successive fields preceded by equalizing pulses will therefore accurately control the oscillator and assure proper interlace.

ACTION OF THE HORIZONTAL-DIFFERENTIATING CIRCUIT DURING THE VERTICAL PULSE

The formation of positive and negative pips at the leading and trailing edges, respectively, of the vertical sync pulses was described briefly. We will now consider in detail the action of the horizontal-differentiating circuit during the entire vertical pulse. Figure 24A shows the pattern of the vertical signal following field No. 2.



A Vertical pulse group following field 2.



B Output of horizontal-differentiating circuit.

Figure 24 — Action of horizontal-differentiating circuits during vertical pulse period.

The horizontal pulse which starts retrace of the bottom line of the picture is shown at (1) in Figure 24A. The positive output pip produced by its leading edge is shown at (a) in Figure 24B. The pips produced by the trailing edge of this horizontal pulse and of all the other pulses of the period (labeled c) are rejected by the sync system, as previously explained.

Each equalizing pulse (2 and 3) before and after the vertical pulse also produces a pair of positive and negative pips. Only the pips marked (a) are used for oscillator control. Those labeled (b) are rejected, since they occur in the scanning cycle, while the horizontal oscillator is not sensitive to pulse control.

Each pulse of the vertical group (4 and 5) also produces a pair of positive and negative pips. However, only the positive pips (a) of Figure 24B are used. The horizontal pulse shown at (6) is one of a group occurring during the blanking period. The pips produced by the pulse at 6 are the same as those produced by horizontal pulse (1).

It is evident that the vertical-pulse group, because of the individual pulses and their different lengths, can assure vertical retrace at the proper time and keep the horizontal oscillator in step with the scanning in the camera tube at the transmitter.

DEFLECTION CIRCUITS

Up to this point, little has been said about deflection. We now have the video (picture) signal applied to the CRT, sound emerging from the speaker and the sync signal separated and processed for control. In addition, a means has been provided for varying the gain of the receiver so that we have a nearly constant amplitude signal at the picture tube. Now, some means must be provided to deflect this beam back and forth and up and down on the screen exactly in step with the beam in the camera tube in the transmitter.

A portion of the video signal at the video output stage is coupled to the sync separator. Here the horizontal and vertical sync pulses are separated from the video signal. From the sync separator, the horizontal sync pulses are coupled to the horizontal deflection circuit and the vertical sync pulses are coupled to the vertical deflection circuit. These pulses serve to start each line or field exactly in step with the beam at the transmitter. A noise-canceller stage is often included to prevent any noise pulses in the signal from being coupled to the deflection circuit and causing improper triggering of these circuits.

A sync phase inverter may also be included in some receivers. When used, this stage reverses the polarity of the signal so that it will be the proper phase to trigger the deflection circuits. Figure 25 shows a block diagram of a horizontal automatic frequency control (AFC) and deflection system.

The vertical sync pulses are coupled to the vertical oscillator. The vertical oscillator generates a signal at the 60-Hz vertical deflection rate. The sync pulses trigger the vertical oscillator so that each cycle will start exactly in step with the transmitted signal.

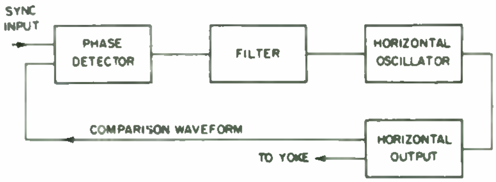


Figure 25 — Block diagram of a horizontal-AFC and deflection system.

The output of the vertical oscillator is coupled to the vertical output stage where it is boosted in amplitude to the proper level to provide vertical deflection of the electron beam.

The horizontal sync pulses are not coupled directly to the horizontal oscillator. Instead, they are first sent to the horizontal AFC (automatic frequency control) stage. The AFC tube then provides a correction voltage for the horizontal oscillator to keep it exactly in step with the horizontal scanning rate at the transmitter. The primary purpose of the AFC stage is to provide greater immunity to noise pulses which might enter with the horizontal sync pulses.

Like the vertical circuit, the horizontal oscillator generates a signal which is amplified by the horizontal output stage. The amplified signal is coupled to the horizontal deflection coils of the picture tube where it serves to trace the individual horizontal lines across the screen.

The damper tube is connected to the horizontal output stage. During the horizontal retrace period when the beam is returning from the right to the left of the screen, undesired oscillations would be set up in the horizontal-output transformer unless something is done to suppress them. The damper tube serves to squelch or clamp out these oscillations. It also permits the deflection coil current to decay at a uniform rate so that the left side of the screen will be linear—that is, not distorted.

Notice, it was stated that both the vertical and horizontal oscillators generated a signal. The sync pulse is not necessary for the stages to operate. The purpose of the sync pulse is to keep the circuits operating exactly in step with the ones at the transmitter.

Television receivers have generally employed three types of circuit arrangements, or combinations of these circuits, to produce sawtooth waveforms for scanning purposes.

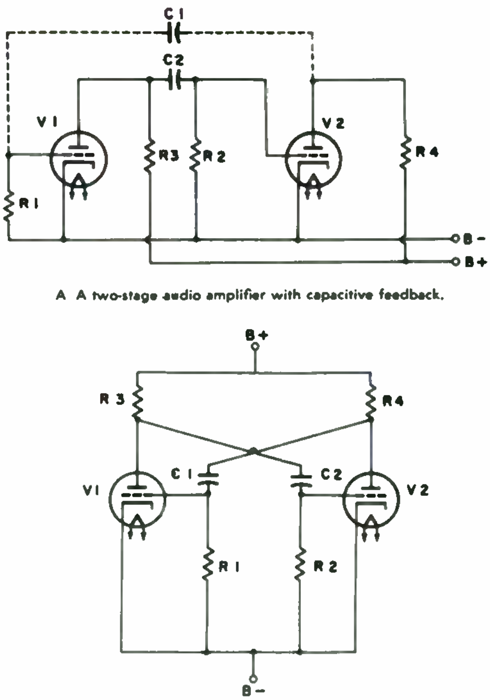
1. **The multivibrator.** This circuit arrangement has many variations. The most popular variation is the cathode-coupled version.
2. **The blocking oscillator.** This type of circuit permits the formation of a short pulse of energy. This pulse can be used to produce the sawtooth wave across a capacitor directly associated with the oscillator tube, or the pulse can trigger a discharge tube which acts as a switch across the capacitor.
3. **The sine-wave oscillator.** An oscillator of the correct frequency supplies the timing voltage for the discharge tube. The sine-wave output of this oscillator is modified into short pulses by wave-shaping circuits. These pulses then operate a discharge tube to produce sawtooth waves.

Multivibrators

One of the more popular television sawtooth generators is the multivibrator. The multivibrator is a form of relaxation oscillator and employs vacuum tubes, resistors, and capacitors in a feedback arrangement.

The multivibrator is useful because tubes can act as automatic switches to control the charge and discharge of capacitors. This action produces a sustained output of rectangular waveform whose frequency can easily be controlled by the horizontal or vertical synchronizing pulses.

Several versions of the multivibrator circuit are found in modern television sets. Since they are derived from a basic or conventional type, we will first examine the operation of the fundamental circuit.



A A two-stage audio amplifier with capacitive feedback.

B A rearrangement of the circuit in (A).

Figure 26 — The multivibrator.

The Conventional Multivibrator—The basic free-running multivibrator can be considered a two-stage resistance-capacitance coupled amplifier. Over-all feedback is applied by means of a capacitor connected from the output of the second stage to the input of the first stage.

Figure 26A shows a familiar two-stage audio amplifier. The added capacitor C_1 (shown in dotted lines) converts this amplifier into a free-running multivibrator. Figure 26B shows a symmetrical rearrangement of the same circuit as it usually appears in textbooks and receiver schematics.

In a single-stage resistance-coupled amplifier, the plate voltage is 180° out of phase with the input voltage. Therefore, the output voltage of the second stage (V2) of the two-stage amplifier will again have been inverted and will be in phase with the input voltage to V1. Capacitor C_1 of Figure 26 will impress upon the first grid a voltage of the proper polarity to increase the original input voltage, and oscillation can take place.

In this circuit the corresponding grid resistors, plate resistors, and coupling capacitors are equal. When this is true, the time constants are equal, and the output waveforms from the plates are identical. The frequency of this multivibrator can be changed by altering either resistors R_1 and R_2 or capacitors C_1 and C_2. A lower time constant will increase the frequency. If the values of R or C are changed equally, the output wave remains symmetrical; that is, the positive and negative portions occupy equal time periods.

The Asymmetrical, or Unbalanced, Multivibrator. To produce the type of sawtooth wave required for television scanning with a multivibrator, succeeding square waves must be unequal in length or spacing. For this reason, the time constant of the RC circuit of one tube is made much greater than the time constant of the other. Such a multivibrator is called asymmetrical.

Use of the Multivibrator to Produce Sawtooth Scanning. Figure 27 shows a circuit similar to those discussed for symmetrical and asymmetrical multivibrators. By adding two new circuit elements, we can generate sawtooth voltage waves to control the electron beam with either the horizontal or the vertical sweep circuits. These new circuit elements are C_3 and C_4 (Fig. 27). Coupling capacitor C_3 connects the multivibrator circuit to a source of synchronizing pulses, which are part of the transmitted television signal.

The additional circuit element which concerns us is capacitor C_4 between the plate and cathode of V2. For a horizontal-line scanning frequency of 15,750 Hertz, the circuit is so arranged that the time constant of R_1 and C_1 is approximately one-ninth the time constant of R_2 and C_2. The plate current of V2 will consist of short pulses which represent periods of low plate resistance. During the conducting period, V2 will act as a short circuit across capacitor C_4. The multivibrator thus acts as a periodic switch and fulfills the requirements for producing a sawtooth wave.

A significant difference between the circuit in Figure 27 and the one in Figure 26 is that R_2 has been made variable. This variable resistor is one of the major controls of a television receiver. From the previous discussion of multivibrator theory, we know that varying R_2 alters the length of the portion of the operating cycle controlled by R_2 and C_2. This represents the active portion of the sawtooth wave when the face of the cathode-ray tube is scanned during video modulation. This variable adjustment permits the multivibrator to be locked-in with the synchronizing pulse and is known as a hold control.

The voltage of the sawtooth wave across capacitor C_4 (Fig. 27) is too small to produce the required deflection of the electron beam; therefore, amplifiers are needed.

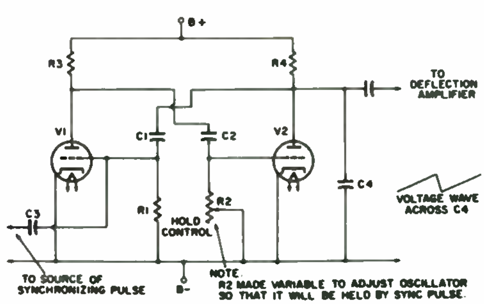


Figure 27 — The multivibrator arranged to produce sawtooth waves.

Cathode-Coupled Multivibrator. A variation of the multivibrator is the cathode-coupled circuit. This circuit is shown in Figure 28. A significant difference between this circuit and the conventional multivibrator is that feedback is accomplished in two ways. Coupling capacitor C_2 transfers charges from the plate of V1 to the grid of V2. In addition, this circuit employs a cathode-bias resistor common to V1 and V2. This common-cathode resistor is responsible for the unique action of the circuit. The second tube (V2) functions as a switch or discharge tube for capacitor C_4, which produces the sawtooth waveform.

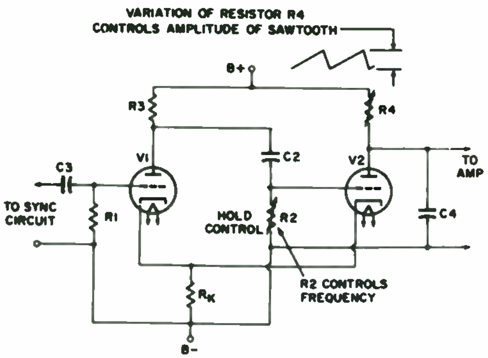


Figure 28 — The cathode-coupled multivibrator.

The cathode-coupled multivibrator is preferred in television over the asymmetrical multivibrator because:

1. It can be triggered and controlled by a negative pulse of voltage. Thus, the control circuits can often be simplified.
2. Its sudden and cumulative pulsing action in V2 permits a higher ratio of linear-sweep time to return time.
3. Variable resistors R_2 and R_4 of V2 (Fig. 28) permit control of its scanning frequency and amplitude.

Blocking Oscillators

Another tube of vacuum-type circuit for producing controlled sawtooth voltage waves is the blocking oscillator. The blocking oscillator was originally quite popular, especially as a vertical-sweep oscillator, but has been discontinued in favor of the multivibrator.

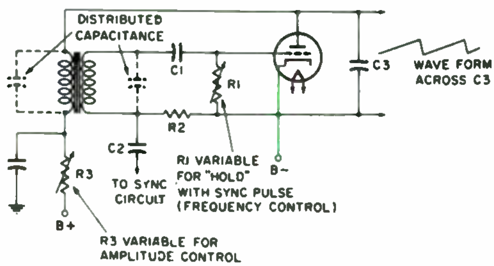


Figure 29 — The blocking oscillator.

Figure 29 shows a simple blocking oscillator. Upon casual inspection, it looks like a Hartley oscillator with an iron-core transformer. Basically, it is such an oscillator. However, instead of sustained sine-wave oscillations, it produces short pulses of energy, with correspondingly long intervals of relaxed action. For this reason, it is classified as another form of relaxation oscillator. Two significant differences distinguish this circuit from the common Hartley oscillator:

1. The time constant of grid resistor R_1 and grid capacitor C_1 is such that long periods of blocked plate current occur

between short periods of plate-current conduction. During these short conductive periods, oscillation takes place.

2. The natural period of oscillation of the transformer, with its associated distributed and lumped circuit capacitances, is such that the desired pulse time approximates one-half cycle of the frequency at which the circuit would oscillate if it were the continuous sinusoidal type. The period of conduction, however, is much less than one-half cycle of the natural period of oscillation.

Discharge or Trigger Tube. In some television receivers, pulse generators do not directly control the sawtooth charge and discharge of the capacitor; they are used to trigger an additional tube known as a discharge tube. This tube short-circuits (discharges) the capacitor. Figure 30 shows a blocking oscillator of the kind previously described. Its grid is connected directly to a second tube, whose only function is to conduct plate current and discharge capacitor C_2 at the proper instant to produce the sawtooth wave.

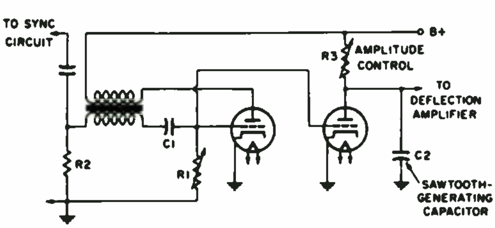
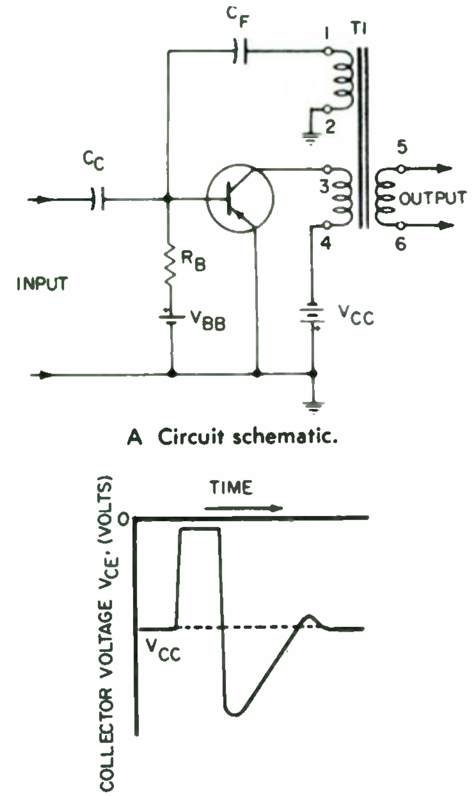


Figure 30 — The blocking oscillator and discharge tube as a sawtooth generator.

In transistor TV receivers, blocking oscillators are commonly employed in both the vertical and horizontal deflection sections. Figure 31 shows a vertical-oscillator configuration. The tightly coupled windings of transformer T_1 provide positive feedback from collector to base of the transistor. This transistor operates in Class C and conducts only for brief intervals—that is, the circuit operates as a pulse oscillator. During conduction, the base is driven strongly by the amplified output from the collector. After the passage of each pulse, the transistor is cut off or blocked. Thus, in Figure 31, the circuit action is as follows:

1. When a negative trigger pulse is applied to the base, the transistor begins to conduct. Collector current then flows through the transformer windings 3 and 4, and produces a varying magnetic flux which induces a voltage of opposite polarity in windings 1 and 2. This voltage is coupled through capacitor C_F to the base, thereby providing regenerative feedback. The transistor is quickly driven into collector saturation, and the collector current cannot rise further.
2. Since the collector current is now constant, T_1 can induce no more feedback voltage into the base circuit. The base is now reverse-biased, and the transistor is cutoff.
3. Stopping the collector current results in a collapsing magnetic field through windings 1 and 2, which induces a voltage



A Circuit schematic.

B Collector waveform.

Figure 31 — A triggered blocking oscillator showing the collector-to-emitter voltage waveform.

in windings 3 and 4 that exceeds the supply voltage. This is seen as the backswing following the pulse in Figure 31. In this example, the backswing approximately doubles the collector voltage. Unless the transistor is rated for this peak value of collector voltage, the collector junction will break down.

Next, let us consider a blocking oscillator utilized in a horizontal-oscillator section. With reference to Figure 32 transistor Q20 operates as a blocking oscillator, and the time at which it comes out of cutoff (and hence its repetition rate) depends on the value of base bias voltage. L_{16} and C_{99} form a ringing circuit which stabilizes the cutoff point for Q20 by superimposing a sine wave on the blocking-oscillator waveform.

The action of the horizontal stabilizer is seen in Figure 33. When a ringing coil is not used, the decay of

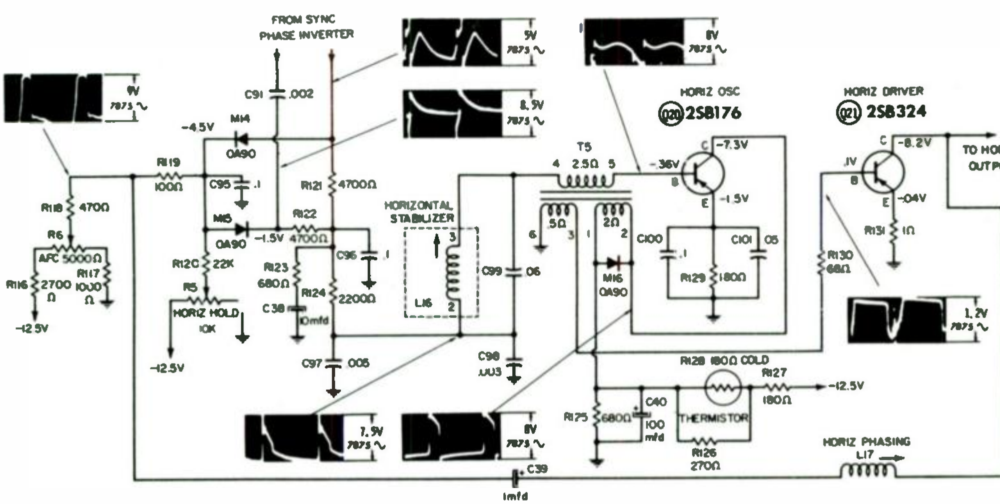
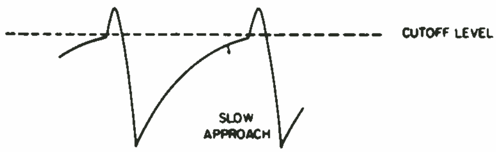
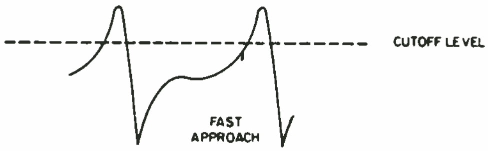


Figure 32 — A typical transistor horizontal-AFC, oscillator, and driver configuration.



A Without ringing coil.



B With ringing coil.

Figure 33 — Oscillator waveforms with and without a ringing coil.

the voltage is exponential and approaches the cutoff level slowly. In turn, the instant at which conduction is initiated can vary appreciably due to slight voltage fluctuations or small noise voltages. On the other hand, when a ringing coil is used, a sine wave is superimposed on the exponential waveform, and the combined waveform approaches the cutoff level rapidly. Because of the steep slope of the waveform through the conduction level, the instant at which conduction is initiated does not vary to a disturbing extent, even when small noise voltages or other fluctuations are present. Horizontal-stabilizer coil L_{16} is adjustable so that the optimum phase of ringing waveform can be utilized.

Regenerative feedback occurs from collector to base of Q20 in Figure 32. This feedback is provided by the tightly coupled windings of transformer T_5. In turn, blocking oscillation occurs. Diode M16 short-circuits the backswing of the generated waveform, as explained previously. This prevents excessive peak collector voltage from being applied to Q20. Collector-current stabilization is provided by thermistor R_{128}. If the temperature rises, the resistance of R_{128} increases, thus reducing the collector voltage and preventing Q20 from drawing increased current from the DC supply.

Sine-Wave Generators

The familiar sine-wave oscillator can produce pulses which will trigger a discharge tube associated with a sawtooth-waveforming capacitor. Only a short portion of the sine wave is used. It is passed through clipping stages to "bite off" a small section of the wave. The output of the clipper is a pulse. The usefulness of this type of circuit will be discussed later when we consider how scanning is controlled by synchronizing pulses.

TYPICAL MODERN HORIZONTAL-DEFLECTION SYSTEMS

A typical horizontal-deflection system is shown in Figure 34. Tube V1 receives its signal from the horizontal oscillator. The horizontal-drive adjustment consists of a variable capacitor at the grid of the horizontal-output tube. This capacitor and the coupling capacitor (not shown) form a voltage divider. A change in the setting of the drive adjustment changes its capacitance; thus, the voltage across it changes. Resistor R_2 is not put in the cathode circuit to develop a bias voltage, but to protect the output tube if the oscillator fails.

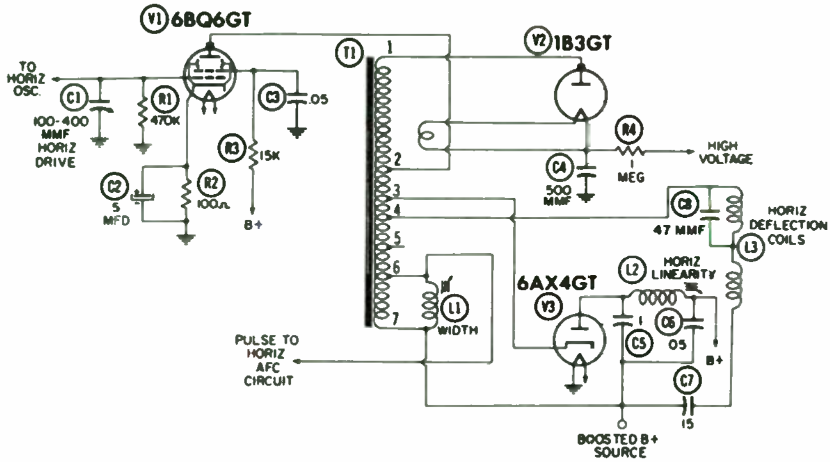


Figure 34 — A modern horizontal-deflection circuit.

The output transformer is an autotransformer. Plate current from the output tube flows to the B+ supply through the damper tube and through that portion of the winding between terminals 2 and 3. Autotransformer action builds up the higher voltage for rectifier V2, and the lower voltage to the deflection yoke is obtained from terminals 4 and 7 of the transformer. Capacitor C_7 is needed to eliminate direct current in the deflection yoke. Width coil L_1 functions by absorbing more or less power from the transformer.

Damper tube V3 damps the oscillations in the circuit when the voltage between terminals 7 and 3 reverses because of the inductive kickback produced by the sudden cutoff of output-tube plate current. The voltage provided by the damper conduction is stored in capacitors C_5 and C_6 and is used as the boosted B+ source. Linearity coil L_2 is in series with the damper tube and changes linearity by changing the phase of the damper conduction current.

In a receiver utilizing a deflection circuit like this, horizontal and vertical centering and an ion trap, if one is used, are provided by permanent magnets on the picture-tube neck.

Figure 35 is the schematic of a horizontal phase detector and multivibrator system that is typical of a great number of present-day receivers. The phase detector compares the horizontal-sync pulses to pulses fed back from the horizontal output and produces a DC voltage which represents the phase difference between the two signals. This voltage is applied to the grid of the multivibrator and controls the firing point.

The coil in the plate circuit of the first triode of the multivibrator is known as a ringing coil. It and its associated capacitor are tuned to the horizontal frequency and develop a sine wave of voltage. This sine wave steepens the slope of the grid waveform on the second triode of the multivibrator when this triode is approaching its conduction point.

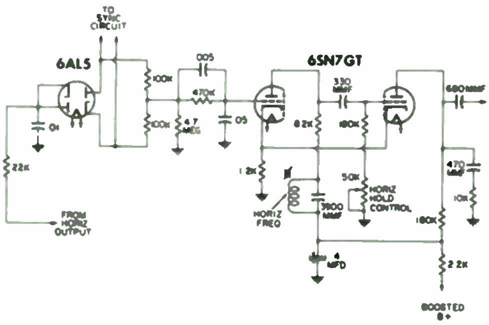


Figure 35 — Horizontal phase detector and multivibrator circuit in many modern receivers.

Thus, the sine wave lessens the chance of accidental triggering of the oscillator by a noise pulse.

Pulse-width control is often used for horizontal synchronization. One of the latest versions of the pulse-width system is shown in Figure 36. All the adjustments of the control tube have been eliminated, including the horizontal-hold control potentiometer. A hold adjustment has been provided by extending the screw on the slug in coil L_2 and putting a knob on it.

A further refinement, which has been used with various pulse-width systems in the past, is coil L_3 labeled horizontal waveform and commonly called a stabilizing coil. This inductance and the capacitance across it are tuned to the horizontal frequency, and they will produce a sine wave of voltage in series with the plate circuit. The sine-wave voltage steepens the slope of the grid-voltage waveform immediately before conduction time. This action improves the frequency stability of the oscillator by reducing the possibility of random noise triggering the oscillator. Waveforms A and B in Figure 36 show the V2 grid voltage, and point (a) in each waveform shows the change of slope.

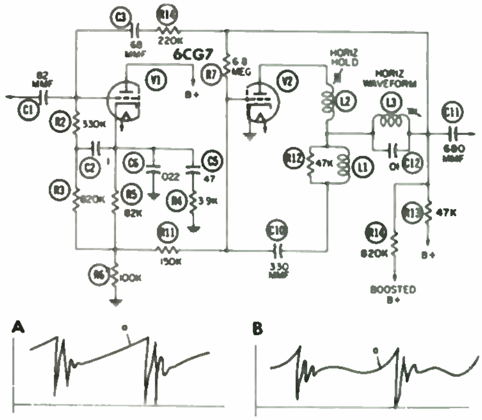


Figure 36 — A pulse-width circuit and waveforms showing effect of stabilizing coil.

The pulse-width system previously discussed and the cathode-coupled multivibrator of Figure 35 are being used in more than 90 percent of present-day television receivers.

TRANSISTOR HORIZONTAL DEFLECTION SYSTEM

A typical transistor horizontal-deflection circuit is shown in Figure 37. This is called a hybrid arrangement because a tube is used in the high-voltage section. The driver transistor Q602 is first cut off and is then driven into collector saturation by the output from the horizontal oscillator. Figure 38 shows the normal waveforms at the base and collector of Q602. The rectangular waveform from the collector is transformer-coupled to the base of the horizontal-output transistor Q603. Q602 is said to operate in the switching mode; this means that the transistor is driven rapidly

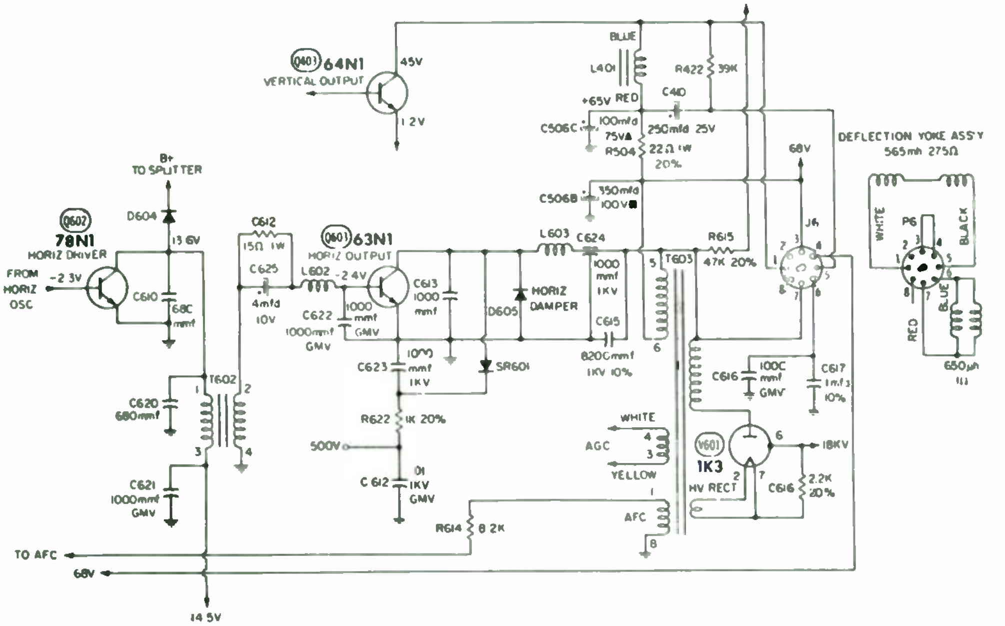


Figure 37 — A typical transistor horizontal-output and high-voltage configuration.

back-and-forth between cutoff and saturation.

Diode D604 in Figure 37 helps to damp out the ringing of transformer T602 and also rectifies the overshoot to boost the +DC supply for the preceding phase-splitter stage. Q603 is operated in the switching mode. When Q603 conducts, the yoke current increases linearly. Meanwhile, capacitor C_{617} is charging. At the end of the forward-scan interval, the base waveform suddenly cuts off Q603. Due to the inductance and capacitance of the horizontal-output system, a ringing oscillation starts: Ringing begins with a large positive overshoot pulse that quickly reverses the current through the horizontal-deflection coils and thereby initiates the flyback interval.

As the negative half-cycle of ringing starts, damper diode D605 becomes forward-biased. In turn, the low impedance imposed by D605 limits the negative ringing excursion. At the same time, C_{617} discharges linearly through the horizontal-deflection coils and D605 to ground. This linear discharge provides the first half of the ensuing forward-scan interval. To summarize briefly, the first half of the forward scan occurs while Q603 is cut off, and while C_{617} discharges through the yoke and D605. The second half of the scan occurs as

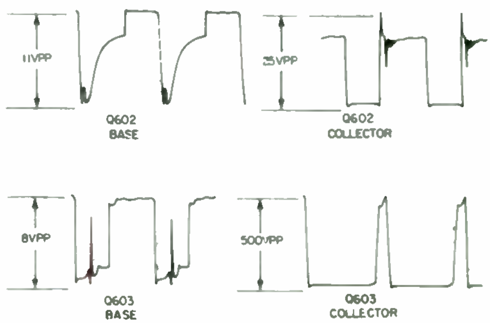


Figure 38 — Waveform found in horizontal-output system of Figure 24.

Q603 is switched into conduction, and C_{617} proceeds to charge once more through the yoke.

VERTICAL DEFLECTION SYSTEMS

Figure 39 shows the details of an early vertical-deflection system. The system combines a number of the circuit elements previously discussed, such as the vertical pulse-integrating circuit, the blocking oscillator, the discharge tube, and the series RC circuit which forms the combination sawtooth and pulse wave required for electromagnetic deflection.

The network of resistors and capacitors R_1-C_1, R_2-C_2, and R_3-C_3 comprises the integrating circuit which shapes the vertical-sync signal and applies it in series with the grid circuit of blocking oscillator V1. The pulse arrives at the grid at the proper time to trigger the plate-current pulse, as described and illustrated previously. This insures that retrace of the vertical scanning from bottom to top of the picture occurs at the correct instant.

The action of the blocking-oscillator circuit of V1 has been covered. In the present circuit, its application is conventional. The free-running frequency is controlled by the time constant of capacitor C_4 and of its discharge resistors R_4 and R_5 in series. R_5 is variable and acts as the hold control to adjust the oscillator frequency to lock with the repetition rate of the vertical-sync pulses.

The second section of the dual triode acts as a discharge tube to short the network of C_5 and R_8, which forms a voltage wave consisting of a linear sawtooth followed by a pulse.

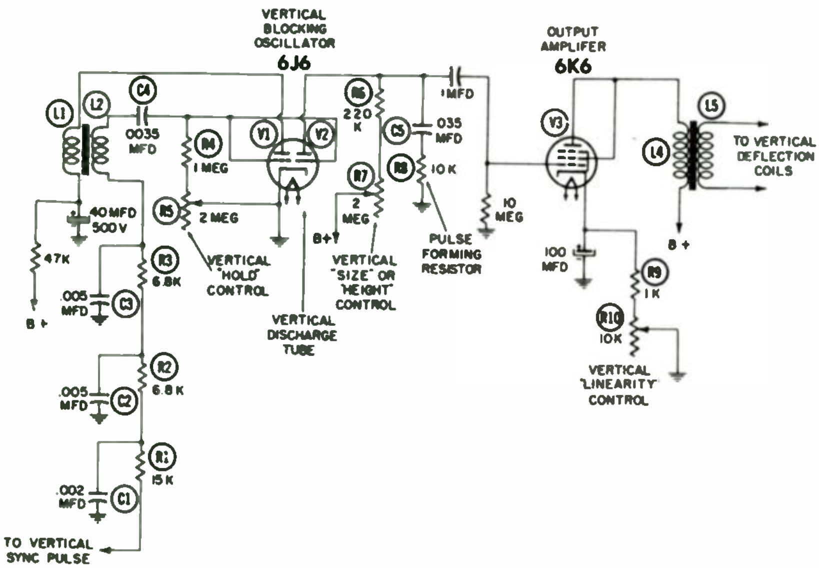


Figure 39 — Use of the blocking oscillator in a vertical-sweep circuit.

The charging voltage supplied to network C_5-R_8 is controlled by the series combination R_6 and R_7 connected to the B+ supply. $R_7$is made adjustable to act as the height or size control.

Tube V3 is a triode-connected output amplifier. It increases the amplitude of the sawtooth pulse to the proper level. The only feature of special interest in this part of the circuit is the variable cathode-bias resistor (R_9 and R_{10} in series). Adjustment of the operating point on the grid-voltage versus plate-current curve by the setting of R_{10} introduces the proper amount of distortion to correct any departure from linearity of the sawtooth scanning wave. This control is known as the vertical-linearity control.

In practice, adjustment of R_7 (vertical height) and R_{10} (vertical linearity) are somewhat interdependent. In this type of circuit, the vertical size or height control primarily affects the lower half of the picture, and the vertical-linearity control has its major effect upon the upper half of the picture.

The vertical oscillator and output circuit in Figure 40 is found in many popular portable receivers and is also typical of other modern receivers, and tube designers have provided a special tube for it. The 6CM7 tube consists of two dissimilar triode sections—the output section will handle more current and provide more output power than the oscillator section.

Like all multivibrators, oscillation takes place due to alternate conduction of the two sections of the tube. The circuit is free-running and will oscillate at its natural frequency without the necessity for external triggering. To synchronize the oscillator action with a signal from the transmitter, however, positive-going sync pulses are coupled to the system through capacitor C_1.

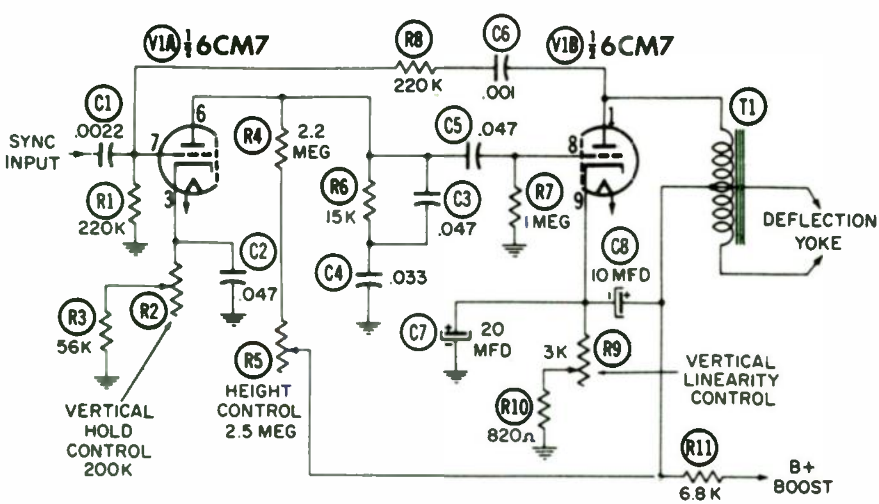


Figure 40 — Vertical oscillator-output system employing a modern TV receiver.

Tube V1A acts somewhat as a switch which automatically charges and discharges the saw-tooth-forming capacitor C_4. During vertical trace time, V1A is noncon-ductive and capacitor C_4 charges. The positive-going signal voltage developed across the combination of C_4, C_3, and R_6 is then coupled to the grid of V1B, where it causes a sawtooth-deflection current in the plate circuit and through the yoke.

When retrace starts, V1A conducts and capacitor C_4 discharges, so that a sharp negative voltage is applied to the grid of V1B and cuts it off. The circuit is so designed that V1A conducts during the re-trace period only, or approximately 1/15th of the vertical cycle.

V1B is not only the vertical output tube but also functions as part of the multivibrator. This circuit is very similar to the asymmetrical multivibrator shown in Figure 27. Note that the hold control has been moved to the cathode of V1A. If this control were in the grid circuit of V1B, it would affect linearity as well as hold. The output transformer is the autotransformer type with the yoke connected across a small portion of the winding.

TRANSISTOR VERTICAL SWEEP SYSTEM

Operation of a transistorized blocking oscillator has been explained previously. In Figure 41 the pulse waveform from the transistor is first changed into a saw-tooth waveform by the same circuit that provides the time constant of the blocking oscillator. Discharge of this network produces a curved (exponential)waveform which is then linearized by means of negative feedback. Manual control of vertical linearity is necessary, and this is provided by a variable resistor which operates in combination with a capacitor to introduce controlled waveshaping. The resulting sawtooth wave can be made either convex or concave by adjusting R_{6B}. Between these two extremes, the desired linear sawtooth waveform is obtained.

It is also necessary to control the amplitude of base drive in order to adjust the raster height. This is provided by a control. Negative feedback is also provided. That is, the waveform from the vertical-deflection coil returns to ground through the emitter resistor. Some additional negative feedback is also provided from collector to base. These negative-feedback circuits not only serve to produce basic linearity in the system, but also make tolerances on replacement transistors less critical than otherwise. Any residual nonlinearity is corrected by adjustment of the R_{6B}.

The vertical-output transistor in Figure 41 employs a power transistor. Because of the comparatively critical bias that is required, a bias control R_{6C}, is provided for maintenance adjustment. Q16 operates near its maximum rated output, and since the collector current is heavy, the collector junction heats up appreciably. Although a heat sink (heavy metal mounting) is used, the transistor heats sufficiently in normal operation that the bias voltage must be stabilized.

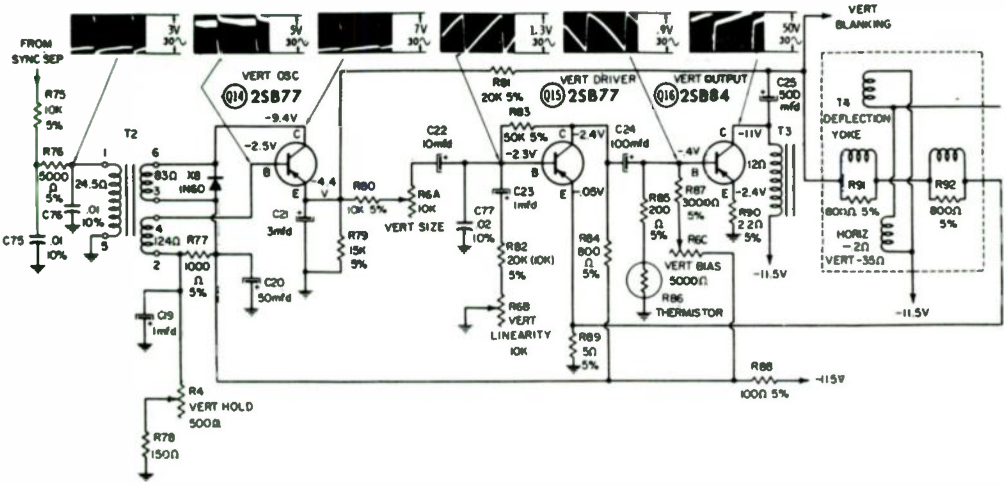


Figure 41 — A typical transistor vertical-sweep system.

Unless the base-emitter voltage is stabilized, thermal runaway and resulting damage to the transistor would occur. R_{86} is a thermistor which operates to control the forward bias on Q16, and thereby stabilizes operation. When the emitter-base current tends to increase, R_{86} heats up and its resistance decreases. In turn, the base voltage is decreased.

Since the vertical-deflection coils have both resistance and inductance, a peaked-sawtooth waveform is required to produce a sawtooth current through the coils. The negative peaking spike at the collector of Q16 is produced by inductive kickback from inductor T_3 and the vertical-deflection coils. Note that although there are only 8.6 volts DC between the collector and emitter of Q16, this inductive kickback generates a total peak-to-peak voltage of 50 volts for the output waveform. The peaking pulse is tapped off for vertical-retrace blanking of the picture tube. Negative feedback is provided by the unbypassed emitter resistor R_{90}, which also assists in DC stabilization of Q16.

CONTROLLING SWEEP OSCILLATORS

As we previously stated, the sequence of events when reconstructing a scene on a TV screen must occur exactly in step with a similar sequence occurring at the same instant in the camera tube at the transmitter. To accomplish this action, pulses are sent out from the transmitter between each horizontal trace. The shape of these pulses is shown above the sawtooth wave in Figure 42. At the instant shown as F, enough voltage appears at the grid of the picture tube to blank out all light. The region from F to G is known in television slang as the "front porch." This region is slightly more than one-millionth of a second in duration. At point G, the carrier wave of the transmitter

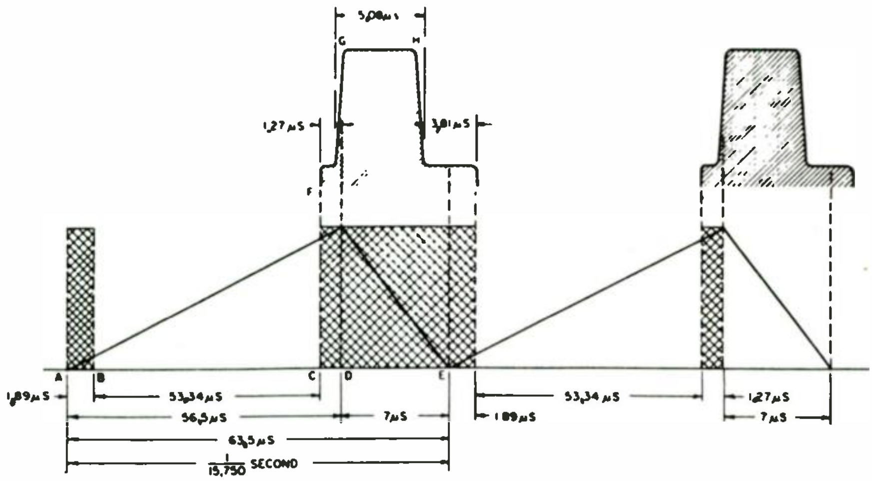


Figure 42 — Horizontal-scanning wave and synchronizing signal.

abruptly increases by approximately 25% of its average value. This sharp rise in the carrier triggers the scanning generators in the receiver. The scanning generators produce the required sawtooth motion of the electron beam. Exactly how the pulse accomplishes this triggering will be described later.

The horizontal beam does not trace a line parallel with the top of the picture, but has a slight downward slope. This vertical motion is controlled by a scanning sawtooth which moves the scanning spot to the bottom of the image and then rapidly returns it to the top. The electron beam moves from the top to the bottom of the picture and back to the top in 1/60 of a second. It is easy to see that this vertical scanning is much slower than the horizontal line tracing action and requires 16,666 microseconds. Pulses are sent out between successive fields to lock in, or control as a slave, the vertical-scanning oscillator of the receiver. A cycle of the vertical-deflection sawtooth wave, together with an enlarged section of that part of the wave which occurs during blanking and retrace, is shown in Figure 43.

The portion of the television signal which controls vertical retrace and synchronization is much more complicated than the single horizontal pulses which occur between successive horizontal lines. The vertical synchronizing signal resembles a comb with uneven teeth. If its only function were to trigger the vertical oscillator and to blank out the picture-tube screen during retrace, it could be made in the form of a single long rectangular pulse whose time duration would be from 20 to 22 horizontal lines (1,250-1,400 microseconds). However, the vertical synchronizing signal must perform two other functions. It must continue to keep the horizontal-scanning oscillator in step during vertical retrace and also assure that alternate fields have proper interlace of the horizontal lines.

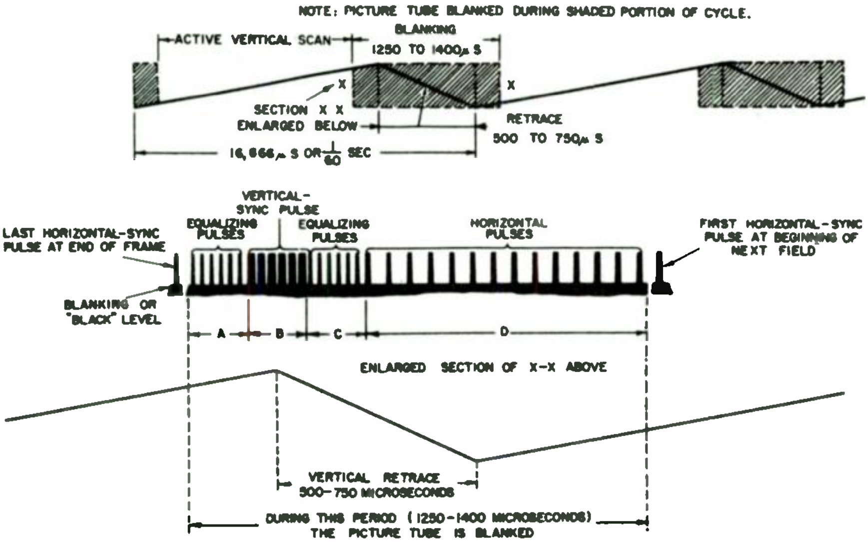


Figure 43 — Vertical-scanning wave and synchronizing signal.

Horizontal synchronization is kept in step by notches B and pulses A, C, and D (Fig. 43). Interlace is controlled by equalizing pulses A and C (Fig. 43) preceding and following the vertical sync pulse.

We have seen that the scanning systems of the receiver must keep in accurate step with the scanning raster of the camera tube at the transmitter and that the synchronization pulses satisfy this requirement.

For a satisfactory reproduced picture, the picture elements of adjacent horizontal traces must line up accurately, and the lines of alternate fields must interlace or space accurately between each other.

To avoid a displacement of more than one picture element in successive horizontal lines, the frequency stability of the horizontal oscillator must be 0.2% or better. Figure 44 illustrates horizontal displacement.

To avoid "pairing" of the lines of successive fields (the line lying on top of those of the preceding field instead of being properly interlaced), the stability of the vertical oscillator must be better than 0.05%. Figure 44B illustrates this displacement.

In each of the impulse-generating circuits (cathode-coupled multivibrator and blocking oscillator) suitable for television scanning, coupling means have been indicated in the grid circuits for the introduction of synchronizing pulse controls.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits which classify the pulses so that

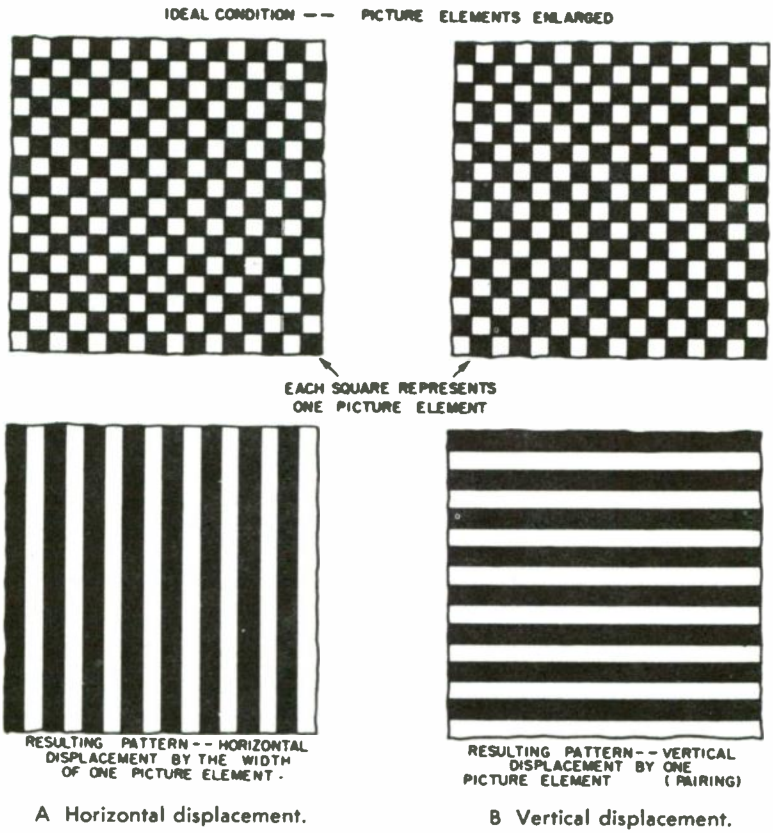


Figure 44 — Picture-element displacement that might result from scanning-oscillator instability.

each will control its own scanning oscillator only. The end results is a short, sharp pip for the horizontal control and long triangularly shaped pulse for the vertical control.

In considering how the pulse controls the oscillator frequency, three items are important:

1. **Free-running frequency of the sweep generator.** This frequency is that which would be generated at any particular setting of the hold control if the sync pulses were not present. The frequency can be slower or faster than the pulse repetition rate, or in exact step. We will show later that, for proper stable operation, the slow rate is required.
2. **The firing point of the sweep generator.** This is the grid-bias voltage required for the controlled tube in order to initiate conduction in the discharge tube, and to start capacitor discharge and scanning-wave retrace. At this point in the cycle the oscillator is most sensitive to control by the sync pulse.
3. **The synchronizing frequency.** This is the rate at which the pulses are applied

to the control-input terminal of the oscillator—60 hertz for vertical synchronization and 15,750 hertz for horizontal synchronization.

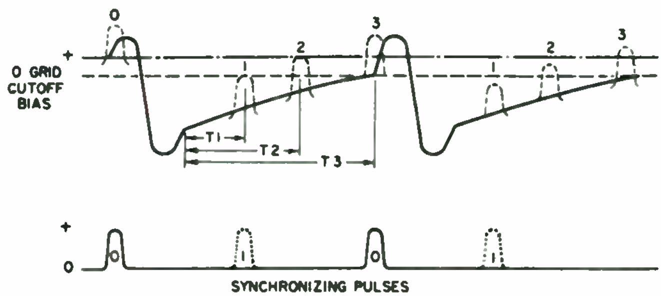
Since the control action of the blocking oscillator can be more readily diagrammed, we will consider it first.

Pulse Control of the Vertical Blocking Oscillator

The triggering, or firing, of the blocking oscillator occurs when the grid voltage passes the cutoff point. The free-running frequency of the oscillator (if no sync pulses are present) is determined solely by the time constant of the grid capacitance and resistance. Once the oscillator is fired, it functions on its own until it is blocked again by the grid cutoff voltage.

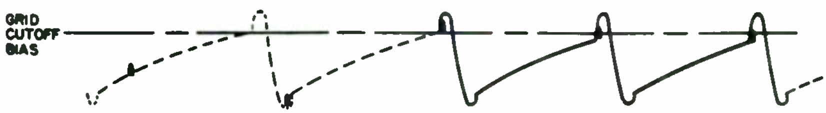
If a pulse of positive potential from an external source is fed to the grid while the grid capacitor is discharging through the resistor, the grid voltage will pass the cutoff point, and the tube will begin to conduct. The sawtooth forming capacitor will discharge, and retrace will occur. A new scanning cycle then begins. Therefore, the repetition of the positive sync pulses can control the firing of the blocking oscillator and lock the picture into synchronization.

Figure 45 illustrates this action in detail. Figure 45A is an enlarged portion of the blocking-oscillator



A Grid-voltage waveform with a series of sync pulses.

B Oscillator frequency fast.



C Oscillator frequency slow.

Figure 45 — Pulse control of a free-running oscillator.

grid voltage. The synchronizing pulses below the grid waveform show a series of pulses marked "O" whose leading edges are exactly in step with the wave. These pulses do not affect the free-running frequency of the oscillator. They merely add to the grid voltage at the same instant it is being driven positive by the plate-current pulse. On the other hand, if the sync pulses occur at the points indicated as "1", the pulse voltage added to the discharge voltage of C_1 through R_1 (Fig. 29) is still short of the cutoff bias point and will not fire the tube. However, if the pulse occurs at points 2 or 3, the critical bias will be exceeded, the tube will immediately conduct, and retrace will begin.

Since the free-running frequency of the blocking oscillator can be changed by varying the time constant of the capacitance and resistance in the grid circuit, let's examine this action under the following conditions: (1) oscillator running faster than the sync-pulse rate, and (2) oscillator running slower than the sync-pulse rate.

Figure 45B shows what happens when the oscillator is running faster than the sync-pulse rate. The dotted portion of the waveform indicates lack of synchronization at that point. Notice that several cycles occur before the pulse reaches point "X". At this point the grid cutoff voltage is exceeded, and the tube fires. Normally, you would expect the picture to lock in satisfactorily. However, this is not true. Lock-in occurs only momentarily during the field initiated at point "X". Succeeding fields do not lock in. With the oscillator running in this fast condition, the sync pulses are occurring during the scanning interval. Consequently, the picture is divided by the blanking bar. Also, the oscillator, running faster than the sync-pulse rate, can easily be triggered into erratic operation by automobile ignition and static interference. Therefore, the picture will be unstable. In modern receivers, however, improved circuit designs have resulted in more stable pictures, even under heavy interference conditions.

Figure 45C shows what happens when the free-running frequency of the blocking oscillator is slower than the sync-pulse rate. Notice that lock-in occurs much faster and a good stable picture is obtained. This is obviously the desired condition because the oscillator should run slightly slower than the sync-pulse rate. The sync pulses will then take over and force the blocking oscillator to lock in with each succeeding sync pulse.

The height and width of the sync pulses are not important as long as they are high enough to drive the grid above the cutoff point. With the sync-pulse amplitude reasonably high, the hold control can be varied over a fairly wide range without loss of synchronization.

For control of the blocking oscillator just described, the sync pulses are positive. Sync pulses can be made either positive or negative with respect to ground (or chassis), depending on receiver design. Negative pulses are ideal for the cathode-coupled multivibrator.

Pulse Control of the Cathode-Coupled Multivibrator

"Tripping," or discharge, of the cathode-coupled multivibrator is initiated by a negative-voltage pulse on the grid of the first tube. Once "tripping" begins, it immediately receives an additional negative voltage from the cathode-bias resistor, which is common to both tubes. Although the control actions and principles just described for the blocking oscillator hold true, it is not feasible to show them in diagram form.

Pulse Control of Transistor Horizontal Oscillator

The basic function of pulse control in a transistor oscillator configuration is to provide horizontal sync lock in a manner that rejects disturbing noise interference insofar as possible. This control of the horizontal oscillator frequency is similar to that found in tube-type TV receivers. To minimize picture tearing or other disturbances due to random noise pulses, the horizontal-sync pulses are processed in a comparator circuit which has a comparatively long time constant. The frequency of the horizontal oscillator, in turn, is controlled indirectly, and the noise-pulse voltages tend to average out and cancel.

Horizontal sync pulses are mixed in a diode circuit along with comparison waveforms from the horizontal sweep section. In turn, a DC control voltage is developed which opposes any tendency of the horizontal oscillator to drift off-frequency. The control voltage is applied through an RC network which has an appreciable time delay, so that successive noise pulses tend to cancel one another. Figure 46 shows the plan of the pulse-control network. A basic automatic frequency control (AFC) circuit is shown in Figure 47. Sync pulses and the comparison sawtooth waves are fed into the diode circuit. In turn, the sync pulses ride on the sawtooth waves. Note that the peak-to-peak voltage of the combination waveform is thereby increased.

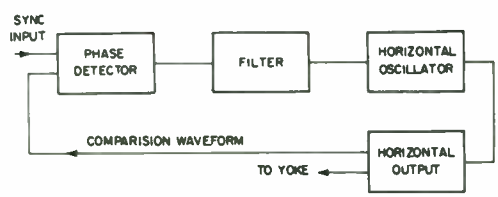
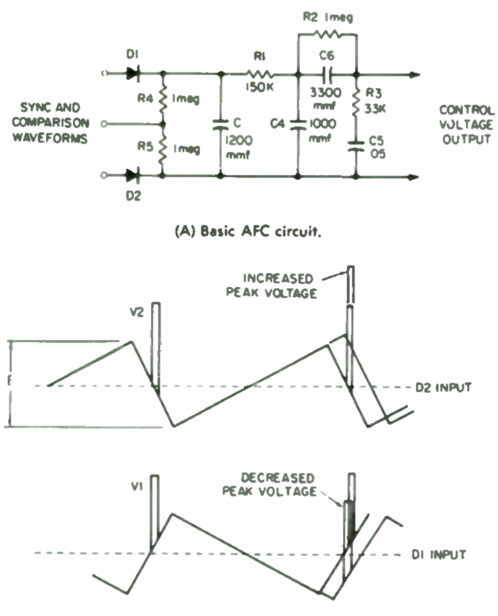


Figure 46 — Block diagram of a horizontal AFC and deflection system.

Capacitor C in Figure 47 can be charged only if one of the diodes conducts more than the other. If the oscillator happens to be exactly on-frequency, both diodes conduct equally because voltages V1 and V2 are equal. On the other hand, if the oscillator tends to run too slowly, the waveforms are changed and D2 conducts more than D1. Hence, the upper terminal of C becomes negative, and a negative control voltage is produced. If the oscillator tends to run too slowly, a positive control voltage is produced. This control voltage is fed directly to the oscillator, or to a control device; in either case, the control voltage corrects the oscillator frequency.

The RC network to the right of C in Figure 47 is basically an integrating and filter circuit which delays and smooths the control voltage. This configuration also provides a fast initial correction, followed by a slower correction in the same direction which eases the oscillator to its correct frequency without over-correction. When a defect occurs in this network, the result is often an over-correction alternating with an under-correction. The result is a picture symptom called the "pie-crust effect." Technicians term the circuit action as "hunting" when the picture has a pie-crust or gear-tooth appearance.



(A) Basic AFC circuit.

(B) Operating waveform.

Figure 47 — Peak voltages change when the phase of the comparison waveform changes.

The amount of electron beam deflection in an electromagnetically-deflected cathode-ray tube depends upon the strength of the magnetic field produced by the deflecting coils. The magnetic field is proportional to the amount of current passing through the coils, and these fields cross the path of the electron beam within the neck of the tube.

We must supply a linear sawtooth of current through the coil so that the electron beam will trace the proper raster under the combined influence of the horizontal- and vertical-deflecting coils. In Figure 48 we see the resultant shape of a current wave which would flow through a pure inductance if a symmetrical square wave of voltage were applied across its terminals. This type of wave, as we have seen, can be developed by a conventional or symmetrical multivibrator. At point A, the voltage has suddenly

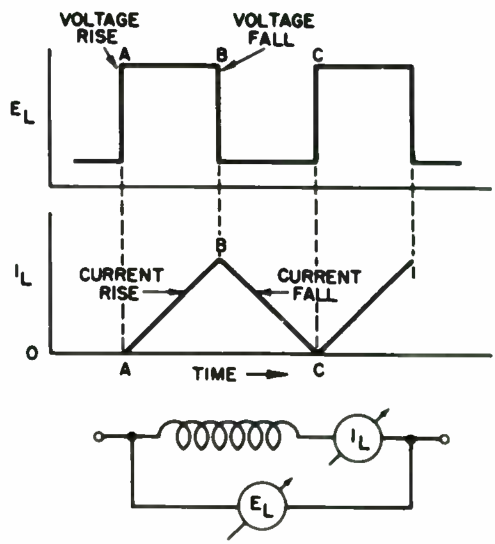


Figure 48 — Rise and fall of current through a pure inductance when a square voltage wave is applied.

been applied to the coil in much the same fashion as if a switch had been closed to connect the coil to a DC source of potential, for example, a battery.

Notice that the current through the coil did not immediately rise to maximum. The self-induced voltage of the coil opposed the sudden change. The current, therefore, increased linearly over that portion of the cycle when the applied voltage was steady. (Theoretically, the current rises exponentially; but for practical purposes, we can consider it to be a linear change.) At point B, the impressed voltage was suddenly removed (the switch was opened). At this point, the current did not immediately fall to zero since it was maintained by the energy stored in the magnetic field. The self-induced voltage of the coil served as the driving potential to produce the linear fall of current from point B to point C.

We have now produced a triangular wave of current through the coil. If we can make the rise portion of the curve longer than the decay portion, we can produce the desired sawtooth-scanning current wave. This wave can be produced by making the impressed voltage wave asymmetrical, as shown in Figure 49.

Since a deflection coil cannot be built as a pure inductance, we must now consider what effect the resistance of the windings will have on the voltage waveform producing a sawtooth of current.

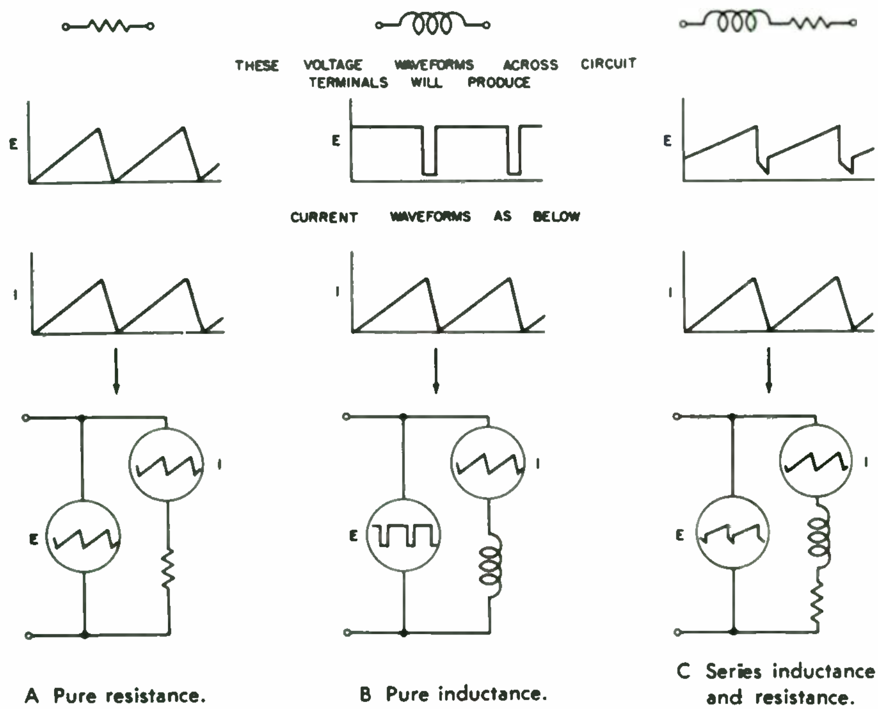


Figure 49 — Voltage and current waveform in inductive and resistive circuits.

Figure 49 illustrates three types of circuits and the voltage waveform necessary to produce a sawtooth wave of current through each circuit. Figure 49A shows a pure resistance. The current is in phase with the voltage, and a sawtooth wave of voltage impressed across the resistor will cause a sawtooth wave of current through it. Energy losses occur only in the form of heat. The voltage required to produce a certain current is equal to the IR drop, as determined by Ohm's law.

Figure 49C shows the circuit represented by a deflection coil. The voltage waveform will be seen as a combination of the sawtooth of A and the rectangular wave of B (often called a trapezoidal waveform). In reality, this shape is the sum of an instantaneous pulse and a sawtooth. We might think of its function as follows:

1. The sawtooth or linear rise portion of the wave tends to produce a sawtooth wave of current through the resistive part of the circuit.
2. The instantaneous pulse portion of the wave forces a sawtooth wave of current through the inductive part of the circuit.

To produce this combination waveshape, additional circuit elements are added to the sawtooth-capacitor charging circuit. The circuit is then known as a peaking type of waveshaping circuit. By proper choice of capacitor and resistor values, either the sawtooth portion or the impulse portion of the wave can be made to predominate. The circuit action will be described later.

It is interesting to note that one part of the wave must predominate over the other because of the differences between the horizontal- and vertical-deflection coils. In the vertical-deflecting coil, the resistive component predominates over the inductive component. Thus, the sawtooth portion of the wave predominates over the impulse portion. For example, this coil might have a resistance of 68 ohms and an inductance of 50 millihenries. When the retrace rate is 60 hertz, a predominantly resistive circuit is presented.

In the horizontal-deflecting coil of the same receiver, the conditions are reversed; the inductive component predominates. The impulse portion is more important, and the required waveshape approaches that of Figure 49B. For example, we would find a resistance of only 14 ohms and an inductance of 8 millihenries. Since this coil operates at the much higher frequency of 15,750 hertz per second the circuit is essentially inductive.

PEAKING CIRCUITS

By a simple change in the discharge-tube circuit the combination sawtooth and impulse wave required for electromagnetically-deflected scanning can be generated. The modified circuit is shown in Figure 50. Resistor R_2 has been added in series with the discharge capacitor C_2. The circuit action will be described in sequence:

1. The sawtooth-forming capacitor C_2 is charged from the B+ source through resistors R_3 and R_2. This charging action takes place when the tube is not conducting.
2. The output-voltage waveform of the circuit is taken across the series combination of R_2 and C_2. R_2 is known as the peaking resistor.
3. During the charging portion of the cycle, the voltage across the capacitor is a sawtooth wave.
4. When the tube conducts because of a positive pulse on its grid, the voltage across C_2 and R_2 is shunted by the low plate resistance of the tube.
5. The voltage across the capacitor cannot change instantly because its discharge path through R_2 and through the plate resistance of the tube is not zero. Therefore, the difference in voltage must suddenly appear across peaking resistor R_2. After this initial sudden change of voltage, the capacitor discharges exponentially through R_2 and the tube until the tube again becomes nonconductive.
6. As the tube is cut off, the B+ potential is applied to the capacitor through R_2 and R_3 in series. Again, the capacitor voltage cannot rise instantaneously. The voltage across R_2 must once more change abruptly, after which the capacitor charges through R_2 and R_3 in its normal sawtooth fashion.

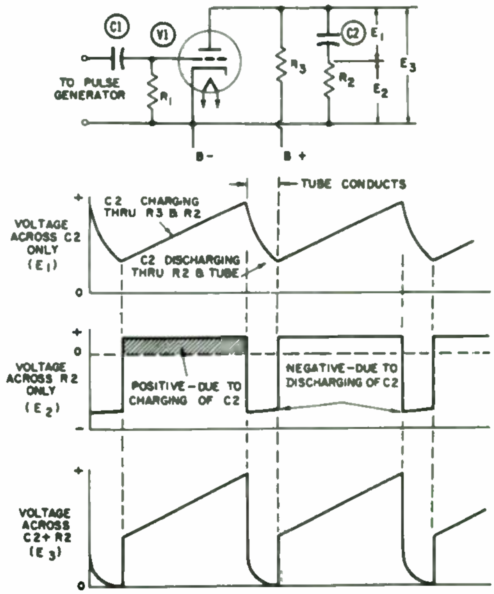


Figure 50 — Typical peaking circuit and associated waveform.

By changing the values of R_2 and C_2, the ratio of the amplitude of the peaking impulse to the sawtooth can be adjusted to match the inductive and resistive requirements of the particular delfecting coil.

SUMMARY

The function of the television receiver is to pick up the signal from the television station, amplify it, and produce a visible picture and audible sound corresponding to the original scene.

In the television receiver, the signal is received, amplified and separated into its individual components. Deflection of the beam in the picture tube is accomplished electromagnetically with coils, external to the tube. The deflection circuits in the receiver are kept in step with the deflection circuits in the camera by the sync pulses transmitted as part of the composite video signal.

The signal from the desired VHF or UHF television station arrive at the television receiver antenna. These signals travel down the antenna line to the RF amplifier where only the desired signals are selected and rejects all others. The desired signal is amplified by the RF amplifier and coupled to the mixer. In the mixer stage the amplified signal from the RF amplifier and the signal from the local oscillator are beat together to produce a lower, or intermediate frequency.

The output of the mixer is coupled to the input of the first video IF amplifier. The signal at this point still contains both video and sound, as well as the sync signals. The IF amplifiers are tuned to pass a band of frequencies approximately 4 MHz wide.

The multivibrator, blocking oscillator, and sine-wave oscillator are the three types of circuit arrangements generally used to produce sawtooth waveforms for scanning purposes. One of the most popular circuits is the multivibrator. The multivibrator is useful because tubes can act as automatic switches to control the charge and discharge of capacitors.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits which classify the pulses so that each will control its own scanning oscillator only. The end result is a short, sharp pip for the horizontal control and a long, triangularly shaped pulse for the vertical control. These signals keep the vertical and horizontal oscillators in step with the segments of the televised scene.

TEST

Lesson Number 89

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-089-1.

1. Cathode-ray tubes produce light from ______ phosphor coated screen.
- A. electron bombardment of a
- B. ion bombardment of a
- C. electromagnetic action on a
- D. the heating of a

2. Electrons are accelerated in the ______ of a CRT.
- A. electrostatic deflection plates
- B. electromagnetic deflection coils
- C. phosphorescent mask
- D. electron gun

3. In large screen CRT's such as those used for TV sets the beam is deflected:
- A. statically.
- B. physically.
- C. electromagnetically.
- D. none of the above.

4. In a properly operating TV set the beam traces a pattern across the face of the CRT in step with
- A. sound pulses.
- B. synchronizing pulses.
- C. noise pulses.
- D. internally generated pulses.

5. **Sync pulses may be clipped from the video wave form with**
   A. diodes.
   B. vacuum tubes.
   C. transistors.
   D. all of the above.

6. **The serrated vertical pulse forms a long control pulse by charging the capacitor in a/an _______ circuit.**
   A. integrator
   B. rectifier
   C. AGC
   D. AFC

7. **The most common type of oscillator used in TV sweep circuits is the**
   A. one shot.
   B. multivibrator.
   C. bistable.
   D. Hartley.

8. **The frequency of the vertical sweep oscillator is controlled by application of**
   A. a DC voltage.
   B. horizontal AFC.
   C. vertical synchronizing pulse.
   D. horizontal sync pulses.

9. **The frequency of horizontal sweep oscillators are generally controlled by the**
   A. flyback transformer.
   B. damper.
   C. horizontal AFC circuit.
   D. vertical oscillator.

10. **The damper is necessary to remove:**
    A. video from the sync.
    B. sync from the video.
    C. vertical pulses from horizontal pulses.
    D. none of the above.

Notes

Exchange

Notes

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two

Portions of this lesson from
Television Service Manual
by Robert G. Middleton
PHOTOFACT *Television Course*
by Howard W. Sams Editorial Staff
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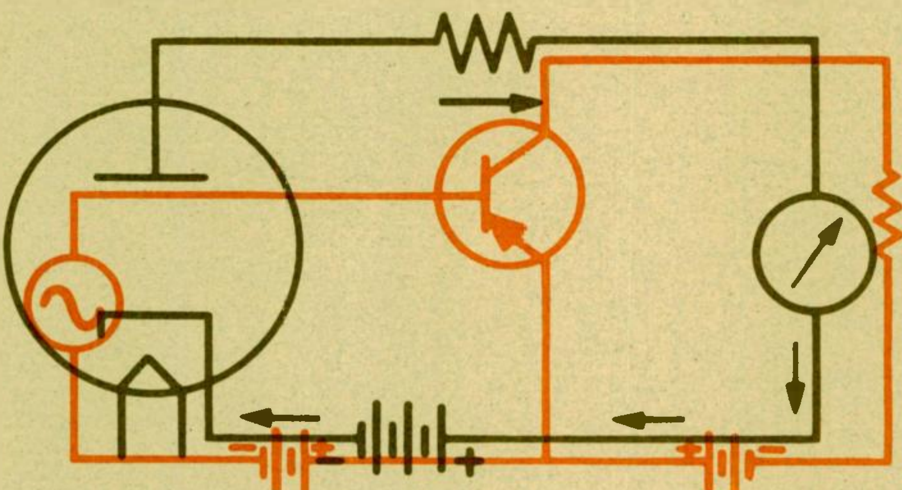
LESSON NO. 90

TELEVISION CIRCUIT TRACING



RADIO and TELEVISION SERVICE and REPAIR

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LESSON CODE
NO. 52-090
410

ADVANCE SCHOOLS, INC.
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Contents

TELEVISION CIRCUIT TRACING

INTRODUCTION

All television circuit diagrams follow the same general layout, with each of the major circuit functions occupying the same area on the diagram. Some of the diagrams show specific parts of the TV circuit in color to aid in following the path of the signal, while some manufacturers use supplementary diagrams to aid in following the action of certain circuit functions.

A comparison of many diagrams, however, will show that most manufacturers present their circuit information in the same general form. But even if most of the circuit diagrams did not follow this general format, experience in using TV service diagrams will make it easy to locate specific circuit functions on a diagram that might be laid out in a completely different form.

TV CIRCUIT FUNCTIONS

The TV Receiver

In a radio there is, in effect, only one kind of signal, usually an amplitude-modulated radio-frequency signal. All that must be done to get an audible signal is to peel off the modulation (by detection) and apply it to an earphone, or amplify it to the point where it can operate a speaker. A television signal is much more complicated, but your understanding of it will be greatly strengthened if you think of a black and white television signal as being made up of four parts:

An amplitude-modulated *picture* signal.
A frequency-modulated *sound* signal.
A *vertical* synchronizing signal.
A *horizontal* synchronizing signal.

Note in the block diagram of Figure 1 that all *four* signals are picked up by the tuner (which is actually a converter circuit with an RF amplifier ahead of it). The same four signals ride on through several stages of video IF, through the video detector (often a diode), and frequently through the video amplifier as well.

At the video amplifier, though, all sorts of things happen to the picture signal before it is applied to the picture tube. Here the FM signal is taken off and sent through a sound-IF amplifier and then to an FM detector. Finally it is boosted in

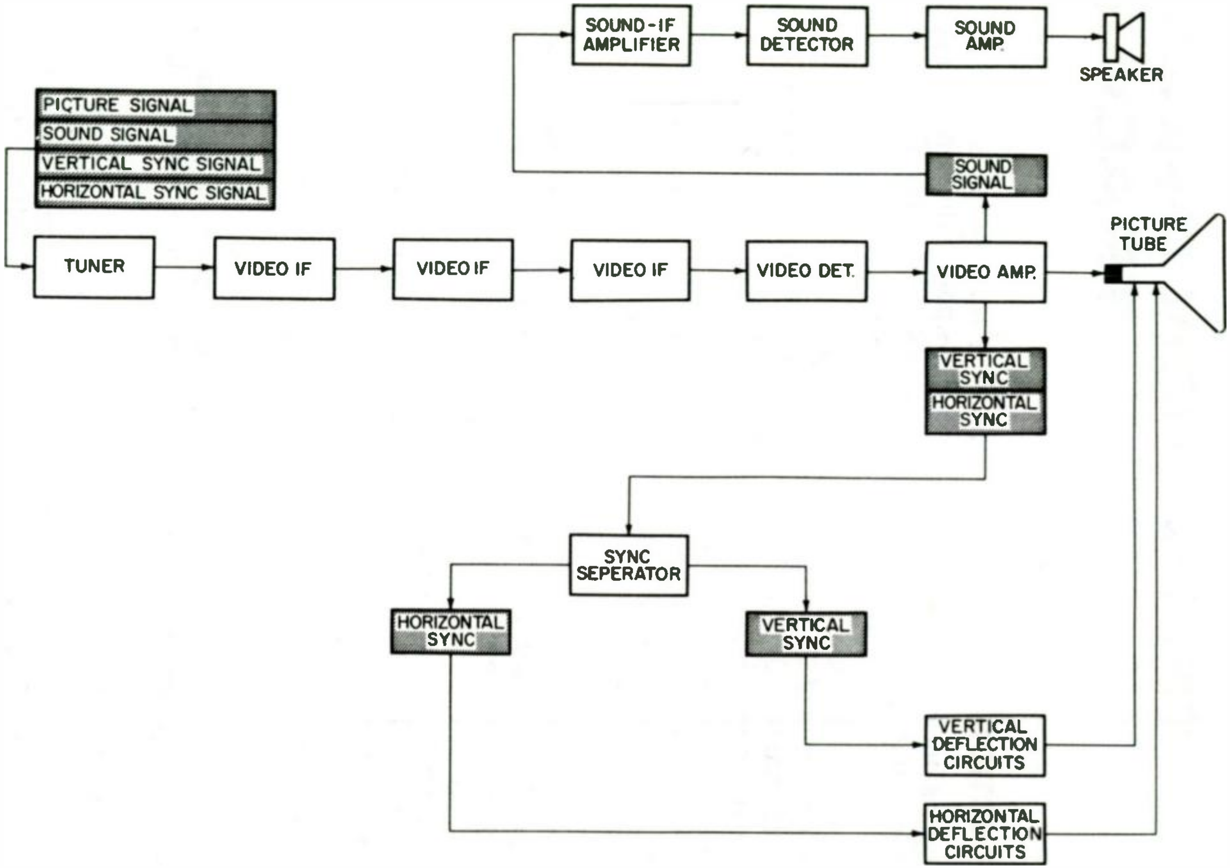


Figure 1 — Block diagram of a typical TV set.

strength by an amplifier—which in most sets resembles a phono amplifier, and which is serviced in much the same manner.

The synchronizing signals are likewise pulled off at the video amplifier and sent to a sync separator. As its name implies, this circuit separates the sync signals (vertical and horizontal) from the video signal. Then the sync signals are fed, through an appropriate waveshaping network which will react only to the desired portion of the sync signal (vertical or horizontal), to the vertical- and horizontal-deflection circuits. Here, the sync signals keep the oscillators in the deflection circuits in step with the transmitted signal. This prevents the picture from "rolling" (vertical-sync loss) or from breaking up into a mass of unintelligible diagonal lines which look like modern art gone wrong (horizontal-sync loss).

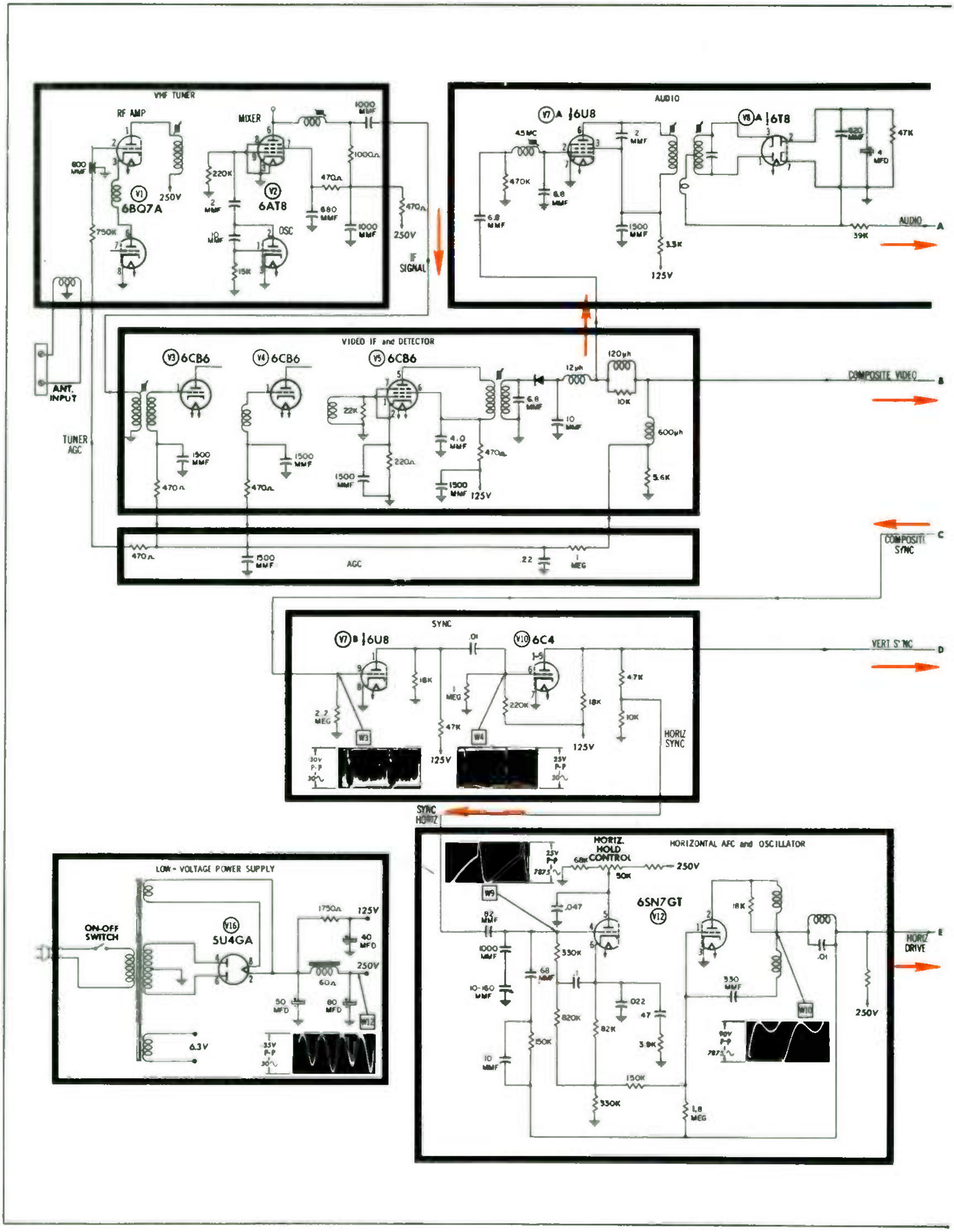
Circuit Analysis

You can see from the foregoing description that there isn't much sense in looking for trouble in the sound-amplifier system when the picture is rolling vertically. Neither is there any reason to investigate sync circuits when the trouble is stated as "no sound" from the speaker. Gaining knowledge of the path followed by each signal in the set is the first step to take when analyzing a circuit for the probable cause of the trouble. That is the logical way to troubleshoot any defective TV set: think the problem through instead of trying a hit-or-miss approach.

After logically thinking through the problem, the next step is to look at the electrical diagram for the TV receiver. The electrical diagram that is included in the service manual will not be divided into sections as shown in Figure 2. Figure 2 is simply another way of arranging the circuit into separate blocks, with each block enclosing a specific circuit function. This diagram, like most diagrams, also includes photos that show the desired shape of the waveform that should be present at the indicated test points.

Even though a schematic diagram shows each circuit action in a straight-line manner, these same components are generally not arranged on the chassis in the same physical relationship to each other. That is why line drawings that identify the location of the major components are usually included, as illustrated in Figure 3. The use of drawings similar to Figures 2 and 3 are included in service manuals, making it possible to locate and identify the components in any signal path.

In the early days of TV, most stations transmitted a test pattern (Fig. 4) for a few minutes before the regular programs. Some stations still transmit this test pattern, but they do it very late at night, or very early in the morning. Even though you might not see the test pattern on your TV, an analysis of its original use will show how the various adjustments and controls in a TV can affect the TV picture. This pattern is still used by manufacturers to align the TV receivers on their production line.


VHF TUNER
RF AMP
MIXER
OSC
V1 6BQ7A
V2 6AT8
IF SIGNAL
ANT. INPUT
TUNER AGC
AUDIO
V7A ½6U8
V8A ½6T8
AUDIO
VIDEO IF and DETECTOR
V3 6CB6
V4 6CB6
V5 6CB6
COMPOSITE VIDEO
AGC
COMPOSITE SYNC
SYNC
V7B ½6U8
V10 6C4
VERT SYNC
HORIZ SYNC
SYNC HORIZ
LOW-VOLTAGE POWER SUPPLY
ON-OFF SWITCH
V16 5U4GA
HORIZONTAL AFC and OSCILLATOR
HORIZ. HOLD CONTROL
6SN7GT V12
HORIZ DRIVE

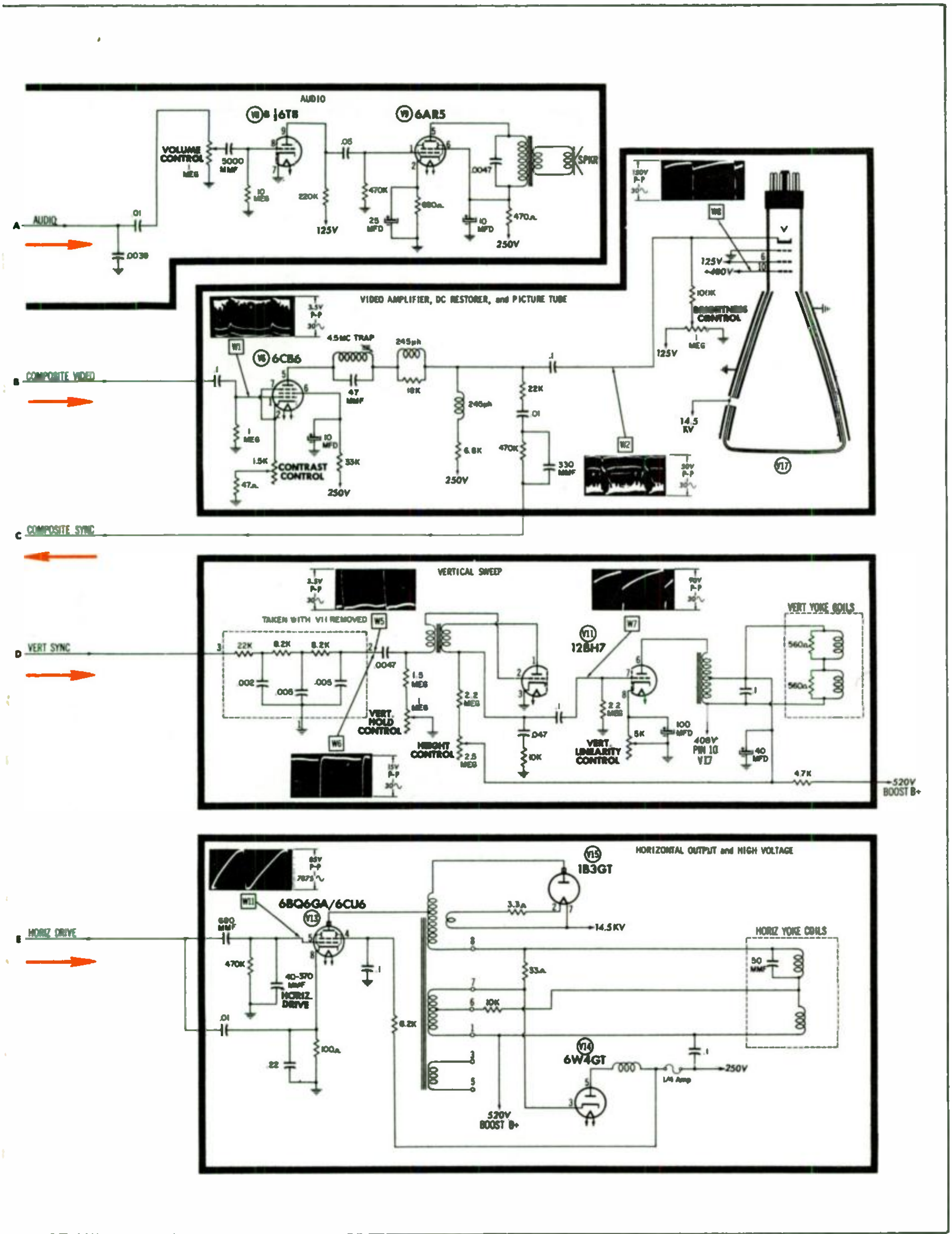


Figure 2 — A block diagram of a typical television receiver.

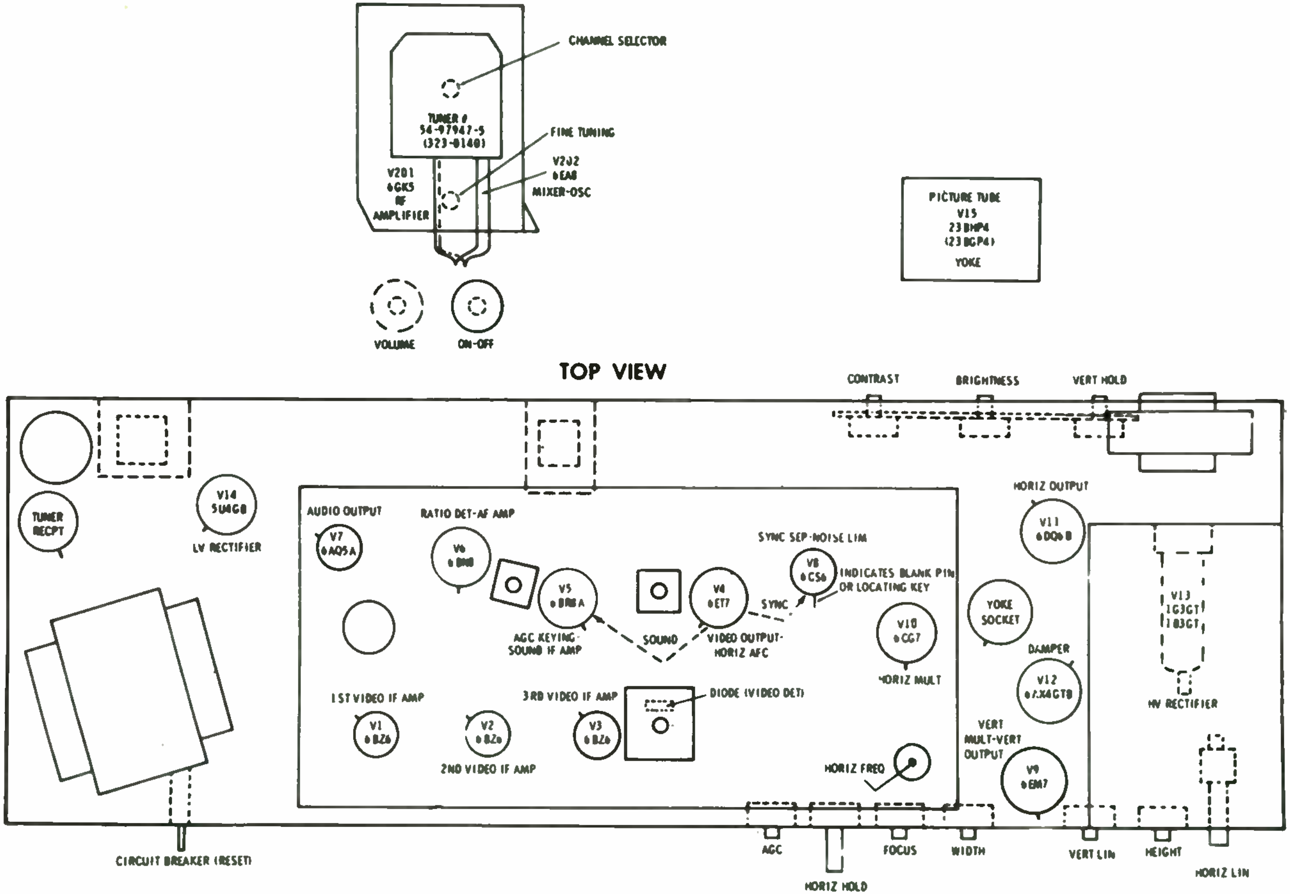


Figure 3 — A line drawing showing the location of the major components.

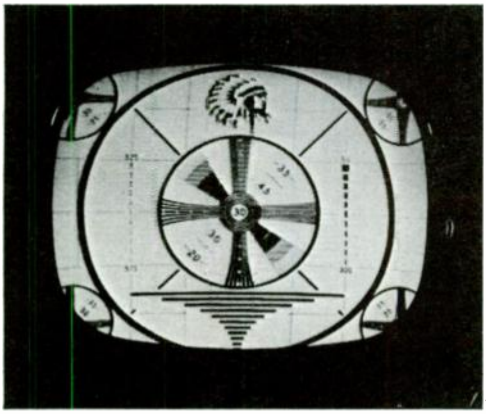


Figure 4 — A normal test pattern as it appears on a receiver that is operating normally.

TEST PATTERN ANALYSIS

A perfect test pattern is illustrated in Figure 5, with some of the more significant features indicated. These are the kind of instructions that would be followed by a technician in aligning receivers on a TV production line.

The shaded areas labeled "shading blocks" in Figure 5 are provided so that the contrast and brightness as well as the AGC can be correctly adjusted. To check these, adjust the contrast to a point about a third of the distance away from that at which maximum contrast is obtained; adjust the brightness control so that the desired screen illumination will be produced; then adjust the AGC so that the distinct values of black, dark gray, light gray, and white will match the values shown in the shading blocks of the figure.

The circles are provided in the test pattern so that picture linearity and centering may be adjusted. The height, vertical linearity, horizontal drive, horizontal linearity, and width should be adjusted so that a circle will be produced. Electrical or mechanical means are provided so that the raster can be correctly centered on the picture tube. Adjustment of the centering device must be done in conjunction with adjustment of the controls for picture size. It is not always possible to obtain a circle as perfect as that shown in the example test pattern. If there is more than a 10-per-cent variation from a perfect circle in either the vertical or horizontal direction, the defective section should be checked and the cause for the poor linearity should be eliminated.

The vertical wedge is used when the horizontal resolution is being checked. Horizontal resolution is an indication of the frequency response of the receiver. When the lines in the vertical wedge are clearly defined all the way up to the point that indicates a resolution of 320 lines, the receiver can be said to have a frequency response of 4 megahertz. (To convert resolution in lines to frequency response in megahertz, you divide the number of lines by 80.) The size of the spot produced by the electron beam also affects the horizontal resolution; therefore, the brightness, contrast, and focus must be correctly adjusted before the resolution is checked. The brightness should be set at a little below normal to prevent blooming of the spot. A very snowy picture cannot be checked for resolution because the snow would prevent an accurate reading. The white spots in the wedges correspond to the numbers shown in

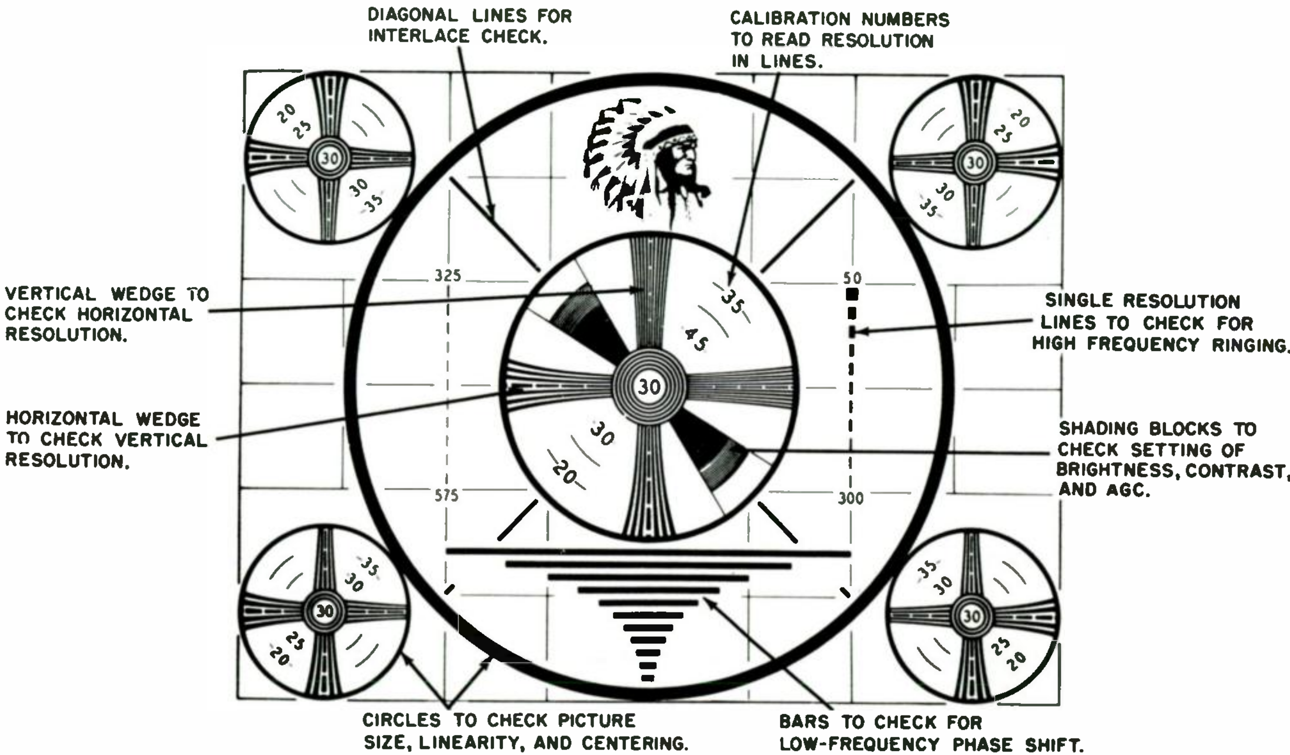


Figure 5 — A perfect test pattern.

the center circle. The number 30 indicates that the resolution is 300 lines at the corresponding radius on the wedge. In Figure 4, the horizontal resolution (as shown in the vertical wedge) is 300 lines. This equals a frequency response of 3.75 megahertz.

The horizontal wedge is used when the vertical resolution is being checked. Vertical resolution is read in lines only because it is a function of the electron-beam size and does not indicate frequency response. Vertical resolution is read in the same manner that horizontal resolution is read, and it indicates the active scanning lines. The number of active lines should be about 435.

The black bars at the lower center of the test pattern represent low-frequency, square-wave signals. The length of each bar determines the frequency–the longest bar represents the lowest frequency. Any smearing or trailing from the ends of the bars would be an indication of low-frequency phase shift, which is usually an indication of some defect in the video amplifier, output, or picture-tube stage. Such smearing or trailing could also be caused by difficulty at the transmitter.

The single resolution lines shown in Figure 5 may be used to check for the presence of high-frequency ringing in the video amplifiers at frequencies ranging between 600 kilohertz and 7 megahertz. There is a difference of 25 lines between each two successive resolution blocks or lines.

If the video amplifier response should happen to be peaked at some frequency because of excessive high-frequency compensation or some defect, a high-frequency oscillation at that frequency can occur. This will cause any video signal at that frequency to repeat itself several times and, in turn, will cause one or more of the numbered blocks or lines to be repeated.

As an example of ringing caused by excessive high-frequency response, let us assume that the line representing 350-line resolution was repeated three times and that the lines representing 325- and 375-line resolution were each repeated once. This would mean that the video amplifier was peaked at a frequency representing 350 lines (or at 4.375 megahertz, as found from the fact that the number of lines divided by 80 will equal the number of megahertz). This analogy can help to determine the frequency at which excessive peaking takes place and can make it easier to remove the cause of the excessive frequency response.

The relationship between the blackness or contrast of the horizontal wedge and the blackness of the vertical wedge is an indication of the low-frequency response of the receiver. If the low-frequency response were poor, the horizontal wedge would be gray and the vertical wedge would be black.

The diagonal lines on the test pattern can be used to check for proper interlacing action. If the interlacing is good, the lines will be straight; if the interlacing is poor, the lines will be jagged.

SERVICE MANUALS

All manufacturers publish service manuals that contain pertinent information about the repair and adjustment of each model of their TV receivers. These instructions usually include a list of the individual components with their electrical specifications. An example of one of these manuals is Diagram 8 in the *Diagram Envelope.* This is the Service Manual and Repair Parts List published by Montgomery Ward for their 12-inch black and white portable television receiver. These 16 pages include a description of the operation of the set, servicing precautions, installation instructions, and a complete set of alignment instructions. In addition, the manual includes a description of the operation of the circuit used in this receiver, views of both the component side and the wiring side of the printed circuit board, and a complete replacement parts list.

Instructions such as these also include a complete list of the test equipment required for a complete bench-type repair in a Ward's service shop. This is evident from the part numbers assigned by Wards to their own service equipment. All of this equipment might not be required each time a service call is made, because the majority of service calls only require tube replacement and minor adjustment of the controls.

A similar type of service manual is published by Howard W. Sams, Inc. under the trade name PHOTOFACT. These particular manuals include pertinent information supplied by each manufacturer. In addition to manuals for TV, PHOTOFACT service instructions are available for radios, record players, tape recorders, and other electronic devices. These manuals are usually available from a local electronics supply house.

The Service Manual and Repair Parts List (Diagram 8 in the *Diagram Envelope*) should be read throughout, except for pages 11, 12, 15, and 16. These 4 pages simply list the replacement parts that are available. Familiarity with the range of detail that is available in these manuals and familiarity with the alignment instructions given for each section of the circuit will go a long way towards analyzing TV troubles.

After some actual repair experience has been gained, the schematic diagram of the TV is sometimes all that is required. It is possible to locate specific controls by the physical nearness to the vacuum tube that is associated with that control. Diagram 9 is a circuit diagram that shows a great deal of information, which might be all that is required when repairing or servicing a TV. This schematic diagram of a Panasonic B&W TV illustrates the desired waveforms in a very clear manner, and a skilled technician would probably find little difficulty in locating and correcting trouble in the TV receiver.

SUMMARY

Most television circuit diagrams follow a general format, making it easy for the service technician to locate specific circuits. These uniform circuit layouts, together with the additional line drawings that are usually included in service manuals issued by manufacturers, enable the service technician to locate and identify the components on the chassis.

Service manuals should always be used when servicing a TV, but only after a logical analysis has been made of the possible cause of the trouble. When the trouble area has been pinpointed, the correct waveshapes shown in the service manual will enable alignment to be made by adjusting the proper controls. If a complete service manual is not available, an experienced serviceman sometimes needs only the schematic wiring diagram because the controls on most TV receivers perform the same function.

TEST

Lesson Number 90

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-090-1.

1. **Television schematic wiring diagrams generally locate the TV tuner**
   —A. in the upper left corner.
   B. in the central portion.
   C. below the picture tube.
   D. close to the power supply.

2. **TV signals after the tuner are first directed to**
   A. the video amplifier.
   B. the sync amplifiers.
   C. the sound circuit.
   —D. the video IF.

3. **The major parts of a black and white TV signal consist of:**
   A. 3 signals.
   B. the video and the sound signal.
   —C. 4 signals.
   D. none of the above.

4. **Synchronizing signals are pulled off after the**
   A. video IF.
   B. synchronizing amplifier.
   —C. video amplifier.
   D. horizontal amplifier first.

5. **Figure 2 shows that the 4.5 MHz trap is between the**
   A. video amplifier and the picture tube.
   B. video detector and the audio circuit.
   C. first two video stages.
   D. power supplies transformer and rectifier.

6. **The various shades of gray in a black and white picture can be obtained by adjusting these controls**
   A. volume and channel selector.
   B. contrast, brightness and AGC.
   C. horizontal hold and vertical hold.
   D. buzz and volume.

7. **Diagram 8 explains that a single video control is used for:**
   A. brightness, because it controls the signal input to the cathode of the picture tube.
   B. brightness and contrast, and is connected to the cathode of the picture tube.
   C. brightness and contrast, and is connected to the filament of the picture tube.
   D. none of the above.

8. **The Channel 2 sensitivity of the television receiver described in Diagram 8 is**
   A. 30 microvolts.
   B. 50 microvolts.
   C. 1.25 microvolts.
   D. 45 microvolts.

9. **The picture IF frequency of the receiver described in Diagram 8 is**
   A. 6 megahertz.
   B. 12 megahertz.
   C. 5 megahertz.
   D. 45.75 megahertz.

10. **The audio power output of the receiver described in Diagram 8 is**
   A. 50 watts maximum.
   B. 2 watts maximum.
   C. 6 watts minimum.
   D. 0.5 watts minimum.

Notes

Portions of this lesson were reprinted
through the courtesy of Montgomery Ward.

Portions of this lesson from
Television Servicing Guide
by Leslie D. Deane and Calvin C. Young, Jr.
Electronic Servicing For The Beginner
by J. A. Stanley
Courtesy of Howard W. Sams, Inc.

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

LET'S TAKE STOCK

Sometimes it's good to sit back and take stock of the progress you have made over a certain period of time—a kind of inventory of your new knowledge and ability.

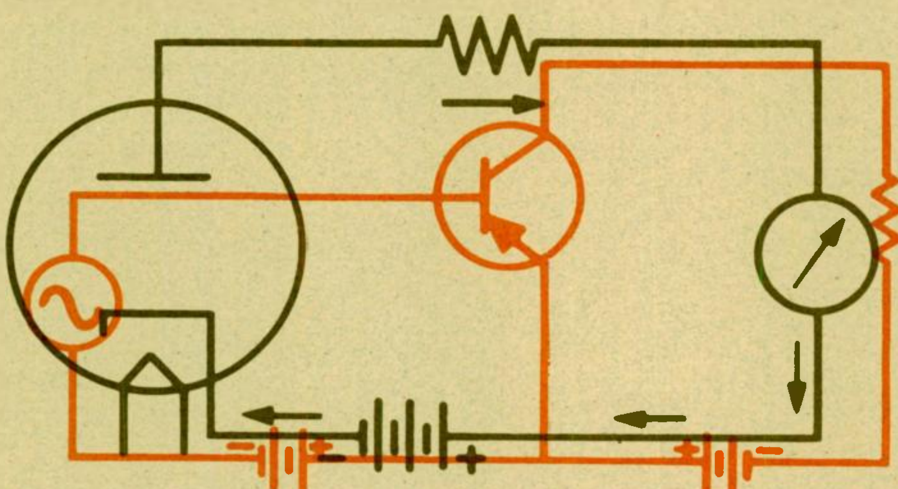
Now that you are nearly finished with your training program here at ASI, you can determine how much you have learned and how well you are able to apply this knowledge.

Upon completion of your course, you can accept your diploma with real pride. You can be very proud of your accomplishments in finishing your training and especially proud of your "stick-to-itivity."

S. T. Christensen

LESSON NO. 92

REVIEW FILM OF LESSONS 88 THROUGH 91



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-092
410

ADVANCE SCHOOLS, INC.
5900 NORTHWEST HIGHWAY
CHICAGO, ILL. 60631

Reprinted October 1974

REVIEW FILM TEST

LESSON NUMBER 92

The ten questions enclosed are review questions of lessons 88, 89, 90, & 91 which you have just studied.

All ten are multiple choice questions, as in your regular lesson material.

Please rerun your Review Records and film before answering these questions.

You will be graded on your answers, as in the written lessons.

REMEMBER: YOU MUST COMPLETE AND MAIL IN ALL TESTS IN THE PROPER SEQUENCE IN ORDER FOR US TO SHIP YOUR KITS.

REVIEW FILM TEST

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-092-1.

1. **All TV receivers have a**
   A. bar generator.
   B. square wave generator.
   C. built-in visual signal tracer.
   D. pulse generator.

2. **A defective filter capacitor in the DC supply generally causes**
   A. loss of FM sound.
   B. horizontal hum bars.
   C. jitter in the horizontal sync.
   D. vertical bars.

3. **Left hand vertical bars on the picture are caused by**
   A. hum on the vertical DC supply.
   B. Barkhausen oscillations.
   C. spurious oscillations in the vertical amplifier.
   D. all of the above.

4. **AM modulated signal generators can**
   A. be used for TV signal tracing.
   B. not be used for TV signal tracing.
   C. be used only on the UHF TV band.
   D. none of the above.

5. **Peak-to-peak hum voltage on the TV's DC supply is**
   A. about 5% of the DC level.
   —B. less than 1% of the DC level.
   C. not important.
   D. between 3% and 10% of the DC.

6. **A BN6 FM detector can be aligned**
   A. only with an oscilloscope.
   B. without a generator.
   —C. with an AM generator.
   D. only with a VTVM.

7. **Diode AGC systems can be clamped**
   A. by shorting the AGC bus.
   B. by a capacitor.
   — C. with a DC bias source.
   D. with an AC bias source.

8. **All keyed AGC systems use pulses from the**
   A. vertical sync system.
   B. quadrature sound detector.
   C. rectified sound carrier.
   —D. horizontal sync system.

9. **Troubleshooting of a television video system may be accomplished using a**
   A. 4.5 MHz FM signal.
   B. 45 MHz FM signal.
   —C. 400 Hz audio signal.
   D. any FM signal.

10. **Tube type instant-on systems**
   A. only open the DC supply voltage.
   —B. open the DC supply and lower the heater voltages.
   C. must use parallel heater circuits.
   D. must use a dual voltage transformer.

Notes

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

IMPORTANCE OF REVIEW

The successful student is a student who has constantly reviewed his lesson material throughout the course. To make it easier for the student, twenty review films are furnished in your Radio and TV Service and Repair course.

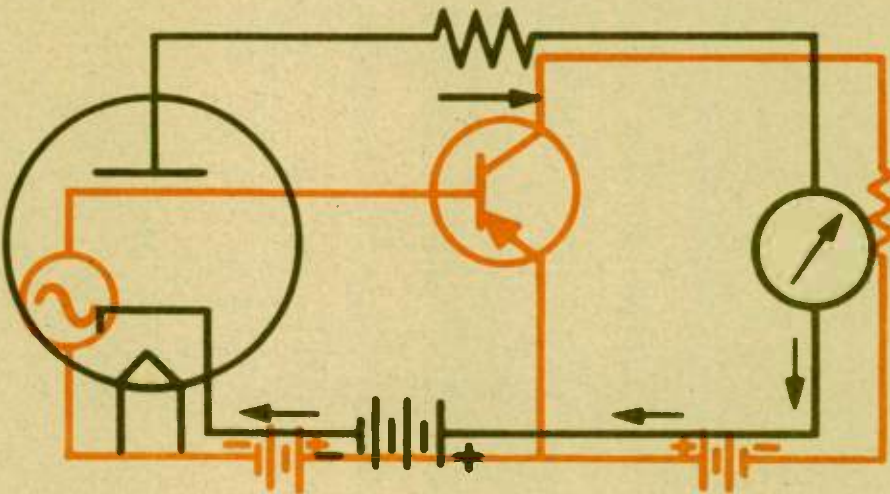
Get into the habit of reviewing these every few days. By the time you have finished the course, you will find that all of the important points are well locked in your mind.

Following the above advice will not only make you a more knowledgeable technician, but will, over a period of years, earn you money . . . hundreds of dollars more than is earned by the man who must constantly look up basic information.

S. T. Christensen

LESSON NO. 91

TELEVISION TROUBLESHOOTING PART 1



RADIO and TELEVISION SERVICE and REPAIR

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Contents

52-091

TELEVISION TROUBLESHOOTING PART 1

INTRODUCTION

In this lesson we will discuss trouble symptoms in the signal circuits in a TV receiver. A brief review of power supplies is also presented. Problems in the power supply can affect any or all sections or stages in a TV set.

Operation of the set is traced by following trouble symptoms through the TV from the input of the tuner to the CRT and speaker. The AGC is discussed in this lesson; even though it does not amplify or process sound or video. Loss of AGC can cause serious picture overload, loss of syncing and buzz in the sound. Excessive AGC voltage can wipe out the picture or make it very weak.

POWER SUPPLIES

Low-Voltage, High-Current Supplies

The signal reception portion of the receiver presents a power requirement not greatly different in voltage range from that of other electronic devices. Therefore, this portion of the television power supply is similar to that found in large radio receivers.

In general, the voltage requirement is no more than 300 volts in late-model tube receivers and may even be as low as 6 or 7 volts in the newer all-transistor sets. The current required, however, is frequently much greater than that necessary for radio operation. In addition, a good supply regulation is needed to operate the sawtooth oscillators for deflecting the electron beam of the cathode-ray tube. These oscillators tend to produce currents in the power supply. If not properly filtered, these currents would appear as serious modulation hum in the beam control and sound circuits.

Early receivers required heavy-duty power supplies to provide the current drawn by the 30 to 40 tubes in the receiver. These supplies employed from one to three rectifiers; the number, of course, depended on the current requirements and the designer's preference as to voltage and current distribution. Different voltages—both positive and negative—were needed by the other stages in the receiver, and an elaborate voltage-divider or distribution network was needed to produce these voltages. The current drawn by several of the stages was generally passed through the focus coil (no longer used), and thus made to do double duty.

As the receivers were simplified, the voltages and currents needed from the power supply decreased; and the power supply was also simplified. Figure 1 shows the schematic of a power supply simplified

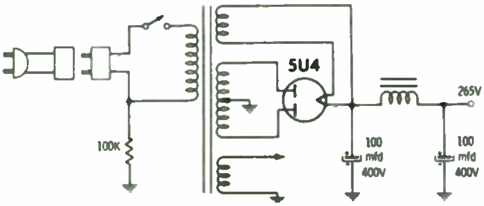

Figure 1 — Schematic of a low voltage power supply using a power transformer and a vacuum tube rectifier.

almost as much as a transformer supply can be. Only one output voltage is available; stages requiring less voltage are provided with individual voltage-dropping resistors. The current requirement is met by a single vacuum-tube rectifier. This type of supply, with many minor modifications and additions, was used in numerous television receivers.

The introduction of semiconductor rectifiers offered an opportunity to simplify and lighten re-

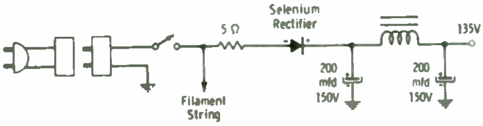

Figure 2 — Schematic of a low voltage power supply using a selenium rectifier.

ceivers by eliminating the heavy and bulky power transformer. Figure 2 shows a typical half-wave rectifier circuit using a selenium rectifier. Since only 135 volts are available from the supply, the other circuits in the receiver must be designed to operate on this relatively low voltage. Those few circuits requiring more voltage, derive it from the boosted B+ voltage from the damper. The development of this extra voltage was discussed previously.

Many of the more modern black-and-white and color TV sets are being provided with a special type of line cord which only allows the set to be plugged into the AC house outlet in one direction. Most homes built within the last few years, use AC receptacles designed for this type of plug that has one slot wider than the other. The wider prong of the AC line cord and the AC receptacle are connected to ground through the house wiring. Some sets designed for commercial installation use a three-wire AC line cord. Both types of cord ensure proper grounding of the chassis and

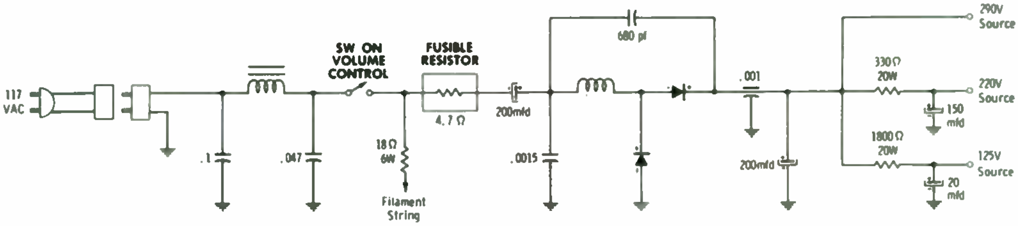

Figure 3 — Schematic of a low voltage power supply using a voltage doubler circuit.

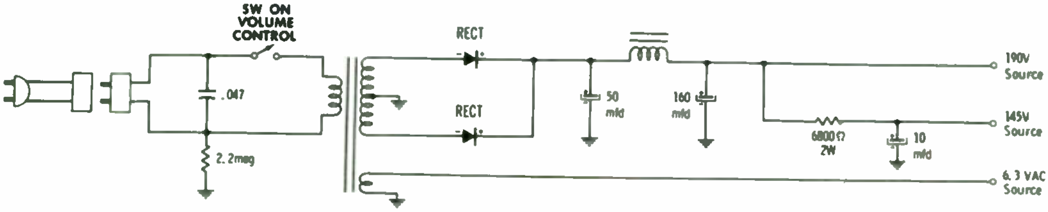

Figure 4 — Schematic of a low voltage power supply using a transformer and solid state rectifiers in a full wave configuration.

any exposed metal parts. Any set owner not having a modern type AC receptacle for his set should be encouraged to have an electrician install the modern receptacle. Under no conditions should the technician alter or replace the AC line cord in such a way as to destroy this safety feature.

While the AC distribution section is considered part of the "low-voltage" system, keep in mind that this section has perhaps the highest shock hazard of any part of the set. *Always be very careful when working in the low-voltage sections.*

The circuit in Figure 3 is used in many present-day receivers. The doubler connection produces a voltage slightly higher than twice the line voltage. The 4.7-ohm fusible resistor in series with the line acts as a fuse. This circuit and the one in Figure 2 have one disadvantage—the chassis is connected to one side of the power line. The user could receive a dangerous electrical shock between the chassis and any grounded metal if the AC plug is inserted so that it connects the chassis to the high, or "hot," side of the AC line. A power transformer can be used with semiconductor rectifiers, as in the full-wave circuit of Figure 4, to eliminate the shock hazard.

When other circuits need various voltages from a power supply, voltage-dropping resistors are necessary. These are usually high-wattage resistors, and they generate considerable heat. To conserve power and to lower the heat in the receiver, manufacturers have used the circuit in Figure 5. In this circuit, the audio output tube serves as a voltage-dropping resistor, in addition to its role as an output tube.

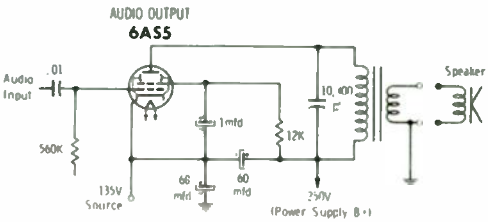

Figure 5 — Audio output stage used as voltage divider for separate B+ source.

The plate resistance of the tube serves as a dropping resistor. The resultant voltage at the cathode is supplied to such stages as the IF, sync, and video amplifiers. Although the output-tube plate current varies at the audio rate, the low B+ is held constant by large-value filter capacitors.

A large number of present-day television receivers are either all-transistor models or a combination of tubes and transistors. The combination sets (often referred to as

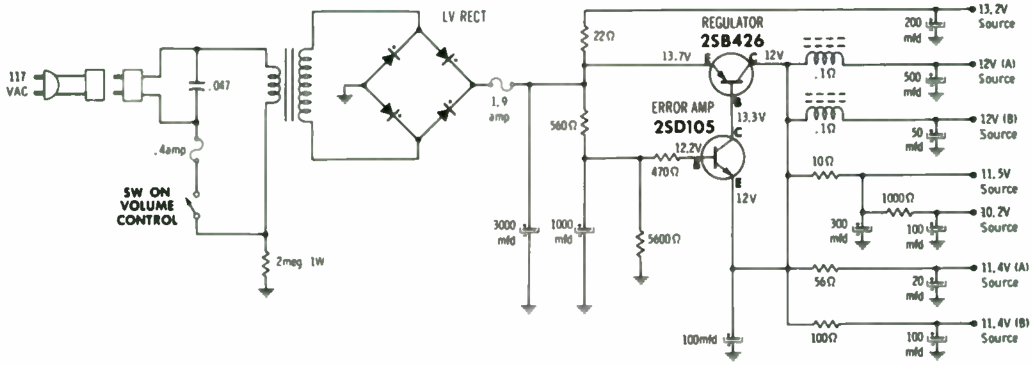

Figure 6 — Typical low voltage power supply used in transistor receivers.

hybrid sets) usually employ a low-voltage power supply similar to that shown in Figure 4, but with an additional secondary winding with rectifier and filter to provide voltages ranging from 5 to 15 volts for operation of the active solid-state elements. Figure 6 shows a typical low-voltage power supply used in all-transistor receivers. Generally such supplies are voltage regulated, as this one is, to deliver a relatively constant output.

High-Voltage, Low-Current Supplies

The high-voltage supplies differ considerably from the supplies just discussed. The current required is quite small, usually around 300 microamperes, while voltages may be extremely high. Present-day receivers may have cathode-ray tube accelerating potentials from 5000 to 30,000 volts.

Since high-voltage power supplies represent extremely dangerous shock hazards, it might be well to consider normal precautions to be followed when working with them.

First, position your bench well away from metal objects or wiring which might provide an accidental contact to ground or to a voltage source. Don't use metal bench tops. If the floor is concrete, it should be covered with a substantial rubber mat or other good insulating material. Make the mat large enough to avoid any possibility of your stepping off during normal service operations.

Second, don't attempt high-voltage measurements unless they are necessary. Resistance measurements will identify many power-supply troubles. If high potentials must be measured, do so in the approved manner. With power switch off and plug disconnected, hook up the test lead to the ground, or low-potential side of the circuit. If you connect a clip lead to the high-potential side of the circuit, use only one hand. Make sure the power is off and the high-voltage supply is completely discharged before making any connection to the receiver.

If a probe-type instrument is used with the power supply operating, use only one hand to place the probe at the test point. Keep your other hand in your pocket to avoid contact which might establish a circuit through the body. In other service operations, such as alignment, the high-voltage circuit should be disabled. Testing any electronic circuit involves nine mental operations to one manual operation. Think—then act!

Troubleshooting Low-Voltage Power-Supply Problems

There are three main types of problems that arise from low-voltage power supplies. They are:

1. Complete loss of voltage.
2. Reduced low voltage.
3. Hum.

We will examine these types of problems one at a time starting with a complete loss of voltage.

If the set you are working with has only one power supply and it fails, then the whole set will be dead. That is, there will be no raster and no sound. Power supply failure can be confirmed simply by measuring the output of the power supply with a voltmeter.

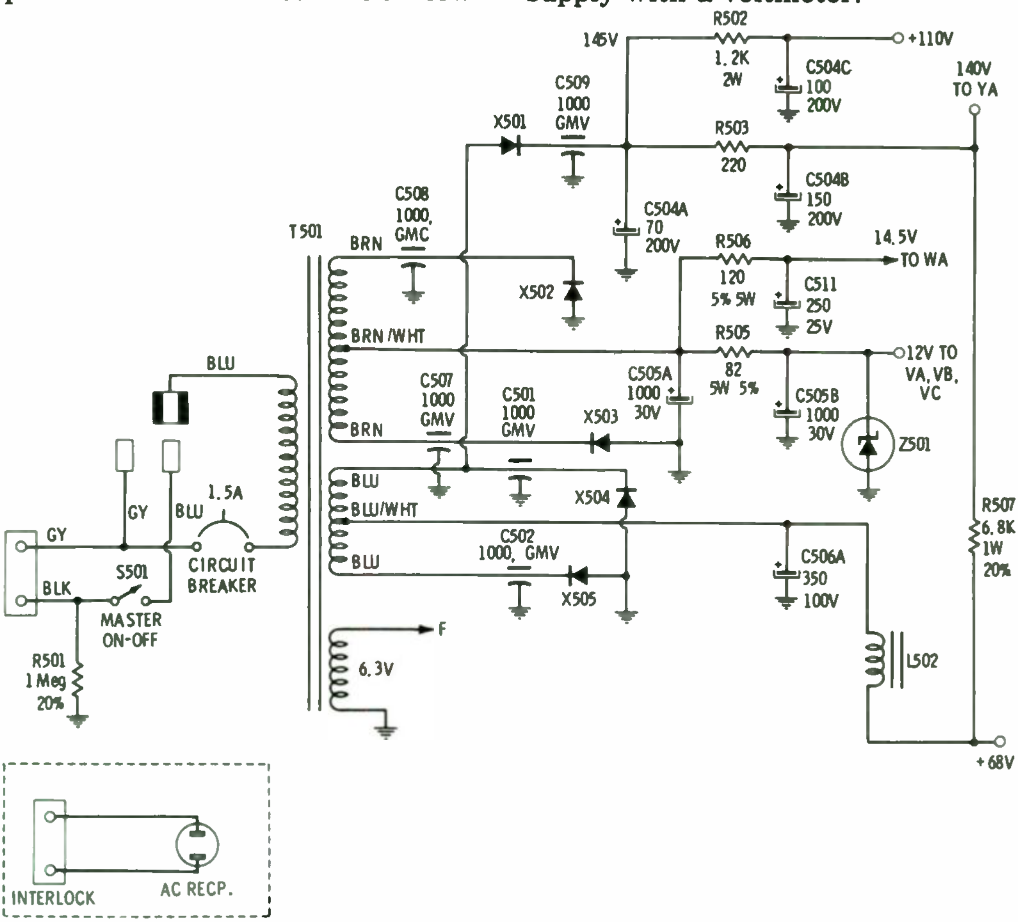

Figure 7 — Power supply for a transistor set.

It is a good idea to measure the DC voltage across one of the filter capacitors with a DC voltmeter. If the DC voltage is zero, check the AC voltage at the input to the transformer. If the AC voltage is zero, then the problem is in the AC distribution circuit. If the AC is all right and the DC output is zero, then the problem is in the transformer, rectifier, or filter. Since there are usually only a few parts in a power supply, each component can be checked individually if necessary.

If the set has several power supplies and one of them fails, then only the part of the set depending on that supply will be dead. For instance, the power supply shown in Figure 7 has three power supplies and five output voltages. These voltages are divided among the stages as follows:

140-volt output. . . .video output stage only
110-volt output. . . .audio output stage only
68-volt output . . . . .vertical and horizontal output stages only
14.5-volt output . . . . . . .horizontal driver stage only
12-volt output . . . . .remainder of set

Suppose that R_{502} burned out. This would kill the 110-volt output and the sound would be dead. As soon as you checked the audio output stage, you would find no collector voltage. Then trace the voltage back to the supply where the trouble would be found.

Similarly, if X501 failed, both the video and sound would be dead. You would find the trouble in the same way.

On the other hand if the 14.5-volt output were out (say R_{505} burned out), then the horizontal driver would not work and there would be no raster, but the sound would be OK. Again, find the trouble by checking the horizontal-sweep section. You would find no voltage in the driver and trace it back to the power supply.

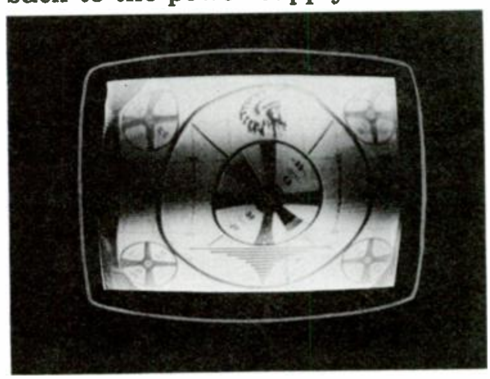

Figure 8 — Reduced low voltage symptom.

If the output of a power supply is low, the classic symptom is a shrunken picture like the one shown in Figure 8. In extreme cases both width and height can be affected. In trouble-shooting this problem, you should check the voltages in the affected sections (horizontal), then check them in the power supply. Comparison to the circuit diagram values would reveal any reduced value. Reduced voltages are most frequently caused by either defective power-supply diodes or leaky filter capacitors.

Filter capacitors are also the

most frequent cause of hum in the sound, video, or raster. When objectionable hum is in the sound, check the filter capacitors in the power supply which operates the sound circuits.

Hum in the video appears as a black horizontal bar in the picture. Figure 9 shows this symptom. Notice that one bar is present; this represents 60-Hz interference such as from a bad filter in a halfwave supply, or a heater to cathode short in a tube. Two separate bars will be present if the interference is 120 Hz. as from a fullwave supply. In this case check the filter capacitors in the power supply which operates the video circuits.

Hum in the raster appears as bending; the sides of the raster have a sinusoidal curve to them. Hum can get into the raster through the stages which operate the horizontal-sweep circuits.

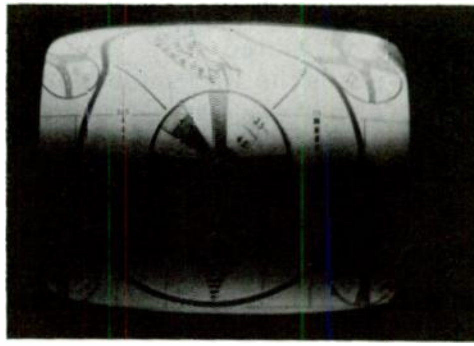

Figure 9 — Sixty hertz hum bars in a picture.

Therefore, suspect the power-supply filter in the supply which furnishes voltage to these circuits.

A current halfwave supply is shown in Figure 10. This is the supply used in the Panasonic receiver represented by Diagram 9 from your *diagram envelope.* The filter is a pi section network with a choke coil. Observe the waveforms and ripple voltages at the input and output of the filter. The 15 volt sawtooth-shaped-waveform at

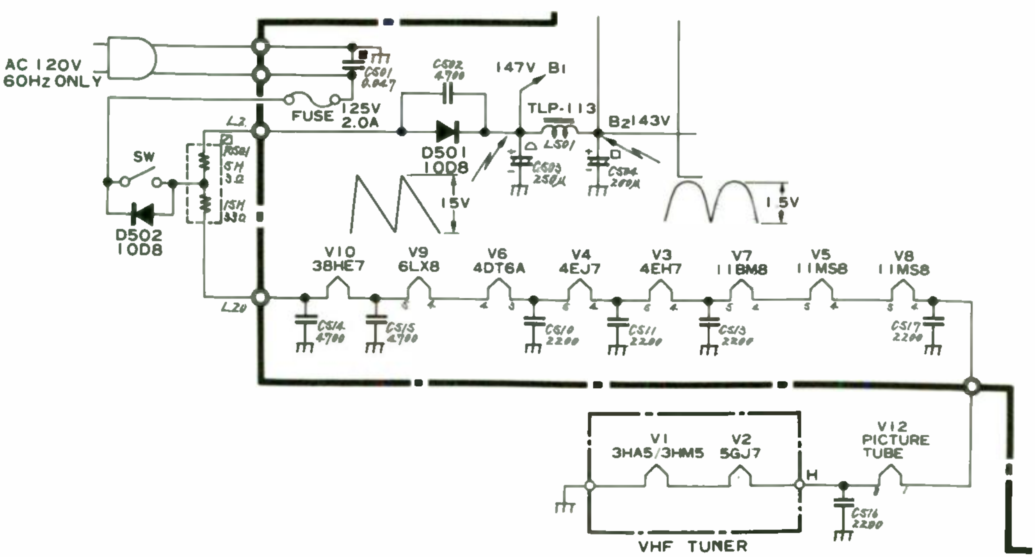

Figure 10 — A halfwave low voltage power supply used in a popular set. ***Reprinted with permission from Panasonic, Matsushita Electric Corporation of America.***

point B_1 is a peak-to-peak reading such as measured with an oscilloscope, as is the 1.5V indication at B_2. If either C_{503} or C_{504} should become defective these voltages will be considerably greater.

This particular set has only one DC voltage line from the power supply, therefore, a defective filter capacitor can affect any circuit in the set. Some functions may be affected more than others depending upon the nature of the defect and how sensitive the stages are to power supply abnormalities. Always be alert for power supply malfunctions as they can be deceiving.

The set illustrated has the instant on feature as do many current sets. Diode D_{502} passes the negative half cycle through the filament string to keep the heaters warm when the switch is off. There is an absence of B+ power, however, because diode D_{501} can pass only the positive half cycle.

A series heater string is used with appropriate bypassing at certain points. Observe that each side of the 38HE7's filament is bypassed (C_{514} and C_{515}). This prevents horizontal pulses on the cathode of V10 from being coupled into other tubes and circuits through the cathode to heater capacitance of the tubes. Other bypasses keep sync, video, sound and other signals from coupling into stages and upsetting their functions.

TUNER TROUBLE

The tuner in a television receiver is a little like the quarterback of a football team. The quarterback selects the play that the team will use, and the tuner selects the channel that the set will work on. In doing this the television tuner has three basic functions:

1. It selects the desired channel.
2. It adjusts the level of the signal.
3. It converts the signal to the intermediate frequency (IF).

These basic functions should be kept in mind as we discuss the tuner's operation. Inside the tuner block there are normally three stages. These stages are:

1. The RF amplifier.
2. The oscillator.
3. The mixer.

Figure 11 shows how the tuner stages are connected to each other.

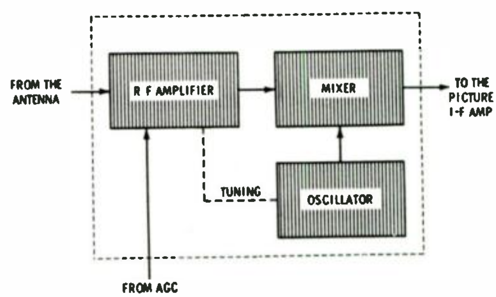

Figure 11 — The tuner stages.

Recognizing The Symptoms

If the mixer stage fails, the symptoms will look very much like a failure in the first IF amplifier. There will be some snow on the screen, and there may or may not be some very weak video and sound.

In many sets (solid-state ones in

particular), you can check the IF amplifiers by switching the channel selector to a point between the two channels. If some snow appears on the screen, the IF amplifiers are alright. However, this test will not work with all sets.

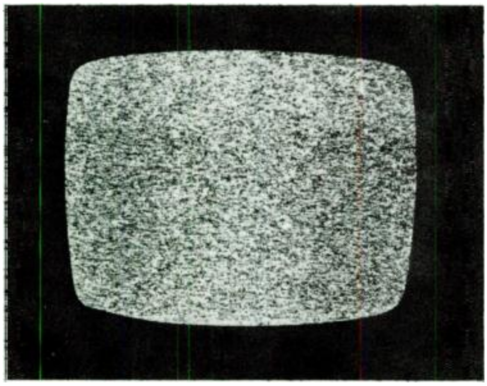

Figure 12 — RF amplifier failure symptoms.

The RF amplifier stage selects the desired channel and adjusts its level. If this stage fails, the symptoms will be about the same as those described for a bad mixer, except that the snow will be much more severe. Figure 12 shows the screen of a set with a defective RF amplifier. It should be kept in mind that there may be some weak video and sound present. The severe snow associated with an RF amplifier failure is dramatic enough that it should be easy to recognize.

The television antenna is really part of the RF amplifier circuit. If there is a problem in the antenna, it will look like a bad RF amplifier. So the antenna connections should be checked when the heavy snow associated with a bad RF amplifier is seen.

The oscillator signal is mixed with the RF amplifier signal to produce the picture IF signal. If the oscillator fails, there will be no IF signal; and since most of the snow seen when the RF amplifier fails comes from the oscillator, there will normally be very little snow.

In summary then, a failure in the tuner will give these symptoms:

1. If the mixer fails there will be some snow and there may or may not be some weak video and sound. It looks a lot like a first IF trouble.
2. If the oscillator fails, there will be little snow and no video or sound. It looks a lot like a third IF trouble.
3. If the RF amplifier fails, there will be severe snow and there may or may not be some weak video and sound. *Do not forget to check the antenna and its connection.*

Tuning a TV Receiver

Before looking at tuner circuitry, consider how a set is tuned to various channels. If every stage from the RF amplifier through all the IF stages to the video detector had to be tuned each time the channel was changed, it would be awfully complicated.

You have probably seen pictures of old-time radios with lots of tuning knobs. Those old radios were called tuned-radio-frequency (TRF) sets, and you did have to tune every RF stage separately.

A television set uses a tuning method called *heterodyning.* With this method, all of the stages except two are permanently tuned to an *intermediate frequency* (IF). In a TV set the intermediate frequency is about where Channel 1 would be if there were such a channel. So, if you want to, you can think of all parts of the set working on Channel 1 except the tuner. The tuner itself works on all of the channels except Channel 1.

To better understand how this heterodyning system works, let's go through an example. Suppose that it is desired to watch Channel 6 which is on a frequency of about 83 MHz. The RF amplifier is tuned to this frequency, and it picks up Channel 6. The RF amplifier amplifies the signal and feeds it to the mixer stage.

At the same time that the RF amplifier is tuned to 83 MHz, the oscillator is tuned to about 129 MHz. The oscillator generates a signal of its own at this frequency and feeds it to the mixer. Inside the mixer, the two separate signals are *heterodyned*—that is, they are mixed together in a way that creates a signal that is equal to the *difference* between them. This difference in signal is the intermediate frequency (about 46 MHz).

If we switch to a new channel both the RF amplifier tuning and the oscillator tuning is changed. But, the difference between them stays at the intermediate frequency. In this way only two stages at a time must be tuned instead of 6 or more as would be the case with a TRF circuit.

You can probably guess it is important that the frequency of each channel be kept very accurately fixed. Also, the tuning circuits of the RF amplifier, oscillator, mixer, IF amplifiers, and detector must not be tampered with if the system is working well, especially by the beginning technician.

The adjustments necessary to get the whole set working right are very delicate and complicated. Only a thoroughly trained, specially equipped technician should undertake to align or adjust a television receiver.

The successful small-shop serviceman confines his alignment activities in the tuner to adjusting the individual channel oscillator screws or slugs, to bring in the channels. In troubleshooting a tuner he confines his repair activities to changing tubes. When problems develop that are due to internal components other than tubes the wise, small-shop operator simply pulls the tuner and sends it out for exchange or repairs. A large number of specialty companies do nothing other than tuner rebuilding and repair. Most of them advertise in leading service magazines, or their locations may be obtained from your local supplier.

Both the video and sound pass through the picture IF amplifiers. Therefore, a failure in this section would be expected to affect both the picture and the sound. This is indeed what happens.

The picture IF section usually contains either two or three IF am-

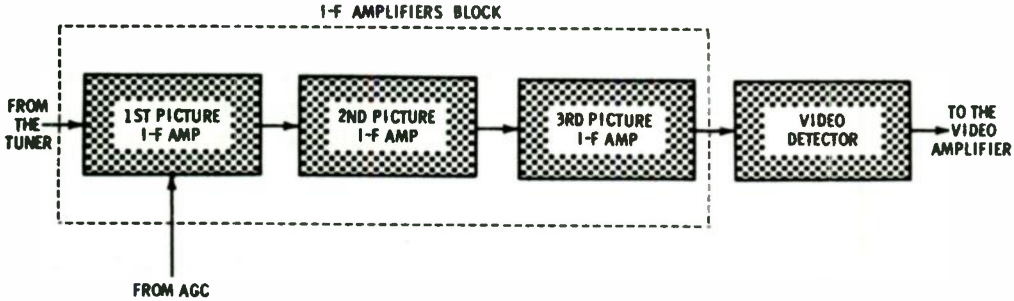

Figure 13 — The picture IF section.

plifier stages. Figure 13 shows a three-stage picture IF block. The video detector is also shown in this illustration. It is often difficult to distinguish between detector and third IF stage failures. For this reason, consider the detector to be a part of the picture IF amplifier section.

RECOGNIZING IF AMPLIFIER TROUBLE

Check the blocks in Figure 13 one at a time and consider what happens if they fail. If the video detector fails, both the sound and the video will be dead. By listening very carefully to the sound while varying the volume control, you will hear:

1. Some soft background hum.
2. Some soft background atmospheric noise. (usually a hissing sound) which goes up and down with the volume control.
3. No program sound.

The picture will have a normal-appearing scanning raster and no video. If the contrast control is varied there will be little noticeable change in the picture.

The third picture IF amplifier will produce the same symptoms if it fails. There may be slightly more hissing in the sound, and at full contrast just a hint of snow may appear in the picture.

Skip over the second picture IF stage for a moment and consider a failure in the first IF amplifier. The first picture IF amplifier stage gets its signal from the tuner and a control voltage from the AGC circuit. The AGC operation will be examined later, for the moment ignore it.

If the first picture IF stage fails, both the sound and the picture will be affected. However, the effect will be quite different from a third IF amplifier failure. Even if the first IF stage fails completely, some picture or sound will usually leak through. Also, since there is some noise generated inside each amplifier stage, some snow can usually be seen when the contrast is turned up.

The symptoms usually associated with a defective first picture IF stage are:

1. Very weak video with some snow.

2. Very weak sound with a hissing background noise.
3. Both 1 and 2 at the same time.

If the first picture IF stage fails a weak, washed-out looking picture will result.

In some sets there are only two IF amplifier stages. In that case there is no problem with the middle IF stage. In other sets there are three IF stages so problems do arise with the middle one.

Because the second IF stage is between the first and third ones, its failure symptoms can be *similar* to those of either of the others. For example, there may be some picture or sound leading through—but then again there may not. Also there may or may not be some snow in the picture. And there may or may not be some hissing noise in the sound.

Perhaps the best way to go is to look at the symptoms and decide if you think it is in the first part of the IF section (weak video or sound, some snow and hiss), or in the last part (no video or sound, little snow and hiss). If the first part is suspected, check both the first and second stages. If the last part is suspected, check the second and third stages.

A good way to isolate trouble to the IF section is to:

1. Vary the contrast control while watching the picture very closely. Any noticeable change in the picture means that the video amplifiers are probably OK.
2. Flip the channel selector from station-to-station. If the IF stages are OK, some change should be seen in the picture. (Provided the video is working all right.)

In many sets, particularly solid-state ones, if the channel selector is set *between* channels, you will see snow on the screen if the IF section is working.

VIDEO DETECTOR CIRCUITRY

The video detector performs two services in a television receiver. It converts the video from the picture IF signal back to actual video. And it also converts the sound signal to the sound IF frequency. Figure 14 shows a simplified video-detector circuit. The input signal from the picture IF stages is usually detected by a solid-state diode.

In some sets the sound IF signal is separated from the video signal at the video detector. This is the case in Figure 14. When the sound is removed at this point there will be a sound trap like the one shown. This trap prevents the sound IF signal from entering the video amplifiers.

In other sets the sound IF signal is taken off *after* the first video stage. In such a case the sound trap would not be in the detector circuit at all. It would be just after the sound takeoff point between the first and second video amplifiers.

A few sets use separate sound

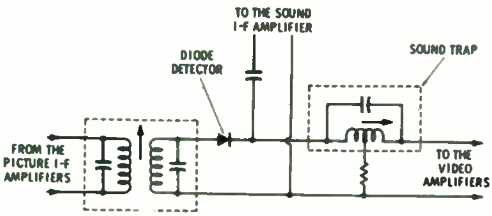

Figure 14 — Simplified video detector circuit.

and video-detector circuits. Both detectors are about like the one shown in Figure 14.

In any case the video detector will be a very simple circuit. Because of its simplicity, it fails only rarely. It should not, however, be completely forgotten.

The tuning of the coils and traps in the detector circuit is critical and difficult. These adjustments should only be changed by an expert technician who is very familiar with the procedure.

VIDEO AMPLIFIERS

A television receiver may have only one video-amplifier stage, or it may have several. Vacuum-tube and hybrid sets tend to have fewer video-amplifier stages than do solid-state sets. In any case, the first video-amplifier stage will perform several functions. These functions are:

1. Video amplification.
2. Takeoff point for the sound IF signal.
3. Takeoff point for the sync signals.
4. Takeoff point for the AGC signal.

If this stage fails it will normally cause symptoms to appear in sound, video, and sync outputs. Consequently, if the sound and raster are normal, then the first video amplifier can be assumed to be functioning properly.

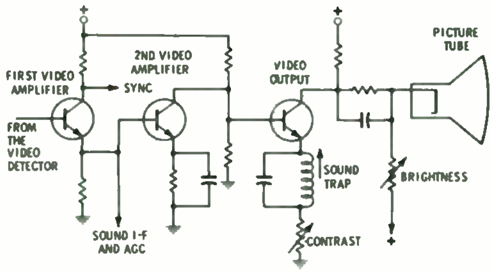

Figure 15 — A simplified video amplifier section.

Figure 15 shows a simplified 3-stage video amplifier. The first stage is an emitter follower and the sound, sync, and AGC are taken off before the second stage. A failure in the second video amplifier or video-output would cause a loss of video but would probably not affect the sound or raster.

A normal troubleshooting procedure would be to measure the voltages and compare them to the normal values. Also the video signal could be observed with an oscilloscope at the input (base) and output (collector) of each stage. When the earliest stage which does not pass the signal is identified, the individual components can be checked to isolate the problem. As in other circuits, the active device (tube or transistor) is the thing which most often fails and it should therefore be checked first.

It is fairly common practice to use direct coupling in video amplifiers as is shown in the illustration. Notice that not only is the video signal directly coupled but the bias on each stage is directly affected by the preceding stages. For example, the base bias voltage on the output amplifier is the same as the collector voltage on the second stage. This type of coupling frequently causes some confusion when troubleshooting.

To illustrate this point, imagine that the second video amplifier fails due to an emitter-to-collector short in the transistor. This failure would cause the collector voltage at the second video stage to drop to a value much below normal. Since this collector is tied directly to the base of the output stage, the output amplifier base voltage would drop also. When the base voltage dropped, the base current would drop, and the output transistor would cut off. This would cause the collector voltage of the output stage to increase to near the value of the collector supply. This increase in output collector voltage would cause an increase in picture brightness so the external symptoms would be normal sound, no video, and a bright raster.

This would be recognized as a video-amplifier failure and the circuit should be checked with a volt-ohmmeter. When the output-stage collector voltage is measured, it will be too high and if no further check is made a lot of time may be wasted looking for trouble in the output stage.

To avoid this kind of confusion, it is sensible to check each stage of a direct-coupled amplifier before jumping to conclusions. If this is done in the case above, it will be found that the collector voltage of the output stage is high, the collector voltage at the second video amplifier is low, and at the first video amplifier it is normal. In almost all cases it is *the earliest abnormal direct-coupled stage* that causes the trouble.

The sound-trap circuit in the video-output stage should also be examined. The circuit is tuned to the 4.5-MHz sound IF frequency. Its purpose is to prevent the sound signal from being seen in the picture. If there is sound present in the picture, it may indicate that the trap is misaligned or that the capacitor in the trap is shorted. If the capacitor is open-circuited, the video gain will be reduced at higher frequencies and will result in a serious loss of picture detail.

The circuit shown in Figure 15 is an extremely simplified version of a video amplifier. To get a more practical familiarity with typical circuits, video amplifiers in the set diagrams in your diagram envelope should be examined.

A failure in the picture tube can also result in a loss of video. When the picture tube is suspected, it can be checked with a CRT (cathode-ray tube) tester or by substituting a known good tube.

CONTRAST CONTROL

Varying the video voltage applied to the picture tube causes the brightness of the spot to vary. When the spot is completely cut off, the screen is dark. When the spot is full on, the screen is producing maximum light. The difference between the light and dark parts of the screen is what is called *contrast*. Since the variation from light to dark depends on the variation in video voltage, it can be seen that the greater the video variation is, the greater the picture contrast will be.

The variation in video voltage depends very much on the gain of the video amplifiers. Therefore the contrast control in the set is actually a video-gain control and will always be somewhere in the video-amplifier circuitry. In most cases (but not all) the contrast control is found in the video-output stage.

Summary of Video Troubles

As previously discussed, when the sound and raster of a set are normal while the video is missing, the trouble must lie in the picture tube or in the video amplifier. However since the sound, sync, and AGC are generally taken off at the first video stage, a failure in this stage will usually also affect the sound output and/or the sync.

AGC PROBLEMS

When a television set is switched from one station to another the picture (and sound) quality should ideally, stay the same. If all television stations delivered the same signal strength to the set, the problem of uniform quality would not be so difficult to deal with.

Unfortunately, different stations have different output levels. Also, the signals from different stations come to us over different distances and from different directions. The signals may be affected by different weather conditions and many other factors. As a result, two different stations will almost always provide different signal levels to the receiver. Moreover, many of the factors affecting the received signal will change from minute to minute.

Purpose of Automatic Gain Control

The *automatic gain control* (AGC) section of the set adjusts the set performance to compensate for these variations in the received signal. To do this the AGC circuit

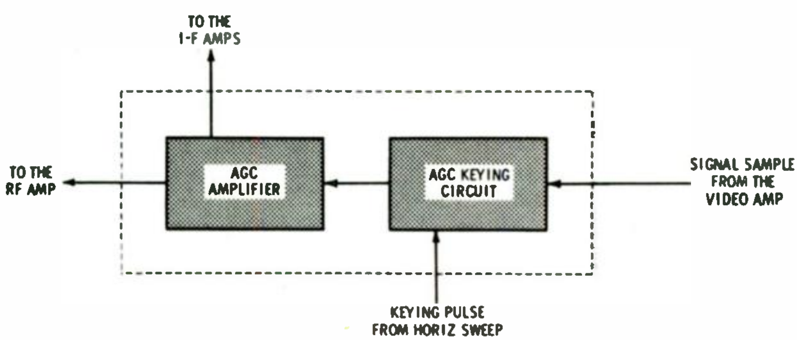

Figure 16 — Typical AGC circuit.

samples the received signal at the video amplifier as indicated in Figure 16. If the video signal is too weak the AGC circuit increases the amplification of the IF amplifiers and the RF amplifier. If the video signal is too strong, the AGC decreases the RF and IF amplification. In this way the AGC system continuously adjusts the receiver circuits to produce a good uniform-quality picture in spite of the variations in the incoming signal strength.

Inside the AGC block two things will usually be found. They are:

1. An AGC keying circuit which is sometimes called the *AGC gate.*
2. An amplifier for the AGC signal.

Figure 16 shows the interconnection of these two circuits.

Producing the Automatic Gain Control Signal

As the television signal at the antenna of a receiver increases, the video level also increases. This increase in video level is felt at the first video amplifier, and the signal at the video amplifier is coupled to the AGC keying circuit shown in Figure 17.

The AGC keying transistor (Q1) is connected so that it is shut completely off except during the time that it gets the positive pulse from the horizontal-sweep circuit. Since these pulses come 15,750 times a second, the keying circuit samples the video that many times every

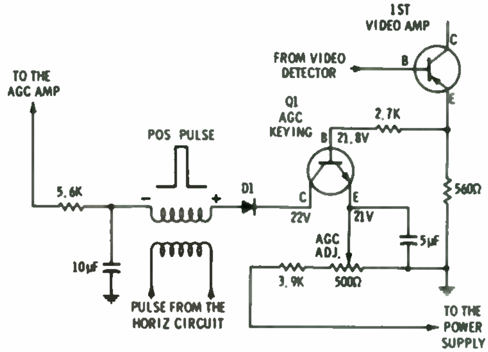

Figure 17 — AGC keying circuit.

second. These many little video samples are averaged out by the 10-μF capacitor and the 5.6k resistor. This average AGC voltage is sent on to the AGC amplier circuit.

The diode (D1) in Figure 17 prevents the large positive pulses from damaging the keying transistor.

Some sets do not have an AGC amplifier circuit. In such a case, the output AGC voltage from the keying circuit is applied directly to the IF and RF amplifiers.

The AGC Amplifier

Many sets have an AGC amplifier stage following the AGC keying circuit. Figure 18 shows the circuit diagram of such an amplifier. The output of this circuit

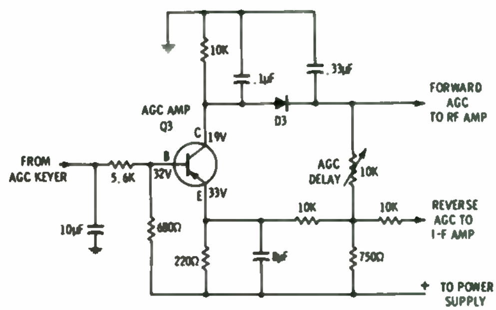

Figure 18 — An AGC amplifier circuit.

provides both basic types of AGC. Reverse AGC tends to reduce the collector current of the transistor being controlled (the IF amplifier in this case). Forward AGC tends to increase the collector current of the transistor being controlled (the RF amplifier in this case). It is very important to understand that both forward and reverse AGC *reduce* the amplification of the stage being controlled. Consequently both the IF and RF amplifier act to reduce the signal in the set when AGC is applied. A few sets use only reverse AGC. Others use only forward AGC, and some use both types.

AGC Action in the IF Amplifier

Either forward or reverse AGC may be applied to the picture IF amplifier. However, since reverse AGC tends to turn a transistor completely off very suddenly while forward AGC is more gradual, the forward type is more common.

AGC could be applied to the collector, base, or emitter circuit of the IF amplifier transistor. The base-circuit control is usually preferred because it requires very little power from the AGC circuit. Figure 19 shows how AGC can be applied to the base circuit of an IF amplifier.

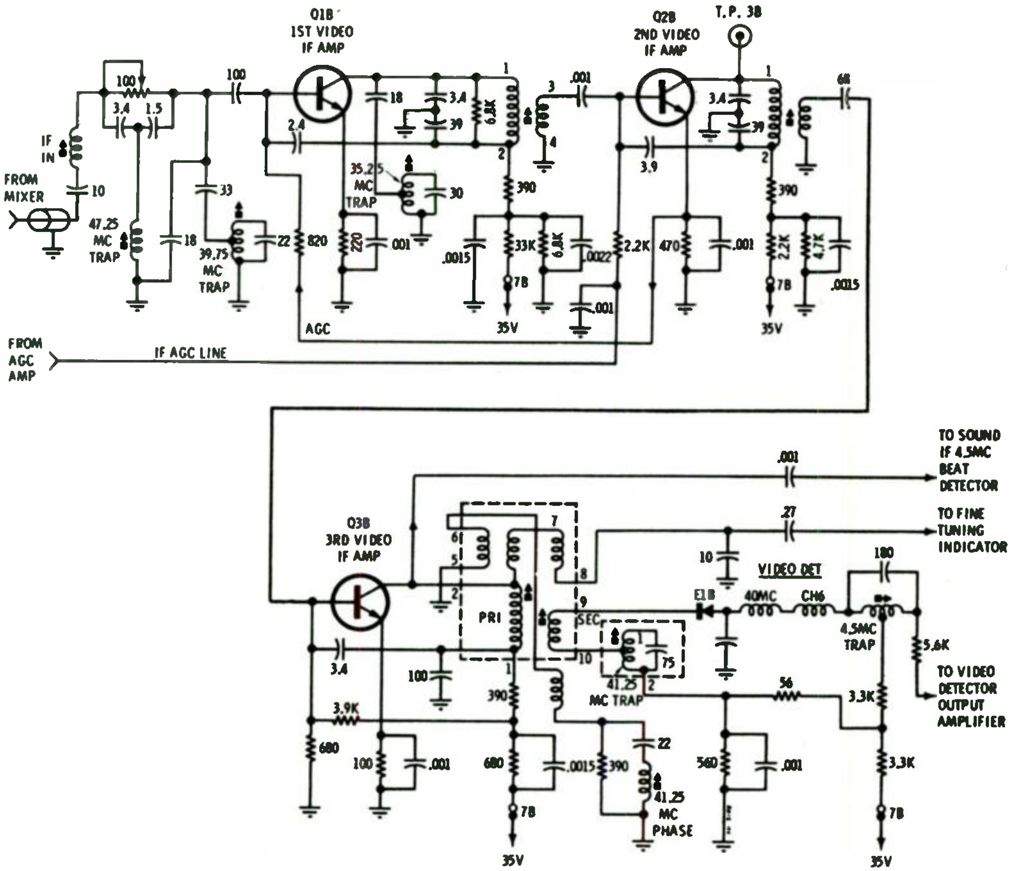

Figure 19 — AGC in an IF section.

Notice that in this set AGC is first applied to the second IF stage. It is then picked up again at the emitter of the second IF and applied to the base of the first IF amplifier stage. Although many sets use AGC only in the first IF stage, controlling both of the first two stages does provide a more gradual and perhaps a wider range of control.

Figure 20 shows a vacuum-tube IF amplifier section with AGC applied only to the first IF stage. While it would be possible to devise other AGC arrangements for a vacuum-tube circuit, current sets use only reverse AGC applied to the control grid of the IF amplifier.

AGC Action in the RF Amplifier

Automatic gain control is normally applied to the RF amplifier in the tuner as well as to the IF amplifiers. However, to get the best amplification and signal-to-noise ratio performance, the RF amplifier is usually operated at nearly full gain for all but the strongest signals.

For weaker signals the IF amplifier does nearly all the controlling. This business of holding off on the tuner AGC until the signal gets large is called *delayed AGC.* Most sets today employ delayed AGC in the tuner.

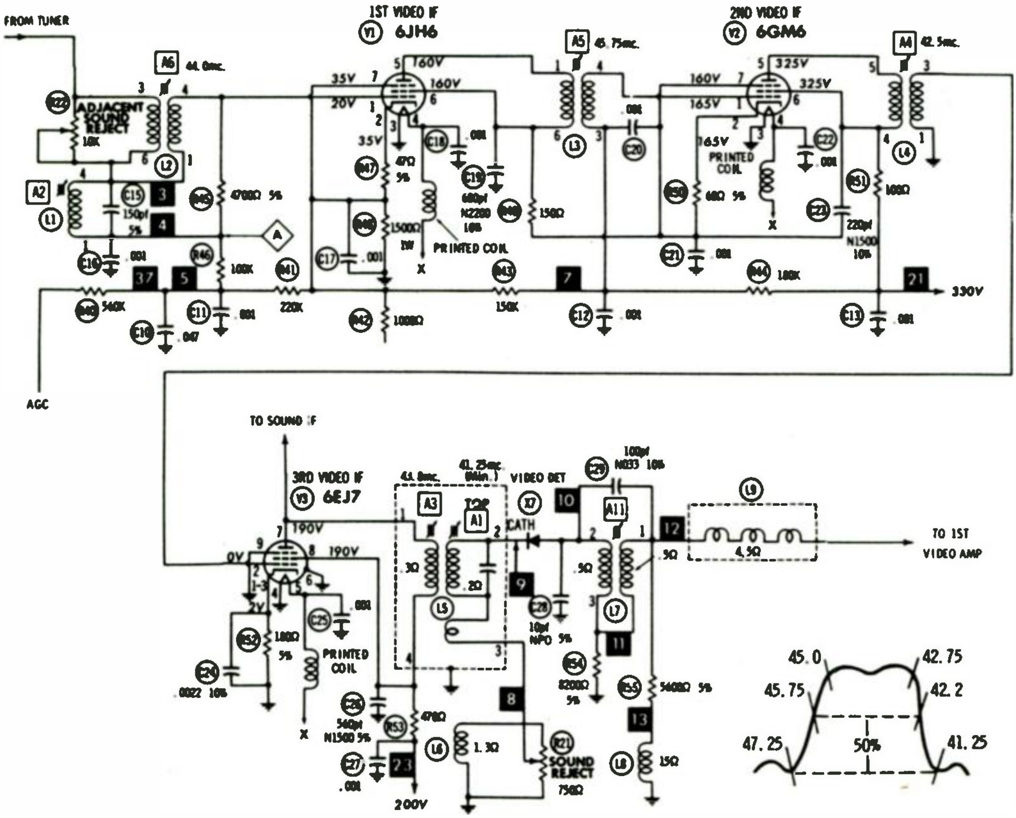

Figure 20 — A vacuum tube IF section.

AGC Trouble Symptoms

Since the AGC system controls the amplification, or gain, of the set, you would probably expect AGC failures to cause too much or too little signal strength, and you would be exactly right.

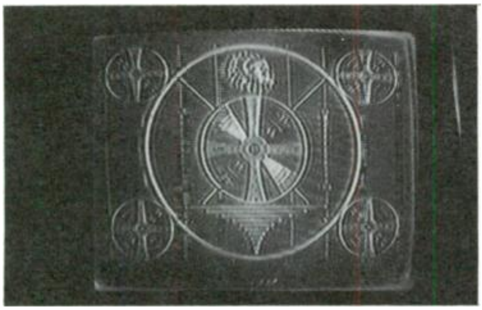

Figure 21 — A negative picture.

Probably the most dramatic AGC symptoms are observed when the IF amplifiers have too much amplification. Figure 21 shows a severe case of picture distortion caused by excessive IF amplifier signal. This symptom is called a negative picture, because the parts of the picture that should be black are white and vice versa. This symptom is more common in tube and hybrid sets than it is in all-transistor sets. If the defect is less

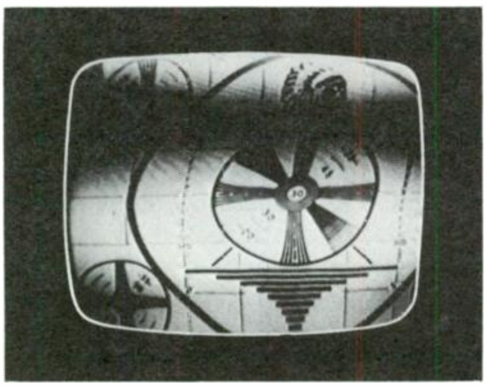

Figure 22 — Bent picture with excessive contrast.

severe the picture will have too much contrast and may bend. Figure 22 shows this symptom. There is usually a raspy buzz in the sound. Varying the contrast control will have only little effect on the picture.

Both of the foregoing symptoms were caused by too much amplification in the set. What would the screen look like if there were not enough amplification? Figure 23 shows a washed-out screen with weak video caused by too much AGC (not enough amplification). This symptom could be caused by a bad IF amplifier or a bad video amplifier. In fact, that is why many people think that AGC troubles are hard to spot.

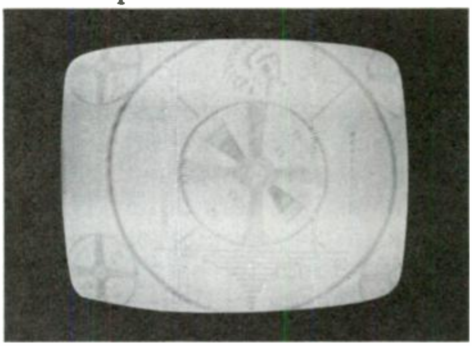

Figure 23 — A faded picture.

It is possible to have an AGC problem which completely cuts off the IF amplifiers. The results of such a failure is a flat white screen like the one shown in Figure 23. This problem, of course, looks exactly like an IF failure. And it easily could be mistaken for a video amplifier trouble.

Troubleshooting AGC Problems

As mentioned above some AGC

trouble symptoms are hard to separate from picture IF and video amplifier troubles. What is needed is a way to recognize an AGC problem.

A quick way to check for AGC trouble is to short circuit the IF AGC line and watch the screen. If the AGC is working, you should see quite a change in picture contrast.

If AGC trouble is suspected, try this test. Hook a voltmeter from the IF AGC line to ground. Then switch the set from a strong station to a channel with no station. The voltmeter reading should change several volts if the AGC is working.

Remember, if the IF amplifiers, the detector, or first video amplier are dead, there will not be any AGC voltage.

When an AGC trouble has been identified using one of the tests above, you troubleshoot the circuits just like any other. That is, you measure circuit voltages and compare them to the values given on the diagram of the set.

If it is uncertain whether the AGC is working or not, take a battery of about 3 or 4 volts and hook it from the AGC line to ground. In doing this, be sure to check the diagram to get the polarity right. With the AGC voltage "fixed" in this way, the rest of the set can be checked out. If the set works with the AGC voltage "fixed" but not without it, then there is an AGC problem. On the other hand if the set does not work with "fixed" AGC (be sure polarity is right), then there is an IF or video problem.

SOUND PROBLEMS

Problems in the sound section will rarely affect the picture, therefore, the picture will be normal. When a set has no sound but a normal picture, it is usually possible to determine quickly whether the problem is in the audio amplifier portion or in the detector or sound IF section. By turning up the volume and listening closely to the speaker a slight hum or hiss will be heard if the audio amplifier is working. Low volume audio may be heard when the FM detector stage is operating and the fault is in the sound IF.

Sound section failures are actually simpler to troubleshoot than FM radios. In TV sound we are dealing only with the sound IF, detector and audio. A check of voltages from the power supply and at tube elements will usually lead to the faulty components. In the few cases in which voltage readings do not isolate the bad part, either signal injection or signal tracing methods can be used.

SUMMARY

The most important aspect of any troubleshooting procedure is logical sequence. This involves first evaluating the customer's complaint as expressed in his own terms. A question or two appropriately interjected will often clear up any doubt about what the complaint really is. If a customer says that the picture jerks, you naturally ask if the jerking is vertical or in a sideways direction. You might further clarify the problem by asking whether the whole picture twitches or if only portions of the picture twitch or quiver.

With a few questions and careful listening you have probably ruled out many sections that cannot cause the problem and determined one or two that can. You might also ask (before you turn the set on) if the customer noticed peculiar odors or heard any snapping or frying sounds.

The serviceman will then turn on the set and verify the complaint. He follows this by checking the front panel controls and the service adjustments at the back. These actions are not expected to correct the problem; they are performed to determine how the controls react with the problem. For example, if the complaint is loss of brightness and you find that the screen is dark throughout most of the range of the brightness control, the control itself may be defective. Furthermore if the control feels raspy or is hard to turn in spots, it may have been burned due to overload from another faulty component.

Whatever the problem, there is no substitute for a systematic and logical sequence in troubleshooting. With correct service literature and a good understanding of how the circuitry operates, no problem should elude you for long.

TEST

Lesson Number 91

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-091-1.

1. **Two kinds of DC power supplies are used in all tube TV sets. They are**
   A. high voltage and low voltage.
   B. high voltage and filament.
   C. filament and low voltage.
   D. none of the above.

2. **Low voltage TV power supply malfunctions can possibly cause problems in**
   A. only a few sections.
   B. only the CRT drive section.
   C. any section in the set.
   D. only the power supply itself.

3. **Failure of the RF amplifier in the tuner is evidenced by**
   A. loss of raster.
   a B. reduced picture width.
   C. reduced picture height.
   D. severe snow in the picture.

4. **When the oscillator in a TV tuner fails, the symptom is loss of both sound and picture and**
   ? A. a lot of snow.
   B. very little or no snow.
   C. absence of a raster.
   D. all of the above.

5. **When a small shop operator encounters a tuner problem that is due to faulty components other than tubes he**
   A. spends whatever time is necessary to repair it.
   B. returns it to the customer unfixed.
   10 C. usually pulls the tuner and sends it out for repair.
   D. none of the above.

6. **When the video detector fails the raster will be unaffected and there will be**
   A. a total absence of snow.
   B. normal sound in the speaker.
   C. a loud hum in the speaker.
   D. a lot of snow.

7. **Failure of the first video IF________symptoms as failure of the last video IF.**
   A. exhibits the same
   11 B. exhibits different
   C. sometimes exhibits the same
   D. occasionally exhibits different

8. **The purpose of AGC is to maintain ________over a range of signal conditions of received channels.**
   A. only good sound
   B. high fidelity sound
   C. good picture and sound quality
   D. good quality stereo FM

9. **Automatic gain control is normally applied to the**
   A. video amplifier.
   B. vertical oscillator.
   C. sound detector and audio amplifier.
   D. RF and IF amplifiers.

10. **High AGC voltage can cause**
   A. excessively loud sound.
   B. a weak picture or washout.
   C. picture overload.
   D. reduce brightness.

Notes

Notes

Notes

Portions of this lesson from
Television Symptom Diagnosis
by Richard W. Tinnell
PHOTOFACT *Television Course*
by Howard W. Sams Editorial Staff
Courtesy of Howard W. Sams, Co., Inc.

"School Without Walls"
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WHO NEEDS THEM?

Who needs men who know how to service all types of electronic units.

Does industry?

Does the need for Radio and TV repair shops exist?

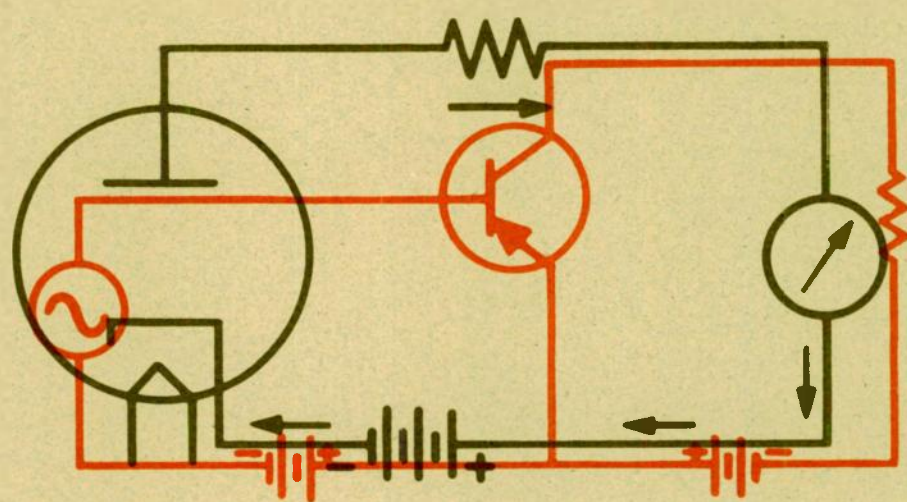
With these questions in mind, look around you. Try to find a place where electronics is NOT used. But don't look at industry. Today's mighty industrial production is made possible *only* by electronics. Don't look at the automotive field either, because electronic units are being used more and more.

Thus you can see that this is a universally desired skill and one that can be very profitable to you.

S. T. Christensen

LESSON NO. 93

TELEVISION TROUBLESHOOTING PART 2



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-093
410

ADVANCE SCHOOLS, INC.
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Contents

TELEVISION TROUBLESHOOTING PART 2

INTRODUCTION

Many troubles will be encountered in the servicing of television receivers. These troubles may be associated with the sound, picture, or both. Since the wrong adjustment of a control may cause the same symptom as a defective component, the controls should be checked first when a problem occurs.

The customer will usually be able to tell the service technician what is wrong with his receiver, at least in layman's terms. The service technician should then turn on the receiver and observe the symptoms. Be alert for the odor of burning insulation or the sound of arcing in the set. If one of these occurs turn off the set immediately. If possible the technician should observe the receiver's picture and sound to determine the section in which the problem originates. The technician should check the receiver controls, on the rear of the chassis, for misadjustment. Often the experienced technician can determine the problem area through adjustment of the controls. Too often the inexperienced technician spends too much time trying to correct receiver operation through adjustment of the controls.

Servicing a television receiver is simplified because there is generally a visual indication and an audio indication of the problem. Often after a careful study of the visual indication (picture) or lack of picture, and study of the block diagram of the receiver, the defective section may be isolated.

A visual check of the suspected area should be made and any defective or faulty components replaced. The tubes in the suspected section should then be tested in a high quality tube-tester or by direct substitution of a known good tube.

If these steps do not locate and repair the problem in the receiver then the receiver should be removed to the service shop for more extensive tests. This lesson will cover the basics of troubleshooting in the sync, sweep, and high voltage sections of the receiver. This lesson will also cover the basic symptoms that will occur in a receiver and the location of the defective section by the symptom presented on the picture-tube screen.

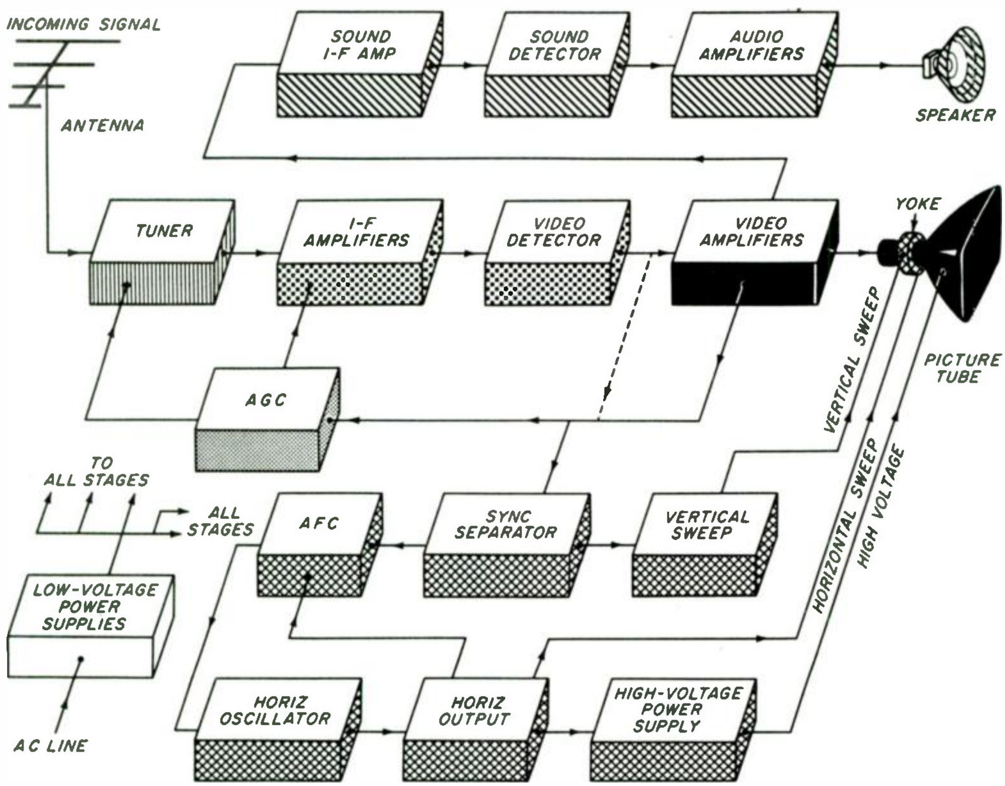


Figure 1 — Block diagram of a typical black and white receiver.

Figure 1 is the block diagram of a typical black and white television receiver. This lesson will discuss the sync circuit, sweep circuits, and the high voltage circuit and their effect on the picture-tube visual indication.

TELEVISION RECEIVER SYNC PROBLEMS

The television station sends out a series of synchronizing pulses which are used to lock the picture in, both vertically and horizontally. Inside the TV receiver these pulses are separated from the video signal by a section called the sync separator. Figure 1 shows the location of this section in the set.

Inside the sync separator block there are three basic operations. Figure 2 shows these operations. The actual sync separator circuit removes the sync pulses from the video signal. The vertical integrator and the vertical sync amplifier separate the vertical sync pulses and send them to the vertical sweep circuits. The horizontal differentiator and phase inverter separate the horizontal sync pulses and send them to the horizontal sweep circuits.

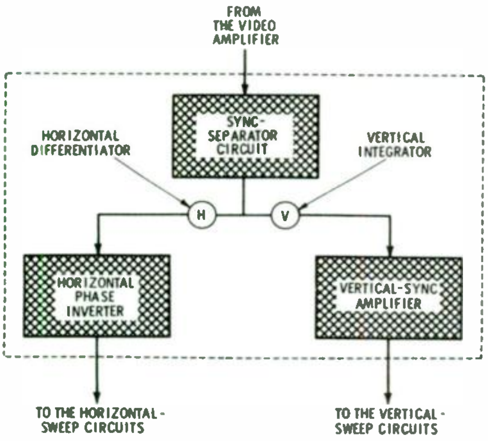


Figure 2 — The sync separator system.

The horizontal and vertical sync pulses are used in the sweep circuits to lock the picture in with the station.

Loss of Vertical Sync Only

If the picture locks in horizontally but not vertically, then the failure must be in the vertical integrator or vertical sync amplifier. Everyone has seen a picture like Figure 3, which is out of vertical sync.

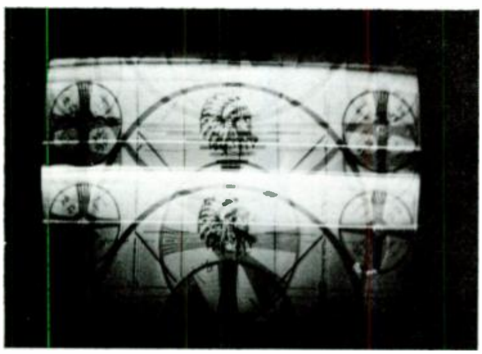


Figure 3 — Loss of vertical sync.

When there is a failure in the vertical side of the sync separator system, any effort to lock the picture in with the vertical hold control just won't hold. By varying the vertical hold control, it is possible to make the picture roll up or down, but not to lock it in. Notice that the important point is that the picture will roll both up and down but will not lock in. As you will see later, failures in the vertical sweep section can cause the picture to roll up or roll down, but not both.

Loss of Horizontal Sync Only

If the set will lock in vertically, but not horizontally, then the problem must be in the horizontal differentiator, phase inverter, or AFC circuit. Figure 4 shows such a symptom.

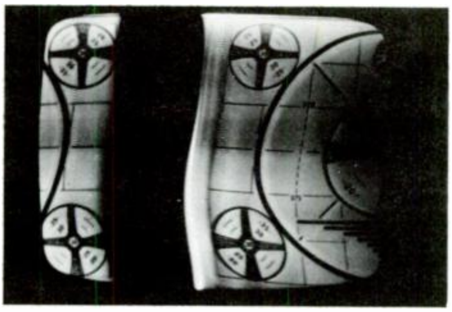


Figure 4 — Loss of horizontal sync.

If you vary the horizontal hold control, you will be able to vary the horizontal sync all the way from severely torn out one way as seen in Figure 5, through sync, to severely torn out the other way; but you will not be able to get it to hold. The important symptom is this ability to change the sync from being severely torn out one way, through sync, to being severely torn out the other way. You will see later that there can be failures in the horizontal sweep section, which will cause the picture to tear one way or the other, but you will not be able to vary it from one to the other.

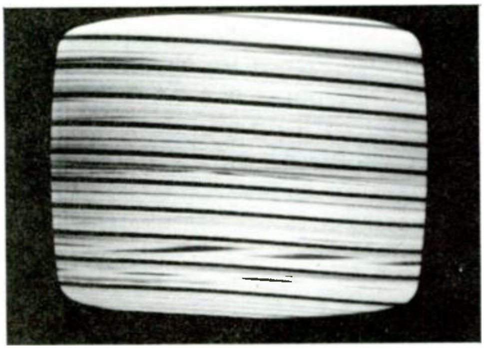


Figure 5 — Severely out of horizontal sync.

Loss of Both Vertical and Horizontal Sync

If there is a failure in the sync separator circuit itself, then both horizontal and vertical sync will be lost at the same time. Figure 6 shows this symptom. This symptom is just the combination of the previous two. If the vertical hold control is varied the picture will roll up and down, while at the same time moving sideways. It will not lock in. If the horizontal hold control is varied, the picture can be made to tear, first one way then the other, and at the same time it will be rolling vertically. If the two hold controls are set very carefully, the picture can be made to look normal for a few seconds, but after a very short time it will start drifting off again.

The thought may have occurred to you that the same symptoms would appear if the sync pulses were lost before they got to the sync separator stage. This is, of course, correct so what is needed is a way to check to see if the sync pulses are getting through. An oscilloscope can be used to look at the sync. Figure 7 shows the video signal at the input of the sync separator. The bright horizontal lines at the top of the waveform are the horizontal sync pulses. The bright vertical lines at the top of the waveform are the vertical sync pulses. The wavy stuff in the bottom three fourths of the waveform is the actual video information. A look at the sync pulses after they have been separated from the video will show a waveform like Figure 8.

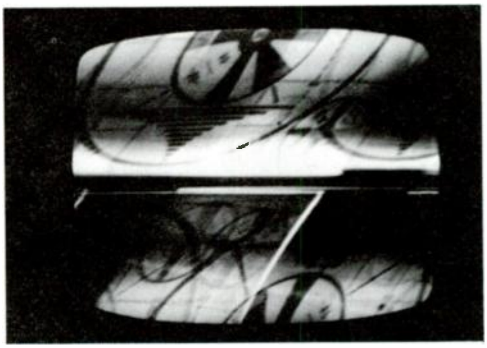


Figure 6 — Loss of both horizontal and vertical sync.

Even though using the oscilloscope to trace sync pulses is very effective when the set is out of its cabinet, you still need a way to check the pulses without removing the set. Possibly you have noticed the black bar that separates the pictures when the set is out of sync vertically. That bar is called the *vertical blanking* bar. In most sets, the screen is blanked out during the time between picture fields. This allows the vertical sweep to

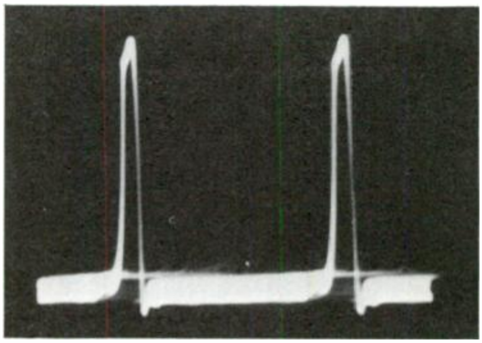


Figure 8 — The separated sync pulses.

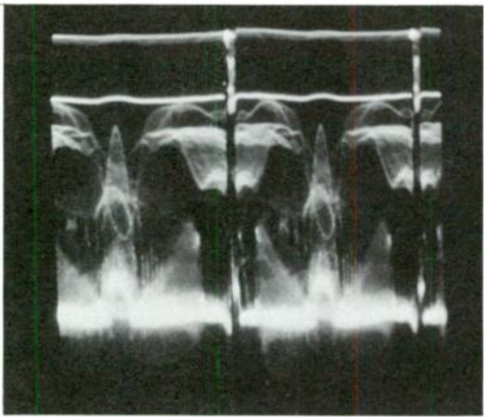


Figure 7 — Video at the sync separator input.

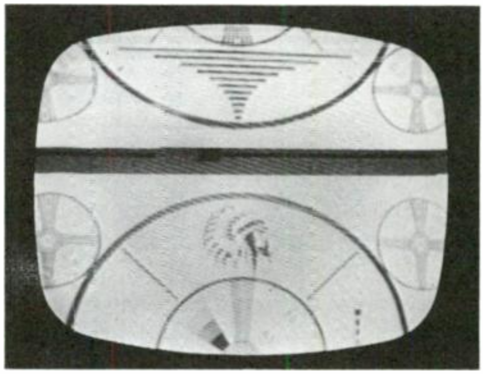


Figure 9 — Vertical sync pulses in the blanking bar.

retrace (go back to the top of the screen) and get ready to start the next field. The vertical sync pulses occur during this retrace time, and since the sync pulses go through the video amplifiers to the picture tube, the vertical sync pulse is on the screen inside the blanking bar. It usually cannot be seen because the blanking bar is so black. On many sets (but not all), you can let the picture roll slowly and turn the contrast way down to make the sync pulse visible. Figure 9 shows what it looks like. This sync pulse pattern is called the *vertical hammerhead* pattern by many technicians. If it is quite black compared to the blanking bar then the sync pulse is strong. On some sets you won't be able to see the hammerhead because the contrast control will not make the blanking bar light enough. Keep in mind that this hammerhead pattern comes from the station. It will only be seen on channels where there is a program being telecast.

Troubleshooting the Sync Section

Once a trouble has been isolated to the sync section, trouble shooting presents no particular

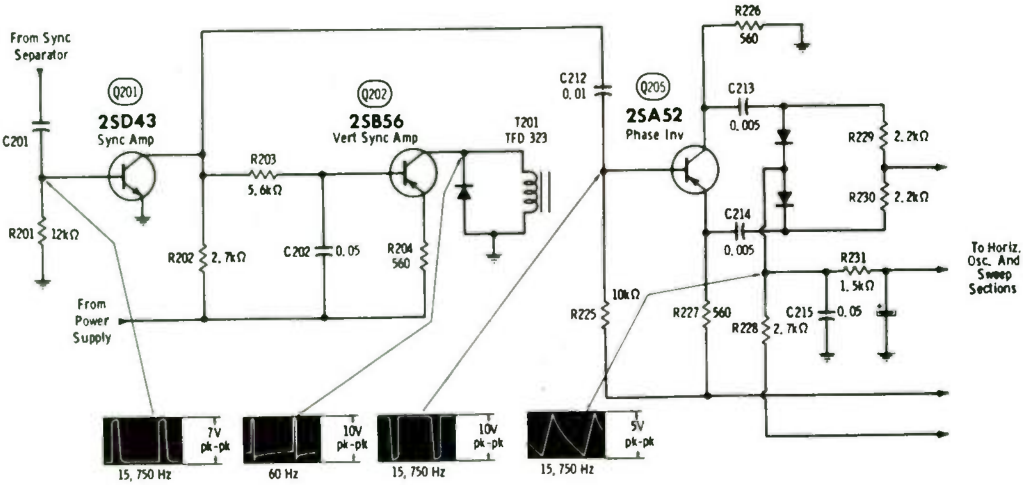


Figure 10 — The vertical and horizontal sync circuits.

problem. Circuit diagrams normally show both DC operating voltages and waveforms.

All that is necessary is to measure the operating voltages and compare them to the values given on the diagram. If this does not reveal the source of the trouble, use the oscilloscope to view the waveforms and compare them to the ones shown on the diagram.

As an example, suppose that the set containing the circuit of Figure 10 will not hold horizontal sync. Varying the horizontal hold control reveals that the sync can be shifted from being torn one way to being torn the other way. The horizontal differentiator or the phase inverter should be suspected. Since operating voltages are not shown in Figure 10, you would go directly to viewing the waveforms. The waveform at the base of Q205 agrees with the one shown on the diagram. It, therefore, should be concluded that the problem must be in the phase inverter. When transistor Q205 is checked, it is found to be open circuited. Replacing Q205 cures the problem.

By use of these troubleshooting methods, problems that affect the sync separator section can usually be found with little trouble.

PICTURE SWEEP FAILURE

The basic function of a sweep section is to move the spot of light across the screen of the picture tube. In a TV set there are two separate sweep sections.

The Sweep Sections

The vertical sweep section in Figure 1 sweeps the spot from the top of the screen to the bottom then very quickly retraces (returns the spot) to the top. The vertical sweep section does this 60 times every second, and as a result, this section is said to operate at a frequency of 60 Hz.

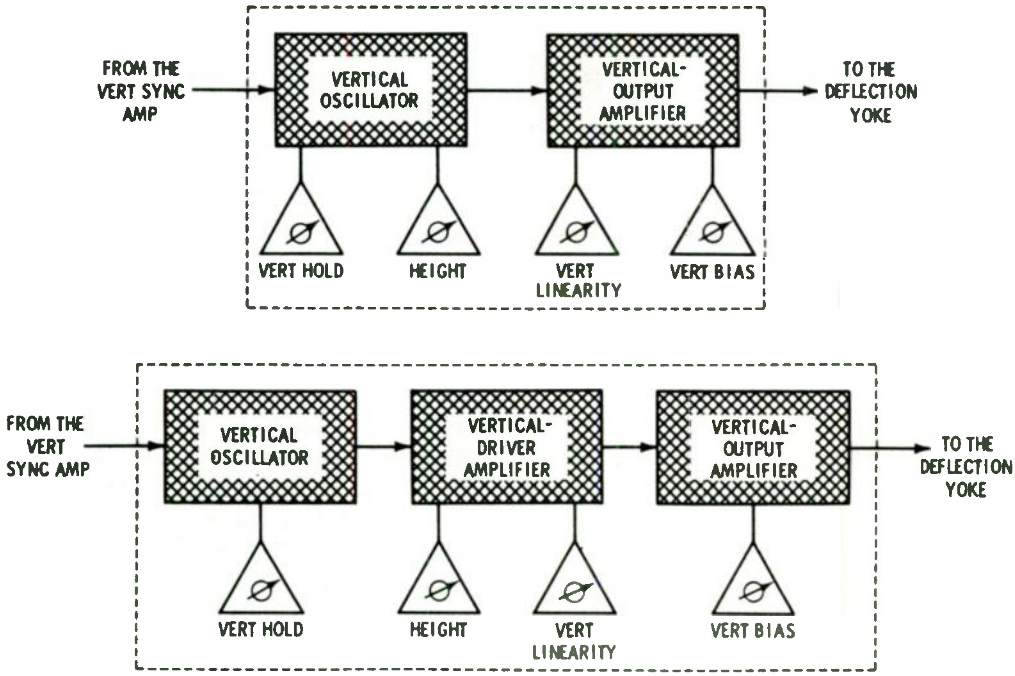


Figure 11 — Two and three stage vertical sweep sections.

The horizontal sweep section shown in Figure 1 sweeps the spot from the left side of the screen (as seen by the TV viewer) to the right side. Then it quickly retraces to the left side. The horizontal sweep section goes through this cycle 15,750 times a second; thus it is said to operate at 15.75 kHz.

Vertical Sweep Failures

Inside the vertical sweep section you may find either two or three stages. Figure 11 shows the block diagrams of both these types of vertical sweep sections.

From either type of vertical sweep section, three basic types of vertical sweep failures can occur. These basic types of failures are:

1. Loss of vertical sync.
2. Loss of picture height.
3. Poor vertical linearity.

Consider each one of these types of failure separately.

Loss of Vertical Sync

Suppose that a set displays the symptoms shown in Figure 12, and when you vary the vertical hold control there is little or no change in the picture sync. The important thing to notice here is that the vertical hold control does not change the sync enough to make the picture roll *both* up and down.

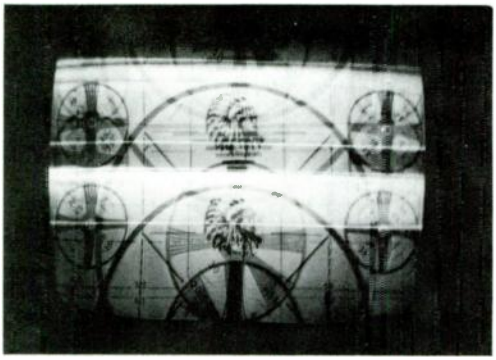


Figure 12 — Loss of vertical sync.

This problem is almost surely in the vertical oscillator stage. The oscillator is not operating at the correct frequency (60 Hz). If the oscillator frequency is too high, the picture will roll downward; if the frequency is too low, the picture will roll upward.

Figure 13 shows the circuit diagram of a typical two-stage vertical section. Notice that feedback for the oscillator is achieved through transformer T_2. The frequency of operation is determined by the components in the base circuit of the vertical oscillator transistor (Q17). These components include the transformer winding, R_4, R_{89}, R_{90}, and C_{22}. If any of these parts changes value enough, it can cause the out-of-sync symptoms. The vertical hold control (R_4) is perhaps the most frequent offender.

Loss of Picture Height

Poor picture height is caused by weak output from the oscillator or reduced gain in the vertical output or driver stages. The symptoms may be only slightly reduced height as shown in Figure 14. Notice that the height control in the two-stage section (Fig. 13) simply controls the bias on the oscillator transistor. You will recall that the gain, and hence the output signal level of a transistor can be controlled with the bias. Weak transistors or tubes are probably the most frequent cause of reduced picture height. However, any other component failure which would cause a signal level reduction could cause this problem.

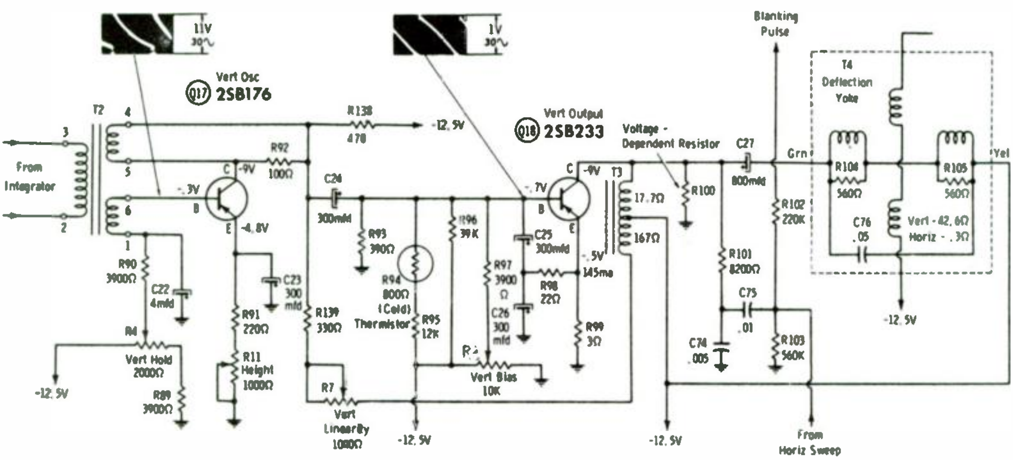


Figure 13 — A two stage vertical sweep section.

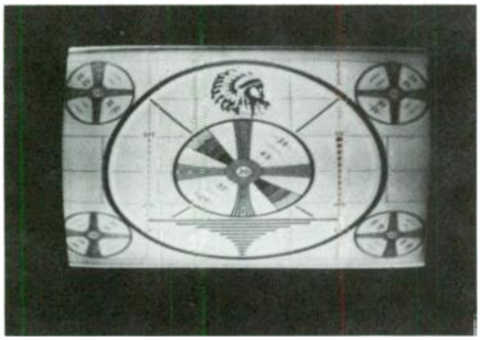


Figure 14 — Reduced height.

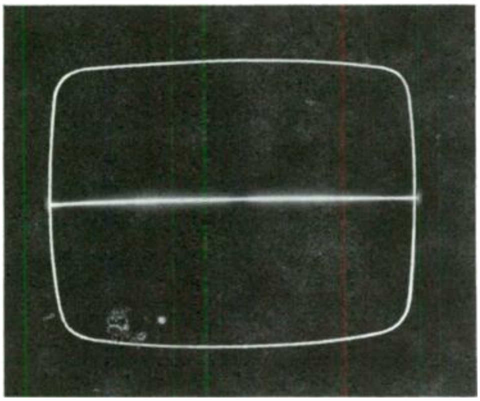
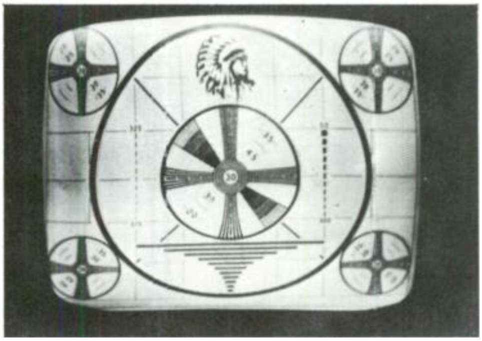


Figure 15 — No vertical sweep.



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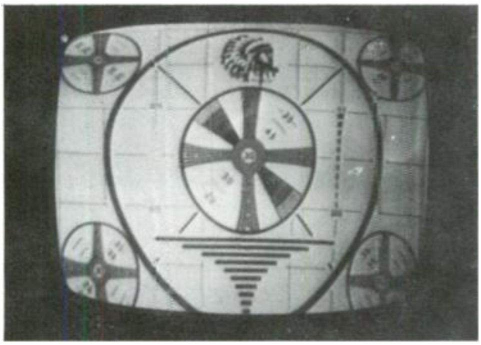


B

Figure 16 — Poor vertical linearity.

If any of the stages in the vertical sweep section fail completely resulting in a total loss of sweep signal, the result will be the symptom shown in Figure 15. Here you see a complete loss of height indicating no vertical sweep at all.

Poor Vertical Linearity

Poor vertical linearity like that seen in Figure 16 is caused by the vertical sweep section having a different sweep rate in different parts of the picture. In Figure 16A, the vertical sweep section is sweeping faster at the top than it is at the bottom. Similarly in Figure 16B, the sweep rate is faster at the bottom than it is at the top.

Inside the sweep circuits, this vertical nonlinearity shows up as an incorrectly shaped vertical sweep signal. Figure 17 shows a properly shaped sweep signal and an improperly shaped one. The nonlinearity shows up as a curved section in the vertical sweep waveform. Notice that the sloping top of the properly shaped waveform is straight. The other one is curved near the top indicating the presence of nonlinearity at the bottom of the screen.

There are two controls in the vertical circuit which affect linearity. They are:

1. The *Vertical Linearity* Control. While this control in-

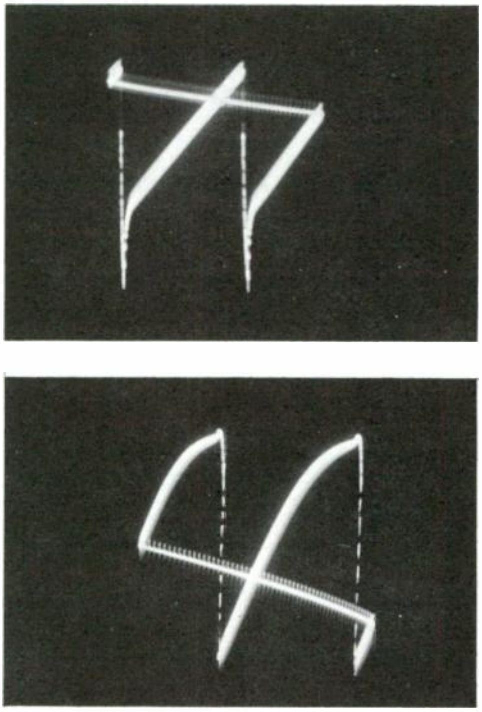


Figure 17 — Vertical waveforms with and without nonlinearity. These displays also contain spurious horizontal pulses which will affect interlace.

fluences the linearity over the whole screen, it has its most obvious effect at the top of the picture.

2. The *Height* Control. This adjustment sets the picture size vertically. It tends to have the most effect at the bottom of the picture.

Both controls interact with each other in most sets. Consequently, you should adjust them alternately for the best overall picture.

The most common causes of nonlinearity are defective capacitors or transistors in the driver or output stages.

Another failure which can occur in the vertical sweep circuit is a short circuit inside the deflection yoke. This failure, while occurring only rarely, causes the symptom shown in Figure 18. This symptom is very easy to spot. Notice that the picture is shaped like a ***keystone;*** hence, we call it a keystoned picture.

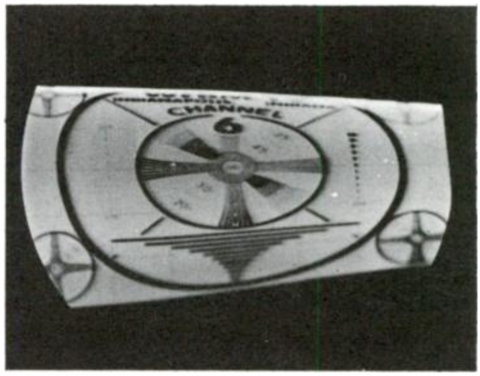


Figure 18 — Keystone picture.

Horizontal Sweep Failures

The horizontal sweep circuits are not entirely different from the vertical sweep circuits. There are, however, a few very important differences. Figure 19 shows a block diagram of the horizontal sweep system.

Notice that the horizontal sweep system has an automatic frequency control (AFC) circuit whereas the vertical circuit did not. This circuit compares the horizontal output signal to the sync pulses. If there is any frequency difference, the AFC circuit corrects the horizontal oscillator frequency.

Another major difference between the horizontal and vertical

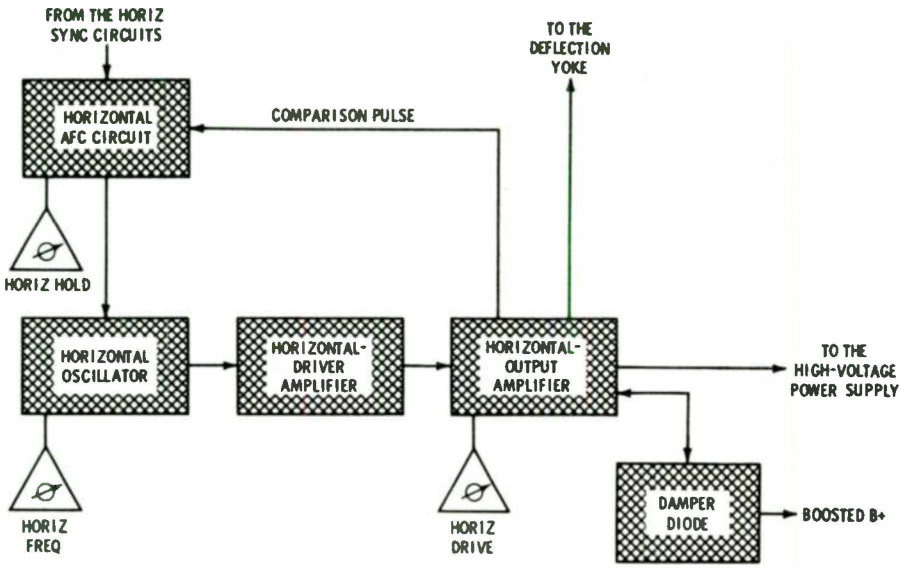


Figure 19 — The horizontal sweep section.

sweep circuits is that the horizontal output stage supplies the input to the high voltage power supply. This fact makes horizontal sweep problems somewhat more complicated than those found in vertical sections.

A third important difference between the two sweep sections is that the horizontal section operates at a much higher frequency. The horizontal sweep system moves the light spot across the screen 15,750 times a second, while the vertical sweep section moves it up and down only 60 times a second. Moreover, the screen is wider than it is tall, so the horizontal section must move the spot farther than the vertical section does every cycle. The overall effect is that the horizontal section must handle much more power than does the vertical sweep system. Higher power means higher energy levels and probably more frequent breakdowns.

The types of symptoms that you are likely to encounter with the horizontal sweep section are more or less similar to those discussed with the vertical system. Specifically, the most common ones are:

1. Loss of horizontal sync.
2. Loss of picture width.
3. Poor horizontal linearity.
4. Loss of raster.

Let us consider each of these horizontal sweep problems one at a time.

Loss of Horizontal Sync

The horizontal oscillator must operate at 15,750 Hz if the picture is to be in sync horizontally. When the picture is out of sync horizontally, *and the horizontal hold control has little or no effect,* the oscillator should be suspected. Figure 20 shows the usual symptoms. However, since the oscillator frequency is determined by the AFC circuit, the trouble could also be in that stage.

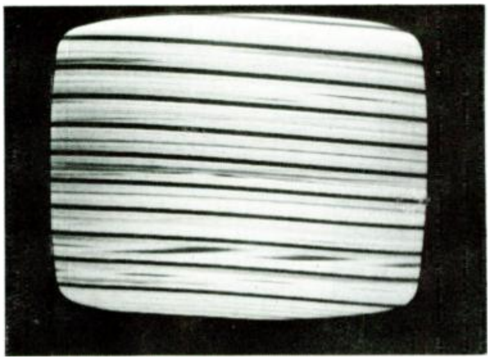


Figure 20 — Out of horizontal sync.

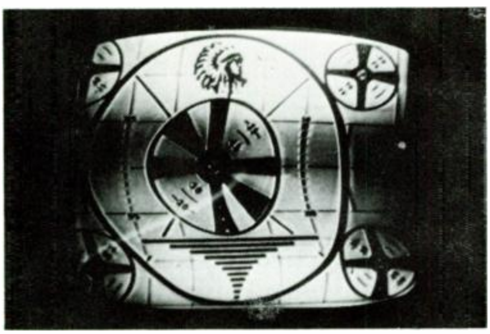


Figure 21 — Mild horizontal sync trouble (pulling).

The out-of-sync condition might be quite mild as shown in Figure 21, or more severe as in Figure 20. The mild horizontal *pulling* is probably harder to repair simply because it is mild (everything is *almost* OK). If the horizontal oscillator frequency is too far away from 15,750 Hz there will be no raster at all on the screen. This problem will be discussed in more detail in the section on loss of raster.

The most common causes of loss of horizontal sync in the AFC-oscillator section are defective AFC diodes or a bad capacitor in the AFC or oscillator circuit. Occasionally the horizontal oscillator coil will cause trouble, and in rare cases, horizontal sync trouble can be caused by a failure in the horizontal output stage.

Loss of Picture Width

Figure 22 shows a picture that is pulled in from both sides. This is the classic symptom of inadequate width. Loss of width can be caused by a bad transistor or tube in the horizontal output circuit or any other problem which reduces the horizontal sweep signal. A weak horizontal driver transistor or oscillator transistor, for example, can cause this problem. So can any other failure which tends to reduce the gain of one of the horizontal sweep section stages.

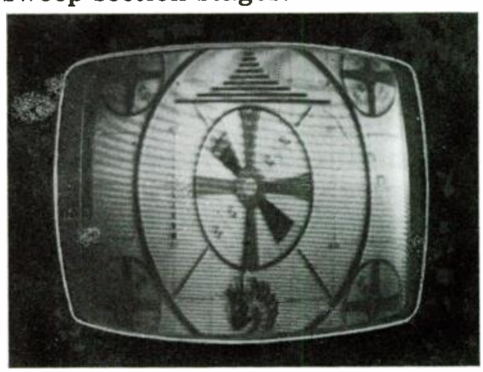


Figure 22 — Reduced width.

The horizontal output transformer and deflection yoke are tuned circuits. They are tuned to about 50 kHz, or roughly 3 times the horizontal sweep frequency. This high frequency tuning is necessary to allow the light spot to be retraced rapidly enough. Tuning the horizontal transformer, while allowing rapid retrace, presents somewhat of a problem. It is inclined to oscillate. To prevent these undesirable oscillations from interfering with the picture after retrace, a *damping* diode is connected across the output transformer.

In many sets the action of this damping diode is used to produce a medium high voltage called the *boosted B+*, which in turn is used to operate various circuits that require higher voltages. In some sets, the boosted B+ is used to operate both the horizontal and vertical output stages. And in yet other sets, a separate boost diode is used to produce the boosted B+ voltage.

A damper diode failure can cause a complete loss of raster, loss of width, or loss of width and height, depending on the circuit configuration. Always check the damper when a horizontal output failure is suspected.

Some sets use a horizontal output stage which does not employ bipolar transistors at all. Figure 23 shows such a circuit. In this circuit a diode (D1) and a silicon controlled rectifier (SCR-1) are used to produce the horizontal trace. Another pair (D2 and SCR-2) are used to control the retrace.

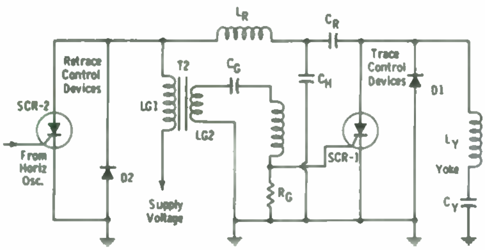


Figure 23 — An SCR horizontal output circuit.

Troubleshooting such a circuit is the same as for a transistor circuit. That is, once the trouble is isolated to the output circuit each component is checked individually. You will recall that if a stage fails in the vertical sweep section completely cutting off the signal, the result is no vertical sweep.

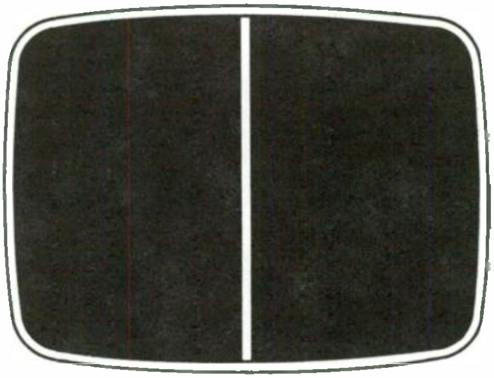


Figure 24 — No horizontal sweep.

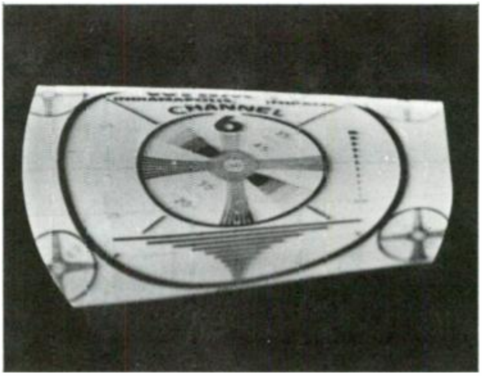


Figure 25 — Keystoning in the yoke (vertical coils).

If a stage fails in the horizontal sweep section the result is no raster. It is possible to have a no horizontal sweep symptom like the one shown in Figure 24. This symptom can only be caused by an open circuit in the horizontal coils of the deflection yoke. If there is a short in the yoke (or sometimes in an output transformer), it will cause ***keystoning***. The keystoning may be either horizontal or vertical as shown in Figure 25. However, these last two symptoms (Figure 24 and 25) are rather rare.

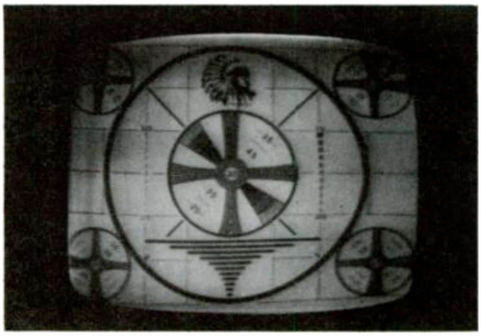


Figure 26 — Horizontal nonlinearity.

Poor Horizontal Linearity

Nonlinearity in the horizontal sweep (Fig. 26) is caused by improperly shaped horizontal sweep pulses. The component at fault is always in the horizontal output stage and is most frequently a capacitor. In some of the more economical sets, a certain amount of nonlinearity should be expected and tolerated. Some sets have a separate ***horizontal-linearity,*** or ***efficiency,*** coil for adjusting the picture.

In many cases, nonlinearity accompanies other symptoms such as loss of picture width. When you encounter such a case, you should concentrate on the other symptom and leave the linearity problem for the last. Frequently eliminating the more serious problem will also correct the linearity.

Loss of the Scanning Raster

Since the high-voltage power supply is driven directly by the horizontal sweep signal, loss of the sweep signal will knock out the high voltage. Without high voltage there is no scanning raster. It is important to know that any horizontal stage from the AFC or oscillator on can cause a high-voltage

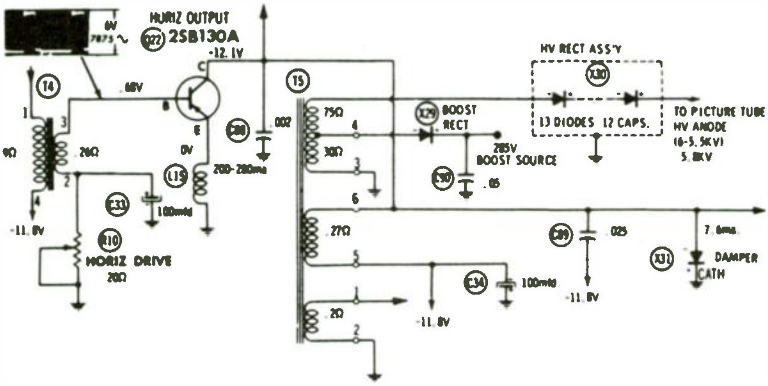


Figure 27 — A high voltage power supply.

failure. The next section will be devoted to a consideration of this problem. Therefore it will not be dealt with further here.

Troubleshooting Horizontal Sweep Circuitry

In the horizontal AFC-oscillator and driver stages, you should troubleshoot just as you would in any other circuit. That is, you should measure the operating voltages and compare them to the values given on the diagram of the set. If that does not locate the trouble cause, use an oscilloscope to view the circuit waveforms and compare them to the ones given on the schematic. One of these two techniques will give you enough information to allow you to find the defective portion of the circuit. Testing the components in the defective portion of the set will reveal the bad one. In case out-of-circuit test does not reveal the defective component, substitute known good ones.

The horizontal output stage is a somewhat different story. It is OK to check the waveform at the *input* of the horizontal output transistor or tube. But you *must not* make measurements or view waveforms in the output part of the circuit unless you have special test instruments for that purpose.

It is not only dangerous for you due to the high energy levels, but you may also damage both the set and your instruments. However, since there are really very few parts in this stage, you can always turn the set off and check each one individually.

A good general rule is to be very careful in deciding whether the problem is in the output stage or in one of the earlier ones. Viewing the waveform at the input of the output stage will be very helpful in making this decision. If it is normal, the problem is in the output stage or beyond. If it is not normal, the problem is before the output stage.

LOSS OF THE RASTER

The scanning raster is composed of the white lines *painted* on the screen by the sweep circuits. The video information is superimposed on the raster. Any problem which prevents the raster from being the correct size and shape can be considered a raster problem. With this in mind, almost any raster problem can be classified as a sweep trouble. Many of these types of raster problems were discussed in the previous sections. In this section only those *sweep* troubles which result in a loss of the raster will be considered. In addition the high-voltage power supply and its effect on the raster must be taken into consideration.

Figure 1 shows the blocks that are primarily concerned with the raster.

High-Voltage Rectifier Circuits

As it was noted in the previous section, the high-voltage power supply is driven by the horizontal output stage. Figure 27 shows a typical circuit. If there is no output from the horizontal output stage, there will be no high voltage. The output from the horizontal output stage can be absent if:

1. The horizontal oscillator fails.
2. The horizontal driver fails.
3. The horizontal output stage fails.

Also since the damper stage is used to produce the boosted B+ to operate the horizontal output, a bad damper can also kill the horizontal section.

The output of the horizontal output stage is a series of high energy pulses at the horizontal sweep frequency. These pulses are stepped up through the horizontal output (or flyback) transformer. The high-voltage pulses at the output of the transformer are rectified by the high-voltage rectifier diode and the resulting DC voltage is applied to the picture-tube anode. The high-voltage rectifier diode itself may be solid state as shown in Figure 27 or it may be a vacuum tube. A typical vacuum tube high-voltage stage for a hybrid set is shown in Figure 28. In a set which uses vacuum tubes only, the high-voltage rectifier will, of course, also be a tube. Figure 29 shows a high-voltage section from a vacuum tube set.

The value of the DC high voltage for a TV set ranges from around 6000 volts for a small black and white set up to 26,000 volts for a large screen color set.

High-Voltage Trouble Symptoms

If the high voltage fails, then the picture-tube screen cannot light up. As a result the symptoms that are associated with a high-voltage failure are normal sound and no raster. Figure 30 shows the no raster symptom.

Some failures in the high-voltage section can cause the HV to be a little weak but still large enough to operate the picture tube.

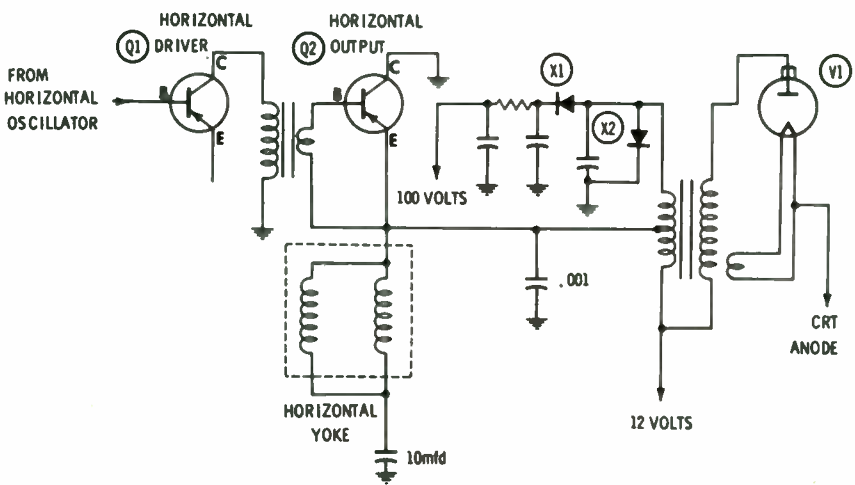


Figure 28 — High voltage rectifier in a hybrid set.

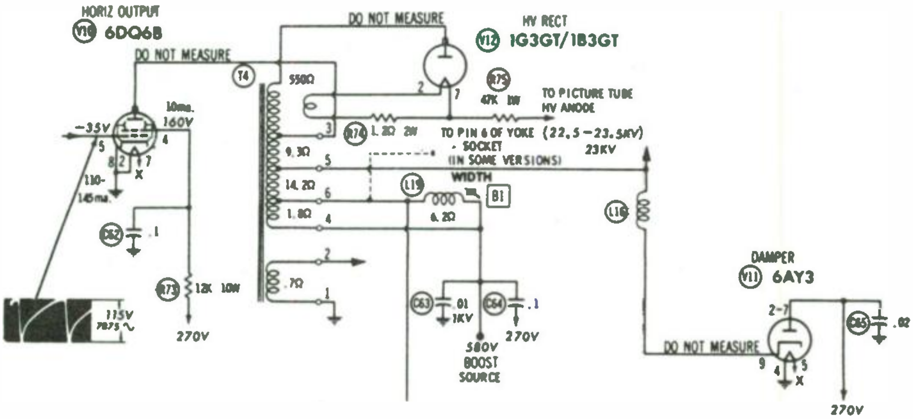


Figure 29 — A vacuum tube high voltage rectifier circuit.

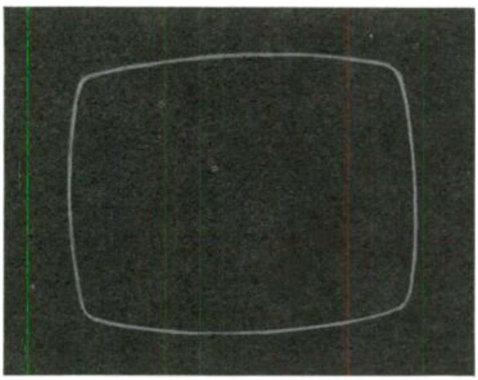


Figure 30 — No raster symptom.

When this happens, the electron beam inside the picture tube is not attracted as strongly toward the screen. As a result the beam moves more slowly. This slow moving beam spends more time inside the yoke region of the tube. Therefore, the yoke has a more pronounced effect and the beam is *over deflected*. This causes the picture to be too big for the screen. Figure 31 shows such a case.

In describing this symptom, it is generally said that the picture is *blooming*. Blooming is usually accompanied by poor focus. Perhaps the most common causes of weak high voltage and blooming are bad HV rectifier diodes and failures in the high-voltage transformer.

It is worth mentioning at this point that X-rays may be generated when high-velocity electrons collide with certain materials. The amount of X-ray energy produced depends on the high-voltage value and the material bombarded. Television set manufacturers design the sets to operate within established safety standards. The high-voltage value in a set should not be increased beyond the specified lev-

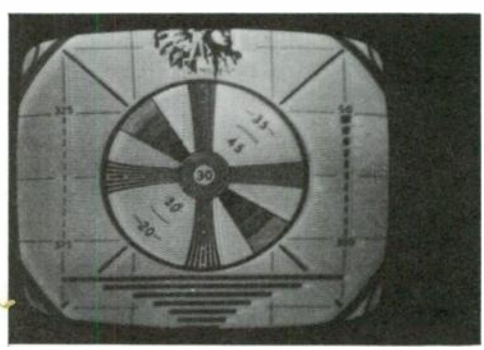


Figure 31 — Blooming caused by reduced high voltage.

el. By increasing the high voltage, you may cause the production of levels of X-radiation that are beyond the established safety standards.

With the high voltage present, possible danger of X-ray radiation and fire within the high-voltage section exists. Each manufacturer gives very special attention to the design of the high-voltage cage and the placement of parts and leads within the cage. Sometimes leaded-glass envelope tubes are used in the horizontal section. Under no circumstances should the service technician take it upon himself to change the safety features designed into the cage. The high-voltage shielding must be restored to its original condition with doors fastened before leaving the set.

Measurements in the High-Voltage Section

Because of the high voltage levels and very high energy pulses that are present, measurements in the high-voltage section require special attention.

The high-voltage values should be measured only with an accurate high-voltage probe. These probes are available for the better multimeters. They are a must for a fully qualified technician. Some of the more modern probes have a built in meter and are designed for only high-voltage measurement. These handy probes make a nice addition to the service caddy and provide an accurate means for the service technician to measure and adjust the high voltage to the manufacturer's specifications in the home. In some systems the high voltage may vary several thousand volts as the brightness level and contrast are increased. For this reason most manufacturers stress that this adjustment should only be made with the brightness and contrast set at minimum (zero beam current).

You should not attempt to view any of the high-voltage points with an oscilloscope unless the scope has a high-voltage test probe. The high energy pulses present in the high-voltage section can easily damage the oscilloscope. However, waveforms can be viewed by clipping the scope lead onto the insulation of the wire. There are usually some waveforms which can be viewed and these are normally shown on the circuit diagram.

Current monitoring test points are frequently provided by the manufacturers for monitoring the current through the horizontal section. Any malfunction within the horizontal section will cause variations in the current or high-voltage limits specified by the manufacturer. The manufacturer normally gives specific details about how the measurements are made, and how the test equipment must be connected.

Probably the most useful troubleshooting technique for use in the high-voltage section is to turn off the set and check the suspected parts one at a time with an ohmmeter. This technique will not, of course, identify shorted turns in one of the coils. Usually the high energy levels present *burn* defective components rather badly. They are, therefore, easy to spot.

SUMMARY

In this lesson it should be easy to see the importance of utilizing the visual information that is presented on the television picture-tube screen. If the picture is rolling then the vertical hold control should be adjusted to stop the rolling. If the rolling of the picture can be reversed by adjustment of the vertical hold yet the picture still will not lock in synchronization, the problem is in the sync circuit. If the rolling picture cannot be reversed then the problem is probably in the vertical oscillator. If the height is reduced or the picture is not linear the problem is generally in the vertical output stage. These same problems and their analysis generally holds true for the horizontal deflection circuits.

Loss of raster problems could include the horizontal oscillator, horizontal output, or high voltage sections of the receiver. Remember in your analysis the horizontal deflection system supplies the positive pulse for the high-voltage system. Work in the high voltage section requires extreme care and the proper equipment. DO NOT WORK IN THE HIGH VOLTAGE SECTION UNLESS THE SECOND ANODE HAS BEEN DISCHARGED. The second anode on the picture-tube acts as a capacitor and will maintain a charge equal to the high-voltage for long periods of time.

To discharge the picture-tube anode a discharge probe should be used. Connect the lead with the aligator clip on the discharge probe to ground. While holding the insulated portion of the probe, slide the probe tip under the cap for the picture-tube anode. You will hear a sharp *snap,* which is the arc of the charge on the anode to ground. If you do not have a discharge probe, you may use a long screwdriver with a well insulated handle. Connect a lead from the shank of the screwdriver to ground.

Loss of raster (dark picture-tube screen) while still maintaining sound generally indicates a complete loss of high voltage. Blooming of the picture usually indicates a decrease in the amplitude of the high voltage.

TEST

Lesson Number 93

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-093-1.

1. **If the picture rolls both up and down when the vertical hold control is rotated, but the picture will not lock in sync, the problem is in the**
   A. horizontal phase inverter.
   B. high voltage section.
   —C. vertical sync section.
   D. vertical oscillator.

2. **If the picture will roll in only one direction, (up or down) no matter what position the vertical hold control is in, then the problem must be in the**
   A. sync separation circuit.
   B. horizontal oscillator.
   C. horizontal output transformer.
   —D. vertical oscillator.

3. **The keystone picture shown in Figure 18 is caused by**
   A. low vertical oscillator frequency.
   B. high vertical oscillator frequency.
   C. a short in the deflection yoke.
   D. low horizontal oscillator frequency.

4. **The symptom shown in Figure 22 is usually caused by a problem in the**
   A. horizontal output circuit.
   B. horizontal sync separator.
   C. vertical output circuit.
   D. vertical oscillator.

5. Which of the following symptoms would indicate a loss of high voltage?
A. Normal raster, no sound.
— B. No raster, sound normal.
C. Blooming raster, sound normal.
D. Picture has poor contrast, sound normal.

6. "Blooming" of the picture is produced by a
— A. loss of high voltage.
B. low, high voltage condition.
C. loss of vertical deflection.
D. extremely high, high voltage condition.

7. The high voltage of a television receiver should be measured with a
— A. high voltage probe.
B. watt-meter.
C. low capacitance probe.
D. none of the above.

8. Loss of high voltage could be caused by
A. horizontal oscillator failure.
B. horizontal output stage failure.
C. high voltage rectifier failure.
— D. all of the above.

9. The value of the high voltage should not exceed that specified by the receiver manufacturer because
— A. harmful levels of X-radiation may be produced.
B. the picture may *bloom*.
C. vertical non-linearity will occur.
D. the deflection yoke may melt.

10. Horizontal non-linearity is caused by a/an
A. faulty vertical output stage.
— B. faulty horizontal output stage.
C. faulty sync separator.
D. open high voltage rectifier.

Portions of this lesson from
Television Symptom Diagnosis
by Richard W. Tinnell
Courtesy of Howard W. Sams Co., Inc.

"*School Without Walls*"
"*Serving America's Needs for Modern Vocational Training*"

MASTER THE FUNDAMENTALS

To be successful in undertaking almost any kind of project, a person must be sure to obtain all the information possible regarding the basic fundamentals underlying such a project. For example, you will be far more able to make the right kind of repair on a piece of equipment if you know the basic operating theories for this equipment.

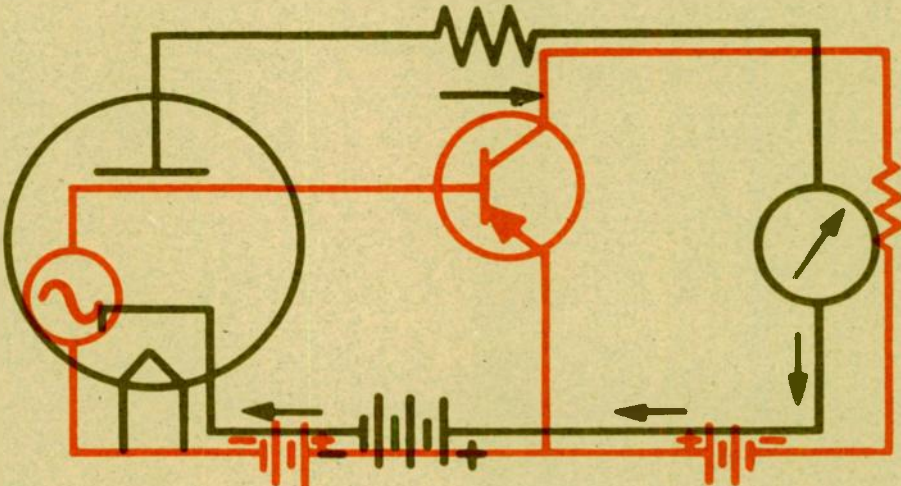
This applies particularly to the modern Radio and TV. So, as you delve into the lessons of this course, constantly review both the theory and operations for all components.

Much of the service and repair work you will do will be done right—the first time—when you have mastered the above. And once you have done this, the chances are you will always remember them.

S. T. Christensen

LESSON NO. 94

ADVANCED TELEVISION SERVICING-PART 1



RADIO and TELEVISION SERVICE and REPAIR

LESSON CODE
NO. 52-094
410

ADVANCE SCHOOLS, INC.
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Contents

ADVANCED TELEVISION SERVICING-PART 1

INTRODUCTION

The introduction of transistors into TV sets lagged far behind their inclusion in most other electronic products. The year 1972 was the year of the all-transistor home television set. Even then, many all-tube and hybrid (mixed tube and transistor) sets were marketed.

The reasons for slow conversion to transistorized circuitry were many. Primarily, there was a lack of devices that could amplify, switch, and rectify the high level signals encountered in TV sweep circuits. A second and equally prominent reason was the availability of more than adequate electric power in homes. Manufacturers felt reluctant to conserve what was plentiful.

Fortunately for solid state, many TV manufacturers have facilities for developing and producing solid state devices. Others, who lack these facilities, have been working closely with semiconductor manufacturers in the development of special, high voltage and power, semiconductor devices.

The result was that in 1972 it was possible to replace every tube in a TV set with semiconductors except the CRT. Replacement of the CRT will come later.

The current TV repairman is faced with having to service both solid state and vacuum tube sets. Therefore, both kinds are being covered in the final two lessons of this course.

There are distinct differences in the approach to problems in transitorized sets versus tube units.Unlike vacuum tubes, transistors do not wear out. Neither do they suffer from intermittant elements, except in very rare cases. A transistor is usually very definitely good or bad, whereas a vacuum tube can become marginal or intermittant.

Another difference between solid state and tube sets is in their construction. Tubes are plugged into sockets and are easily replaced; transistors are soldered into circuit boards. Many manufacturers are using modular construction in which a stage or section is contained in a plug-in module. Each module contains many transistors and components and performs a complete function. For example, there may be a sound module (for the complete sound section), a video IF module, a sync module, etc.

A considerable difference exists in DC voltage levels between tube and transistors. Transistors nearly always operate from very low voltages at higher currents; a reverse of this relationship applies to vacuum tubes.

Even with the many differences between tube and transistor sets the problems encountered still exhibit the same basic symptoms. If the picture on a transistorized set rolls vertically, the problem is still due to lack of vertical sync or an unstable vertical oscillator.

In this lesson we will review common symptoms and relate them to causes. First the symptom will be shown, then the faulty stage will be localized and finally the defective component will be isolated.

COMMON SYMPTOMS TV TUNERS

Raster, No Sound, No Picture, and No Snow

The most significant symptom in this group is lack of snow in the raster. In some receivers, a slight amount of snow (Fig.1), which is visible on careful observation, would be interpreted as a no-snow symptom. To confirm the suspicion of tuner trouble, an IF pattern signal can be injected past the mixer, such as at "test point" in Figure 2; display of a test pattern on the picture tube screen will definitely localize the trouble to the tuner. Next, if the IF pattern signal is injected at point U in Figure 2, and no picture is displayed, the trouble will be localized to the mixer stage.

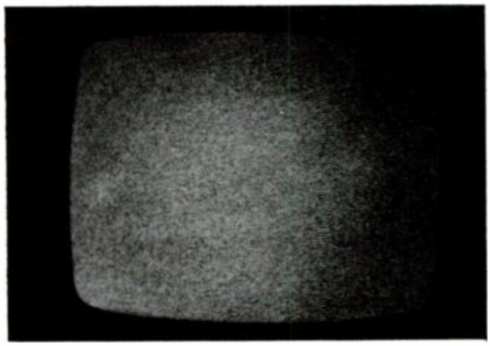


Figure 1 — Raster with a slight amount of snow.

In this group of symptoms, the mixer stage is a prime suspect, even when a confirming test is not made with an IF pattern signal, because the mixer normally contributes appreciable snow to the raster. Possible causes of trouble in this situation are as follows:

a. Defective mixer transistor.
b. Break in printed circuit wiring.
c. Cold solder joint.
d. Incorrect DC voltage distribution.
e. Short circuit due to shorted capacitor.
f. Solder splash, or other mechanical short circuit.
g. Transistor loose in socket (not contacting pins properly).

To pinpoint the defective component, it is advisable to proceed with DC voltage measurements in the mixer stage. For example, you might measure zero volts at a transistor terminal, instead of a specified 9 volts. Lack of voltage could be

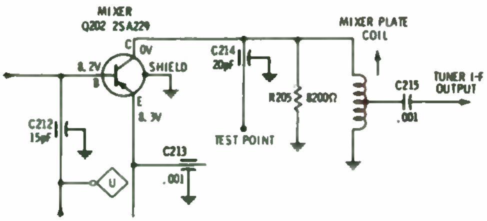
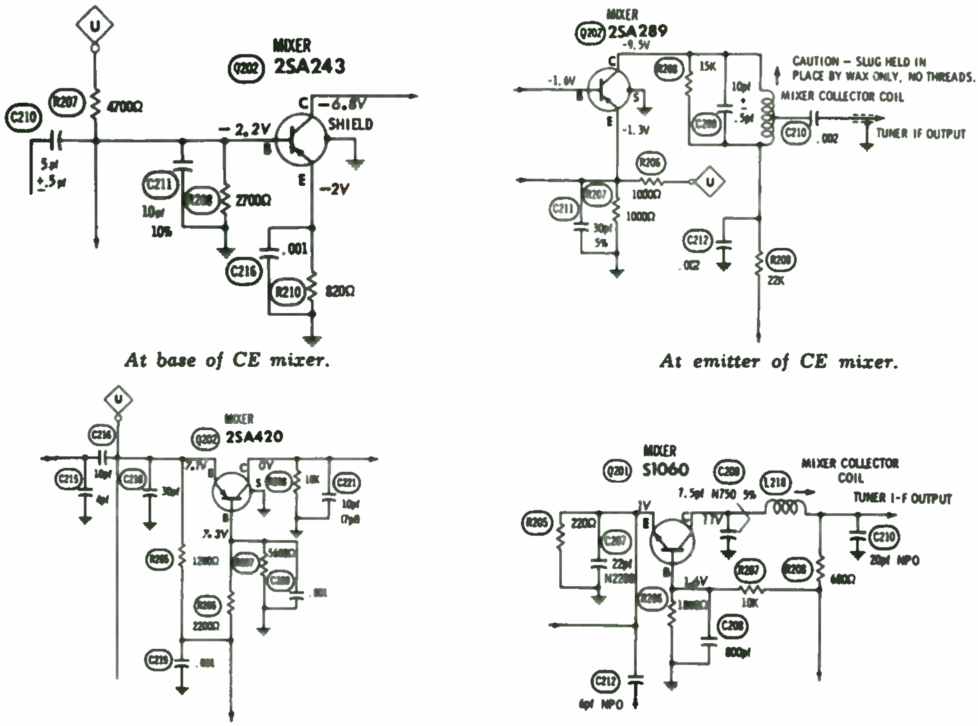


Figure 2 — An IF pattern signal can be injected at "test point".

caused by a short circuit or by an open circuit. For example, if C_{213} is shorted in Figure 2, we will measure zero volts at the emitter instead of 8.3 volts. Or, if there is a break in the printed circuit between the transistor and the supply voltage, we will again measure zero volts. If a capacitor such as C_{213} in Figure 2 is leaky, and not completely short circuited, we will measure a subnormal voltage value. Of course, in other circuit situations, a leaky or shorted capacitor will cause the voltage to measure too high. For example, if C_{210} is shorted in Figure 3A, the base voltage will be excessive, and the transistor will be destroyed.

In rare cases, you may find a defective resistor causing abnormal DC voltage distribution. This is much less likely than in tube type receivers, because the supply voltage .is quite low in transistor receivers by comparison. This difference is seen in Figures 4 and 5.



At base of CE mixer.

At emitter of CE mixer.

At emitter of CB mixer.

No scope test point provided.

Figure 3 — Scope test points "U" on mixers.

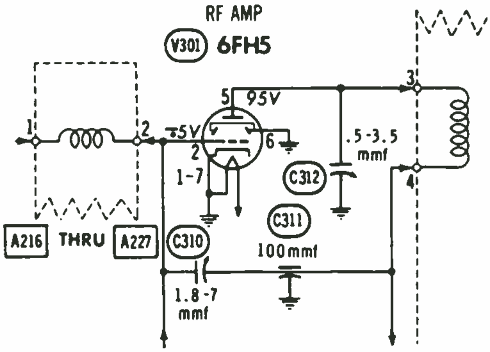


Figure 4 — Electrode voltages in typical tube television RF amplifier stage.

With a low voltage supply, even a short circuit does not overheat the resistors in an RF tuner. Aside from mechanical defects, capacitors are most likely to cause trouble in transistor circuitry. Chain reactions in which a defective capacitor results in burnout of one or more transistors are quite common. Otherwise, transistors can function for a long time.

Snowy Raster, No Sound, and No Picture

Snow in the raster indicates that the mixer stage is operative. Even if the RF amplifier stage is dead, the mixer produces sufficient noise voltage to display snow in the raster, provided the IF strip is operating normally. However, it is difficult to determine whether the RF amplifier stage is dead or not by inspection of the snow level. Hence, suitable localization tests are required, as explained in the following.

Possible causes of the group of symptoms comprising snowy raster, no sound, and no picture are:

a. Defective RF amplifier transistor.
b. Defective local oscillator transistor.
c. Break in printed circuit wiring, or cold solder joint.
d. Oscillator operating off frequency.
e. Incorrect DC voltage distribution.
f. Dirty or defective switch contacts.
g. Open or shorted capacitor in RF amplifier or oscillator circuit.

Figure 6 shows a circuit diagram for a typical wafer type tuner which will be used as an example in evaluating the foregoing symptoms. Note that all three transistors are connected in a CB configuration. The RF amplifier transistor is not neutralized. A CB amplifier has higher voltage gain but less power gain than a CE stage. To localize the trouble area, start by injecting an AM generator signal at the collector of the RF transistor (at C, Q201 in Fig. 6). This terminal is accessible in most tuners, and passes through the PC board to the exposed side. Use a small blocking capacitor, such as 50 pf , in series with the generator output lead to avoid DC drain-off. Set the generator for modulated RF output, and tune to the appropriate channel frequency. If a screen pattern such as shown in Figure 7 is obtained, we know that the tuner is operative through the mixer input circuit. We know also that the oscillator is not a fault.

Next, inject the test signal at the emitter of the RF transistor (at E, Q201 in Fig. 6). If a screen pattern is not obtained, we know that the RF transistor is shorted, open, or biased past cutoff. On the other hand, suppose that a screen pattern is obtained in the foregoing test. In such case, the trouble will be found between the emitter terminal of Q201 and the VHF antenna terminal. Defective switch contacts in the RF input circuit are a prime suspect. Or, if the contacts are not defective, check C_{201} for a short circuit. A short circuit in this area might also be caused by a shorted coax cable, or by a solder splash.

Now, let us consider the case in which the signal is stopped between the emitter and collector of Q201 in Figure 6. We proceed to make DC voltage measurements at the transistor terminals. Abnormal readings indicate a defect in the associated circuitry which may have resulted also in transistor burnout. Therefore, capacitors are checked for shorts, and the PC wiring is inspected, if necessary. If, for example, a short exists between PC points 203 and 204 in Figure 6, the transistor will be destroyed. On the other hand, if C_{204} were shorted, the transistor would merely operate at zero bias and at very low or zero gain.

Next, let us consider the common defects which can cause signal stoppage when a modulated RF sig-

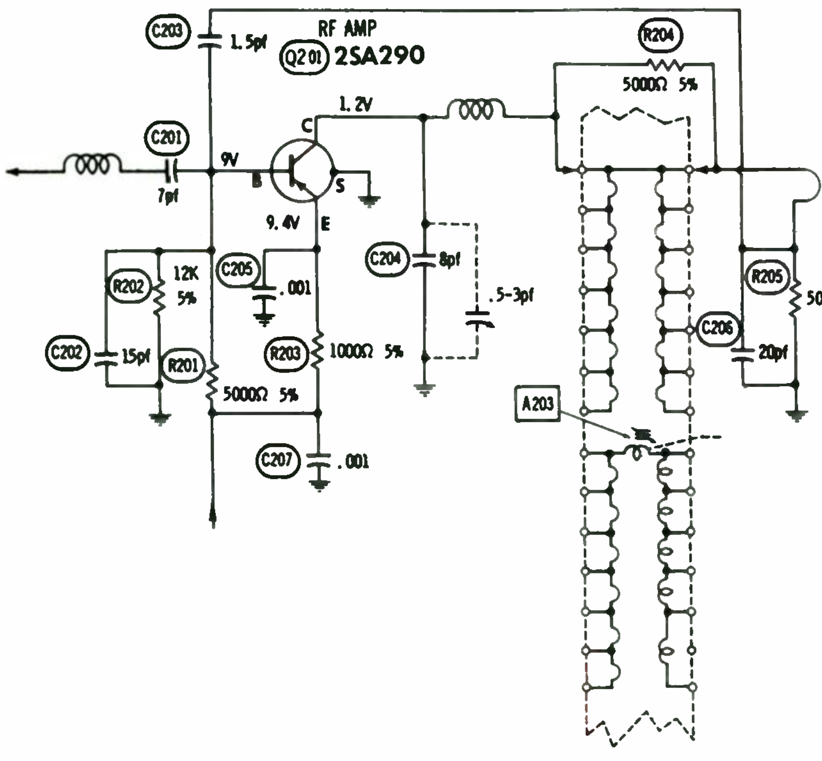


Figure 5 — Electrode voltages in typical transistor television RF amplifier stage.

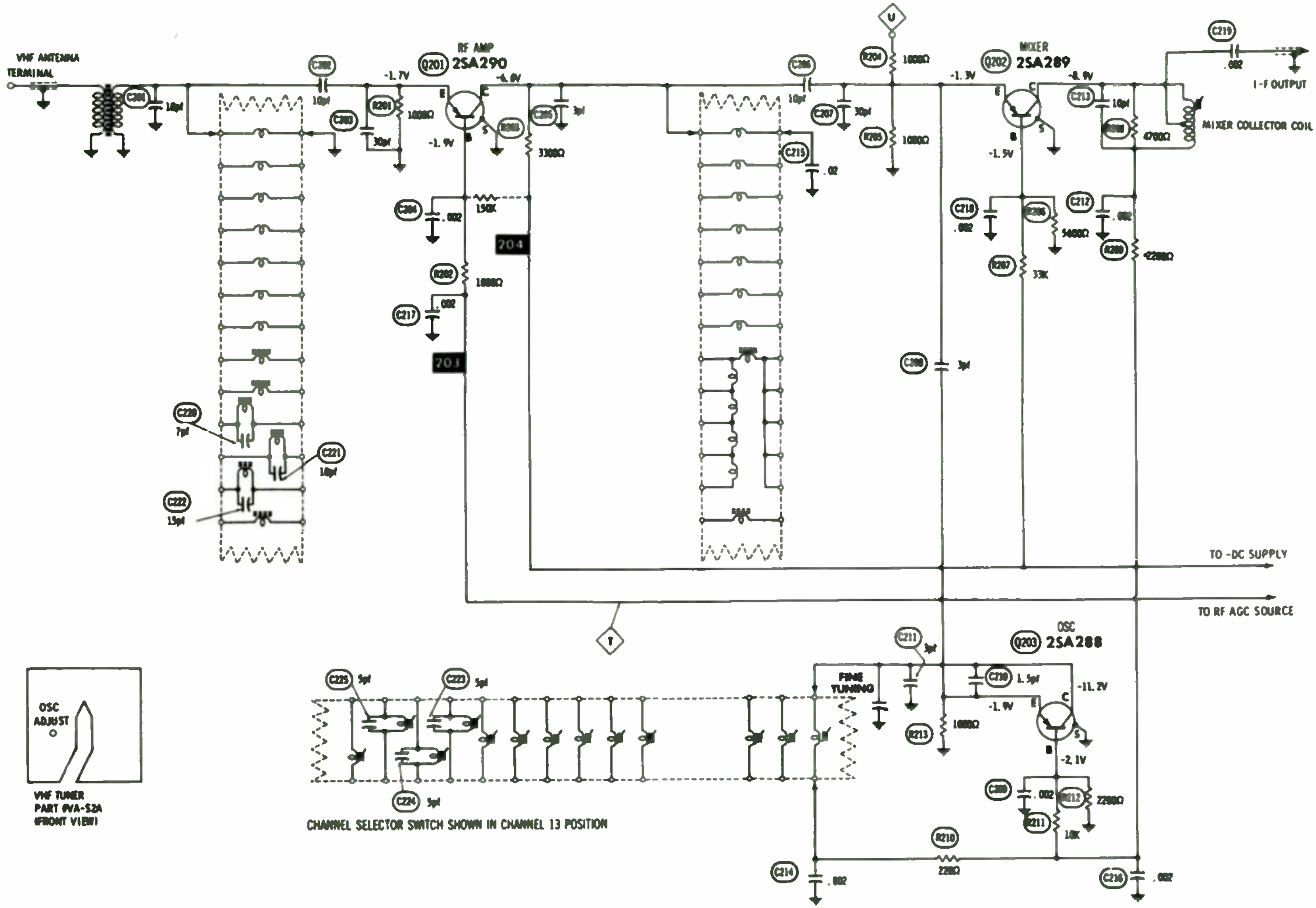


Figure 6 — Schematic of a typical wafer type tuner.

nal is injected at the collector of Q201 in Figure 6. If the RF signal is stopped, make a supplementary test by tuning the AM generator to the IF center frequency. Then, if a screen pattern appears, we know that the local oscillator is either dead or operating considerably off frequency. On the other hand, if no screen pattern appears when an IF signal is injected, we know that the signal is being stopped between the collector of Q201 and the emitter of Q202.

When neither an RF signal nor an IF signal can be passed, the switch contacts for the mixer-input circuit should be inspected first. However, if you must dig deeper, check the DC voltages in the RF amplifier circuit, and at the emitter of the mixer. Zero collector voltage at Q201 points to a short in C_{205} or C_{215}. Zero emitter voltage at Q202 points to a short in C_{207}. In case the DC voltages measure correctly, look for an open in C_{206}.

Let us consider the situation in which no screen pattern is obtained when a modulated RF signal is injected at the collector of Q201, but a screen pattern does appear when the generator is tuned to the IF center frequency. As previously noted, the logical conclusion is that the local oscillator is either dead or operating off frequency. Defective switch contacts in the oscillator circuit are the most likely offenders. If a switch contact is open in Figure 6, the collector voltage will be zero.

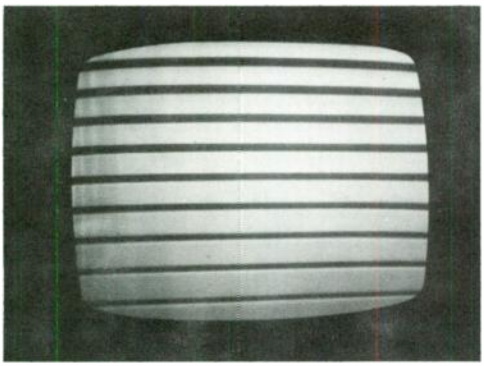


Figure 7 — Bar pattern provided by an AM signal generator.

Hum Bars in Picture, Distorted Sound, Poor Sync

There are two different types of hum bars that may be displayed by a transistor TV receiver. Sixty-hertz hum bars (Fig. 8) may occur in all-transistor receivers that have

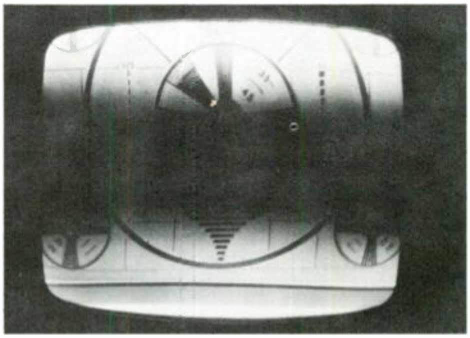


Figure 8 — Sixty hertz hum bars in a picture.

a half-wave power supply. In AC operation, defective filter capacitors can cause 60-Hz hum bars. The hum voltage modulates the video signal in the mixer stage and other stages. If an all-transistor receiver has a full-wave power supply, defective filter capacitors can cause 120-Hz hum bars. A scope check of the DC supply line to the RF tuner will show whether an excessively high ripple voltage is present; also, check the RF AGC line for ripple voltage. Power supply hum bars disappear when the receiver is switched to battery operation.

Separation of Sound and Picture

Separation of sound and picture means that sound reproduction is absent or substantially impaired when the fine tuning control is adjusted for best picture reproduction. This is basically a system response that is associated with changes in AGC voltage. With this condition present, picture quality is subnormal, even with the fine tuning control at its optimum setting. Separation of sound and picture can be caused by defects in either the RF tuner or in the IF amplifier. Hence, a localization test is required. The defective section is localized by use of a sweep generator and scope. Check the receiver service data for instructions on display of the RF tuner response curve. An RF response such as shown in Figure 9 causes separation of sound and picture because the video and audio carriers cannot be brought to correct relative positions.

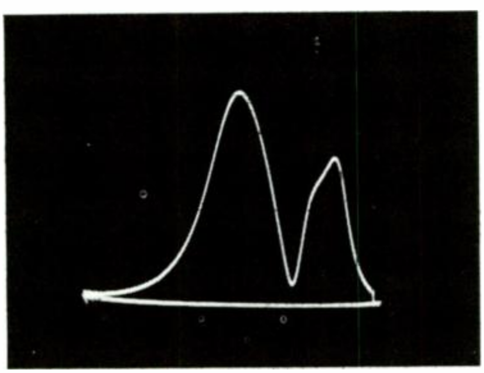


Figure 9 — Abnormal response curve causes separation of sound and picture.

This type of curve distortion is commonly caused by regeneration and is an unstable condition. That is, if you change the signal level from the sweep generator, or the value of the AGC over-ride bias, a regenerative curve changes in shape. We suspect open bypass capacitors, or an open neutralizing capacitor in this situation; for example, C_{204} and C_{217} in Figure 6 can cause regeneration if either or both are open. When peaked RF response curves are not caused by regeneration, look for a solder splash or another short circuit between switch contacts which connects two coils in series that are not normally connected. In rare cases, replacement of an RF transistor with an incorrect type, or loose shielding causes the same symptom. In summary, check for the following defects when picture and sound are separated in the RF tuner:

a. Open bypass capacitors.
b. Open neutralizing capacitors.
b. Short circuits between adjacent switch contacts.
d. Loose or missing shield plates.
e. Incorrect replacement transistor.

Ghosts (Circuit Ghosts or Ringing) in Picture

Ghosts have two common sources. Propagation ghosts are caused by reflections of radiated waves that arrive at the receiving antenna slightly later than the nonreflected. wave. On the other hand, circuit ghosts are caused by tuned circuits in the receiver that have seriously subnormal bandwidth (excessively high Q); that is, a high sharp peak in a response curve is caused by excessively high Q at the peak frequency. (See Fig. 10.) Still another source of ghosts is sometimes encountered in community systems that operate with long cables or lines. Mismatch at the end of a line causes reflections which may appear as ghosts in the picture.

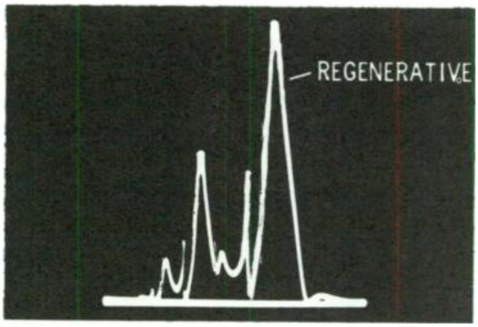
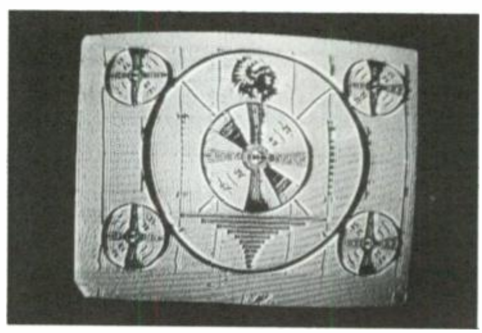


Figure 10 — Circuit ghosts are caused by this type of response curve.

Circuit ghosts are referred to as "ringing" in the picture. To eliminate the possibility of propagation ghosts, a preliminary test should be made with a pattern generator. If the ghosts, or "repeats," in the picture are actually due to ringing, this fact appears in the reproduction of the vertical wedges in the test pattern. Figure 11 shows two picture symptoms of ringing. Note the distortion of the lines in the vertical wedges. Ringing can occur in the RF tuner, although this malfunction is more common to the IF amplifier or video amplifier. Therefore, an isolation test is required at the outset. The best approach is to use a sweep generator and scope to inspect the frequency response curve of the RF tuner. If a normal RF response is displayed (Fig. 12), the trouble is not in the RF tuner. On the other hand, if you observe a response curve such as depicted in Figure 10, the trouble is definitely localized to the RF tuner. In such case, check the same components for defects that were noted under Symptom, "Separation of Sound and Picture."

Smeared Picture

In a smeared picture, the trailing edges of objects or lines are not sharply reproduced. Instead, the



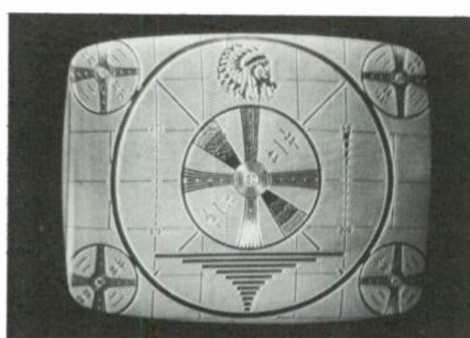


Figure 11 — Two symptoms of ringing.

image "trails off" gradually (Fig. 13). At the leading edge, the transition from black to white, or vice versa, is not a sudden change but passes through gray shades. In turn, edge reproduction is "soft" instead of sharp. With respect to the video signal, a line or stripe in the picture is produced by a square wave or rectangular wave, and picture smearing corresponds to a slow rise and fall of the leading and trailing edges.

Since picture smearing can be caused by defects in circuits following the RF tuner, the tuner section must be checked at the outset. The best way to localize the cause of smearing is to check the frequency response with a sweep generator and scope. If the RF response curve is normal (Fig. 12), the tuner is cleared from suspicion. On the other hand, a distorted RF response curve points to a defect in the tuner. Possible causes of this picture symptom are:

a. Open neutralizing or bypass capacitor in the RF or mixer circuits.

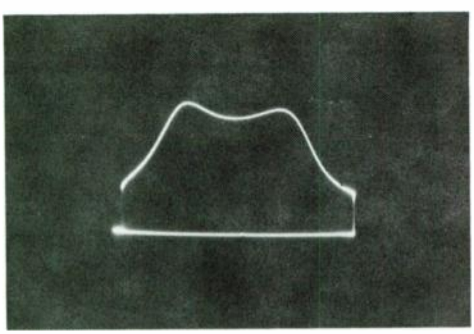
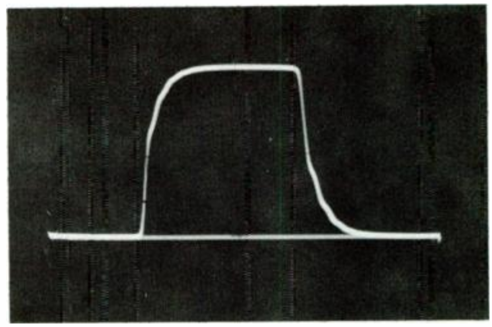


Figure 12 — Normal response curve for a transistor RF tuner.



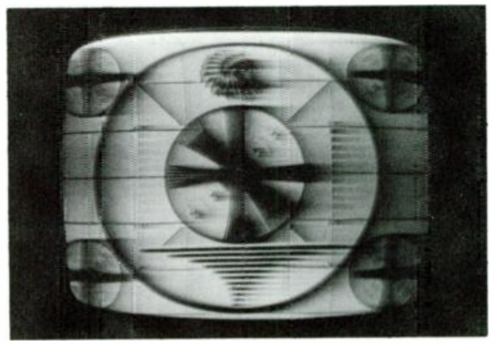


Figure 13 — Picture smearing is caused by poor square wave response.

b. Short circuit between adjacent switch contacts.
c. Loose or poorly grounded shield plates.
d. Incorrect type of replacement transistor.
e. Off-value resistor (rare cases only).

Subnormal Contrast (Weak Picture)

When the picture has poor contrast, and snow is absent or practically absent, the trouble can be caused by a defect in the mixer circuit of the RF tuner. (See Fig. 14.) When snow is prominent in a weak picture (with a normal signal applied to the receiver), suspect the RF stage instead of the mixer

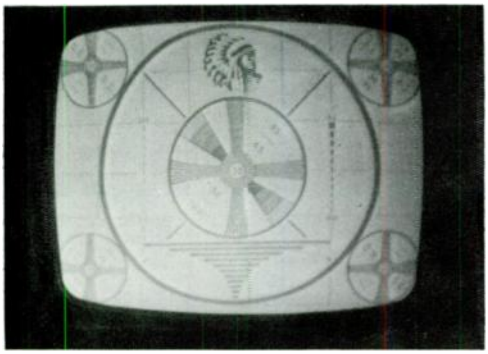


Figure 14 — A weak picture with no visible snow.

stage. It is necessary to localize the trouble definitely, and a signal injection test is the most practical method. A test pattern generator of the analyzer type can be used to inject an IF signal at the output of the RF tuner. Then, if a normal picture is displayed, the trouble will be found in the tuner. Possible causes of a weak picture with little or no snow are:

a. Defective mixer transistor.
b. Incorrect DC voltage distribution in the mixer circuit.
c. Leaky capacitor, such as C_{218} in Figure 6.
d. Incorrect replacement transistor in mixer stage.
e. Off-value resistor in mixer stage (rare cases only).

Snowy Picture, Weak Sound

When we observe a snowy picture with a normal level of RF input signal, suspicion falls upon the RF tuner. A high snow level indicates high IF gain and normal mixer gain. Therefore, we start with checks of the RF stage. If the RF AGC voltage is correct, the next logical step is to check the RF response curve with a sweep generator and scope. In this case, we are not concerned with an alignment check, but with a gain check. This requires familiarity with the test instruments; however, if you do not know how much screen deflection is normally obtained on the scope with referenced control settings, a comparison test can be made on a transistor RF tuner that is operating normally. If a test on the defective tuner produces a response curve with subnormal height, the trouble is then localized to the RF stage.

Possible causes of a snowy picture with weak sound are:

a. Shorted capacitor in the RF stage (such as C_{204} in Fig. 6).
b. Dirty or bent switch contacts.
c. Short circuit due to solder splash.
d. Defect in RF AGC system.
e. Break in printed circuit conductor.
f. Weak oscillator injection voltage.
g. Defective RF transistor.

Negative Picture and Poor Sync in Hybrid Receivers

A negative (or partially negative) picture is a symptom of overloading with comparatively large grid current. Therefore, this symptom is encountered only in hybrid types of transistor receivers. In a receiver that uses tubes in the RF tuner and transistors in the IF amplifier, a negative picture throws suspicion immediately upon the

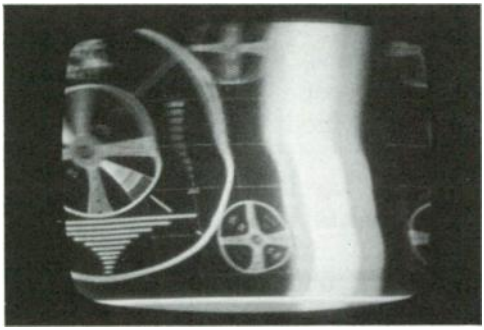


Figure 15 — A reversed or negative picture.

tuner. When grid current flows, the negative picture (Fig. 15) is commonly accompanied by poor sync lock. This results from sync-pulse clipping. The defective component can be in the AGC circuit, instead of the RF tuner; therefore, make a preliminary test by clamping the RF AGC line. Possible causes for a negative picture and poor sync action in a hybrid transistor receiver are:

a. Misadjustment of the AGC control or switch in a strong signal area.
b. Defective RF amplifier or mixer tube.
c. Circuit defect that causes marginal oscillation in the tuner.
d. Resistor or capacitor defect that reduces the B+ voltage to the tuner.

When a negative, or partially negative picture is caused by overloading, the sound and picture are not separated. On the other hand, when the trouble is caused by marginal oscillation, we usually find that the sound and picture are separated. Moreover, the negative picture will often have herringbone interference as illustrated in Figure 16. The amount of herringbone is very responsive to changes in the RF input signal level and changes in AGC voltage.

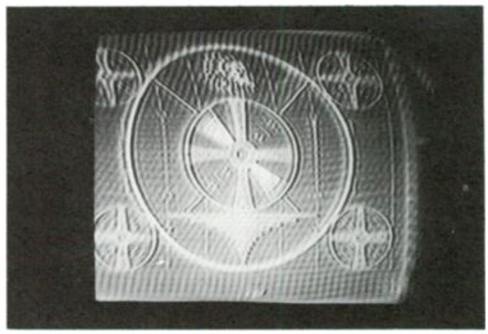


Figure 16 — Negative picture with herringbone.

Delayed AGC is used in all-transistor and hybrid TV receivers in somewhat the same manner as in tube-type receivers. Semiconductor diodes are commonly used to provide delayed AGC, as depicted in Figure 17. The FD 100 diode starts to conduct when the input signal level is sufficiently great, thereby short circuiting the 82-ohm emitter resistor. In turn, the RF gain is reduced rapidly. The RF transistor current increases from 4 ma at maximum sensitivity to 15 ma on strong signals, due to forward-AGC bias. This forward-AGC system supplies up to 3-ma base current on strong signals. Delayed AGC is obtained because the diode has a 0.6-volt offset, and does not conduct until the emitter current reaches 7.3 ma.

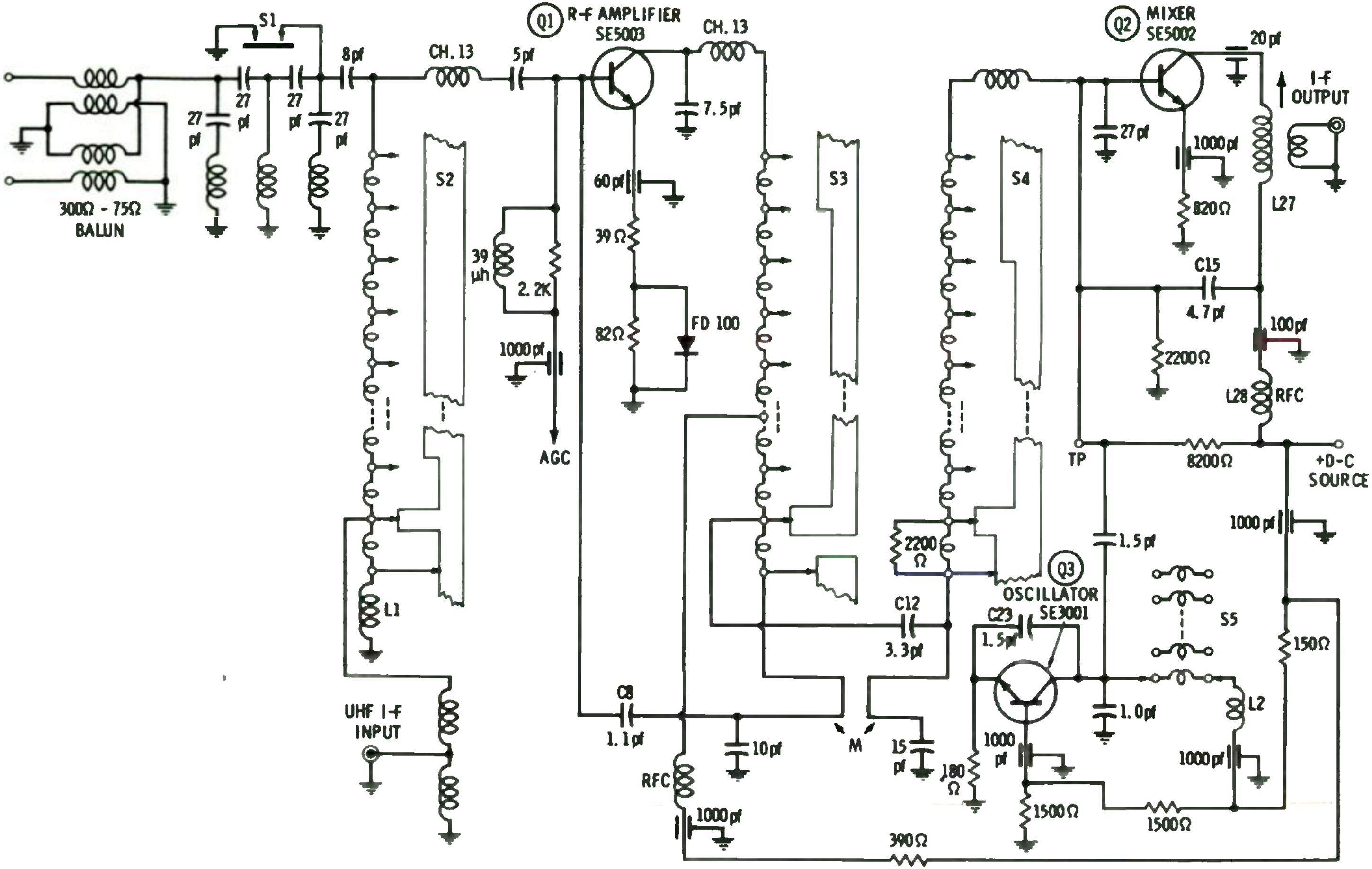


Figure 17 — Diode FD100 provides delayed AGC.

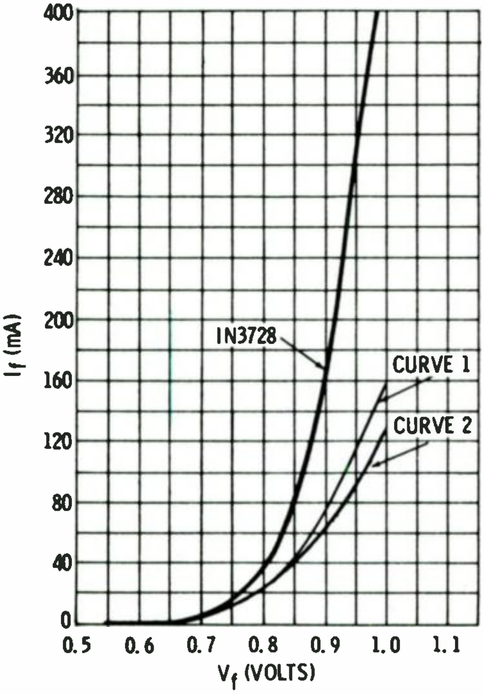


Figure 18 — Characteristic curves for three silicon diodes.

Picture Pulling

Picture pulling or bending (Fig. 19) can result from marginal overload in the RF tuner. In case of severe overload, the picture also appears muddy and "filled up," and sync lock is often completely lost. Marginal overload compresses the sync pulses so that the AFC section cannot keep the horizontal oscillator from pulling noticeably off frequency. When a picture pulling symptom is observed, the first requirement is to find out whether the RF tuner is causing the trouble. Proceed as follows:

1. Observe the edge of the raster with no signal input to the receiver. If the raster edge is straight, the sweep system is cleared from suspicion.
2. Tune in a TV signal (or use a pattern generator), turn down the contrast control, and observe the picture. If the pulling symptom disappears, the fault may be in the video or sync section.
3. If the contrast control has little effect on the pulling symptom, and if the vertical sync is somewhat unstable, the low frequency response of the receiver should be checked. Observe the vertical blanking bar (Fig. 20). If it is not darker than the darkest portion of the picture, either the sync pulse level is too low because of poor low frequency response, or the sync pulses are being compressed somewhere in the video signal channel. Note that you may have to disable the vertical blanking circuit to make the vertical blanking bar visible.
4. If the test results are not conclusive, inject a signal from an analyzer type, test pattern generator to the input termi-

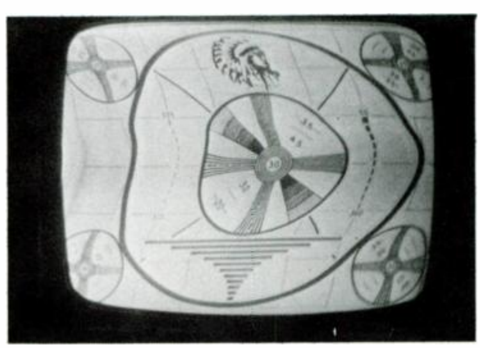


Figure 19 — An example of picture bending.

nal of the IF amplifier. If the pulling symptom disappears, the trouble will be found in the RF tuner.

Possible causes of picture pulling in an all-transistor receiver are:

a. The received signal is too strong. (Older receivers in particular are prone to lose control of very strong signals.)
b. Severe misalignment of RF tuner, with picture carrier much lower than the sound carrier.
c. External interference. (In this case, the pulling symptom will usually be observed on only one channel; in any case, this possibility can be checked with a pattern generator.)
d. Strong standing waves on a lead-in. Again, this possibility can be checked by applying an input signal from a pattern generator.
e. Component failure on the RF or mixer stage that causes incorrect bias.
f. Defect in the AGC section; this possibility can be checked by clamping the AGC line.
g. Defective RF or mixer transistor.

If the received signal is too strong, a resistive pad can be used to attenuate the signal. However, this is an expedient, because it is undesirable to attenuate the signal on weak channels; hence, a switch must often be provided in addition to the resistive pad. When picture pulling is due to poor alignment of the RF tuner, the cause is usually a component failure such as an open capacitor. External interference usually produces interference patterns in the picture, in addition to the pulling symptom. In case there are strong standing waves on the lead-in, the pulling symptom changes when the lead-in is grasped at different points. Standing waves are caused by a broken wire in the lead-in, or by a defect in the tuner input circuit. With reference to Figure 17, the balun windings are common offenders.

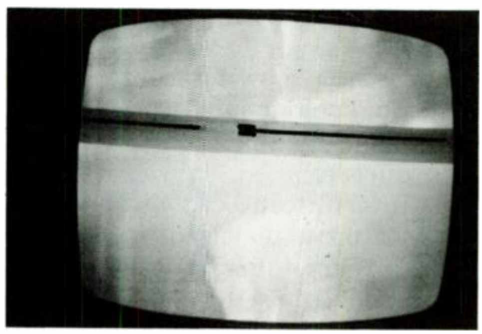


Figure 20 — Vertical blanking bar provides a check of low frequency response.

Intermittent Sound and Picture

Intermittent troubles in RF tuners are the most difficult to find. It is advisable to monitor the supply voltage to find out if the intermittent trouble is actually in the tuner. For example, if the sound and picture disappear at intervals and a snowy raster is displayed, it is easy to assume that the trouble is in the tuner. However, it might be discovered that the defect is in the AGC system, and that the RF amplifier is being cut off intermittently. In addition to monitoring the supply voltages, it is often helpful to monitor the RF signal at the looker point with a sensitive scope. When the sound and picture disappear, we might find that the RF signal disappears at the looker point; in such case, we know that the trouble is in the RF amplifier circuit. On the other hand, if the RF signal does not disappear at the looker point, we know that the trouble will be found beyond this test point. In other words, the most difficult part of intermittent analysis is localizing the trouble—monitoring is the most practical method of localization.

a. Defective switch contacts.
b. Cold solder joint.
c. Break in a printed circuit conductor.
d. Intermittent capacitor in the RF or mixer circuits.
e. Intermittent component in the local oscillator circuit. (To confirm, inject a CW signal from a generator as a substitute for the local oscillator signal as shown in Figure 21.)
f. Intermittent transistor (occasionally).
g. Intermittent resistor (rare cases only).

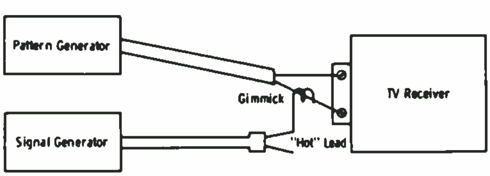


Figure 21 — Signal generator substitutes for dead local oscillator.

The time honored method of tapping suspected components is sometimes helpful in speeding up an intermittent. Be careful, however, about applying heat—transistors are easily damaged by heat. Inspect and clean the switch contacts. Flex the wires connected to suspected cold solder joints. A magnifying glass is helpful in finding a break in a printed circuit conductor. If an intermittent trouble in a tuner cannot be pinpointed within a reasonable length of time, it may be advisable to replace the tuner or send it to a specialized repair shop.

UHF TUNER TROUBLES

As in VHF tuners, the DC voltages in UHF tuners are very different from voltages in tube type units. Figure 22 shows a typical transistor UHF tuner; note that the transistor electrode voltages are 11.5, 1.5, and 2 volts in normal operation. By way of comparison, the plate of an AF4-type tube in a UHF tuner operates at 60 volts. Measurement of DC voltages is the basic approach to trouble localization in a UHF tuner. For example, a collector to base short in the configuration of Figure 22 will cause the base voltage to be 11.5 volts instead of 2 volts. A collector to base open circuit will have little effect on the electrode voltages. However, a base to emitter short causes the emitter and base voltages to be the same. If a base to emitter open circuit occurs, the emitter voltage will be zero.

A UHF tuner also goes dead if the mixer diode is open or shorted. If the UHF IF output lead is disconnected in Figure 22, the front to back ratio of the diode can be checked in the circuit. Defective ca-

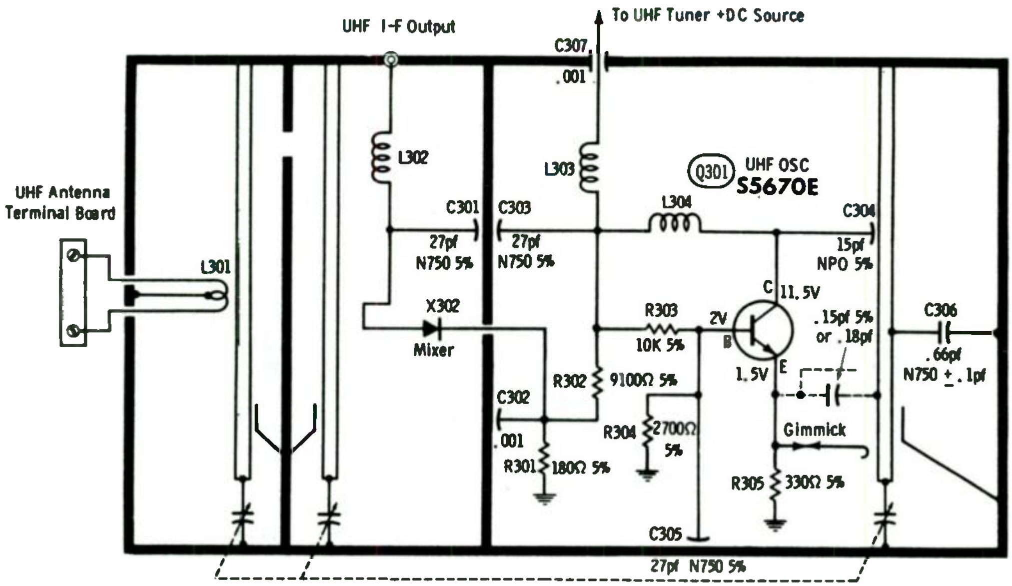


Figure 22 — Transistor electrode voltages for UHF tuner.

pacitors are common culprits; for example, if C_{305} in Figure 22 is short circuited, the base and emitter voltages will be zero. Open capacitors are more elusive, because the DC distribution remains unchanged, although reception becomes weak and/or distorted. Be on the alert for incorrect connections from previous service work; for example, it is very easy to get the connections from VHF and UHF terminal boards interchanged in some receivers and this could account for the above symptoms.

VIDEO IF TROUBLE SYMPTOMS

Raster, No Picture, and No Snow

This symptom is often accompanied by no sound. However, a weak and noisy sound signal may pass through the IF amplifier even though the picture is not reproduced. Video signal attenuation can occur either in an IF stage or in the video detector stage. An analyzer type pattern generator is very helpful to make a preliminary localization by injecting an IF signal step by step, working back from the video detector. If a TV analyzer is not available, an AM generator can be used. It will display a bar pattern on the picture tube screen if the signal is passed. The modulated IF signal is applied at the base of each IF transistor in turn.

An IF sweep generator can also be used for signal injection. In any case, remember to connect the ground return lead first, and remove it last; always use a blocking capacitor in series with the "hot" lead of the generator. Avoid applying an excessive test signal voltage

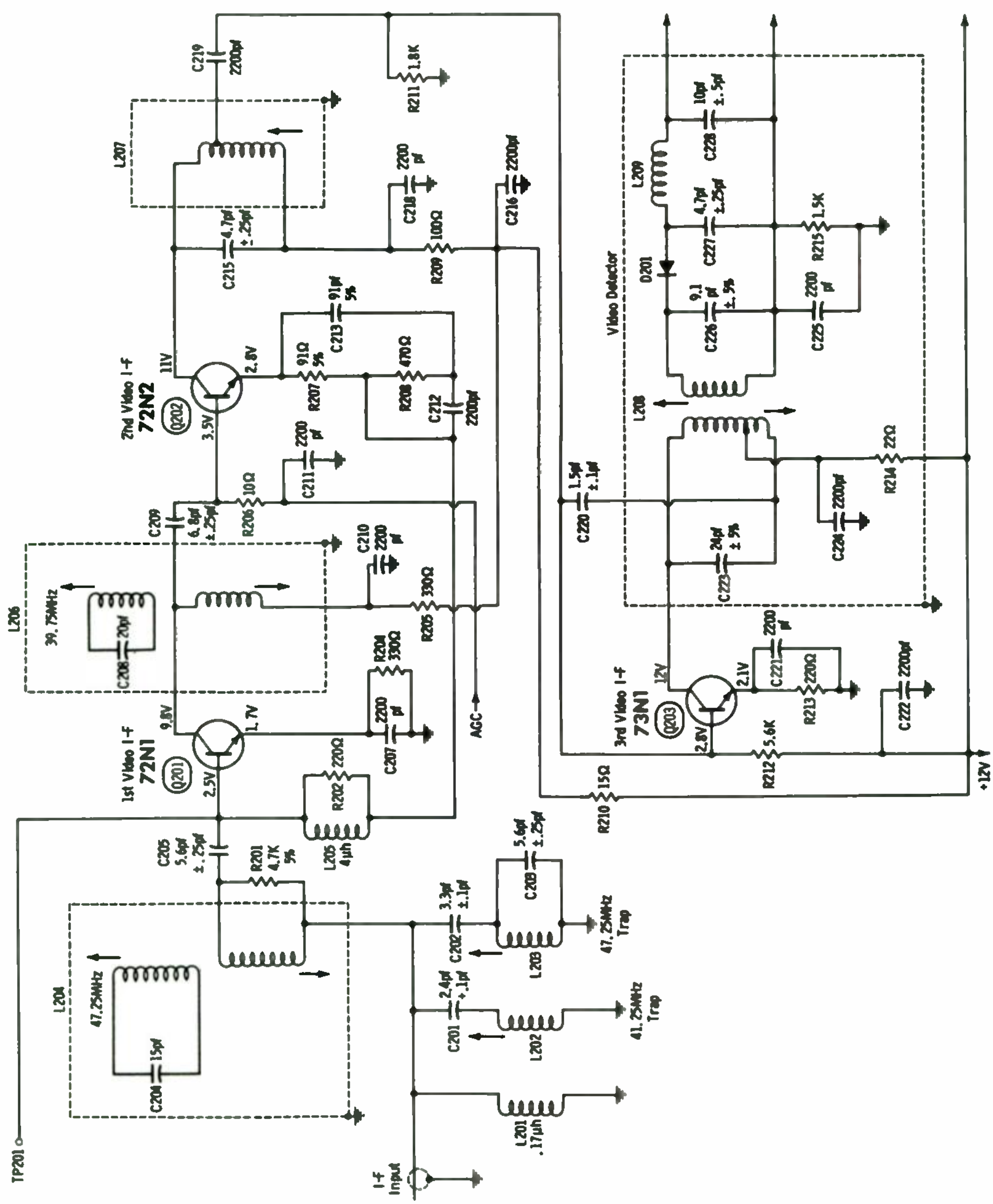


Figure 23 — A three stage IF amplifier circuit.

to a transistor. With reference to Figure 23, possible causes for a raster with no picture and no snow, with weak or no sound are:

a. Leaky or shorted decoupling capacitor (C_{224}, C_{218}, or C_{210}).
b. Open coupling capacitor between video IF stages (C_{205}, C_{209}, or C_{219}).
c. Defective video-detector diode (D201).
d. Shorted or leaky coupling capacitor (C_{205}, C_{209}, or C_{219}). This type of defect is also likely to cause transistor damage.
e. Shorted neutralizing capacitor (C_{220}).
f. Shorted emitter bypass capacitor (C_{207}, C_{213}, or C_{221}). A shorted capacitor may also cause transistor burn out.
g. Defect in AGC section that biases off a transistor (measure the AGC voltage, or clamp the AGC line).
h. Open neutralizing capacitor, resulting in strong IF oscillation (only in some receivers).
i. Cold solder connection, or break in printed circuit conductor.
j. Shorted tuned-circuit capacitor (C_{223}, C_{226}, or C_{227}).
k. Defective transistor.

Ringing in the Picture

Figure 24 illustrates a symptom of severe ringing in the picture accompanied by herringbone. Occurrence of herringbone is associated with marginal oscillation because the IF signal beats with the oscillating frequency. If ringing is not accompanied by herringbone, regeneration is the usual cause. Of course, the herringbone in Figure 24 could be caused by external interference. Therefore, a pattern generator should be used. If a TV analyzer is available the test signal can be injected at the input of the IF amplifier to determine whether the ringing might be occurring in the RF tuner. If the ringing persists when an IF signal is injected, the trouble could be either in the IF amplifier or the video amplifier. Hence, a video frequency signal is injected at the input of the video amplifier to definitely localize the trouble.

With reference to Figure 23, possible causes of ringing in the IF amplifier are:

a. Open collector decoupling capacitor (C_{210}, C_{211}, C_{218}, or C_{224}).
b. Open capacitor shunting a coil (C_{203}, C_{215}, C_{233}, or C_{226}).
c. Open neutralizing capacitor (C_{220}).
d. Abnormal AGC bias (measure the AGC voltage, or clamp the AGC line).
e. Damping resistor (R_{201}) open or greatly increased in value.

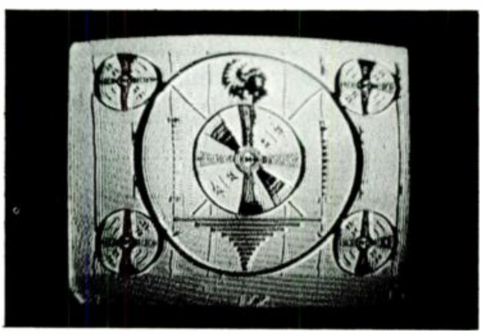


Figure 24 — Severe ringing accompanied by herringbone pattern.

f. Missing or poorly grounded IF coil shields.
g. Poor grounding of coax cable from RF tuner.
h. Leaky coupling capacitor (C_{209}, C_{219}).
i. Defective IF coil or transformer.
j. Replacement transistor with an excessively high beta value. Figure 25 shows an in-circuit transistor checker.

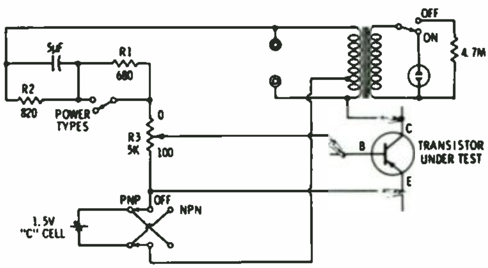


Figure 25 — An in-circuit transistor tester.

Poor Vertical Sync

When vertical sync lock action is unstable (Fig. 26), more than one section of the receiver may fall under suspicion. Hence, localization tests are required. When the trouble is in the IF amplifier or the RF tuner, unstable vertical sync is often accompanied by smear and low contrast of large dark areas. Again, the gray tones may be distorted, with a muddy filled-up appearance. If vertical sync lock is unstable due to hum modulation of the video signal, the hum voltage will also appear as light and dark horizontal shaded stripes or areas in the picture. When the trouble is localized in the IF amplifier, poor vertical sync is observed when an IF signal is injected at the input of the IF strip. On the other hand, the trouble symptom will disappear when a video frequency signal is injected at the input of the video amplifier.

Possible causes of poor vertical sync due to a defect in the IF amplifier are as follows:

a. Poor low frequency response (picture carrier much too low on a narrow bandwidth IF response curve).
b. Hum modulation of the IF signal (hybrid receivers and AC operated all-transistor receivers only).
c. Incorrect AGC bias (measure the AGC voltage, or clamp the AGC line).
d. Open collector bypass capacitor.
e. Shorted or leaky emitter bypass capacitor (C_{207}, C_{212}, C_{213}, or C_{221} in Figure 23).
f. Leaky neutralizing capacitor (C_{220} in Figure 23). Note that an open neutralizing capacitor sometimes produces the same symptom.
g. Defective IF coil or transformer, or defective shunt capacitor.

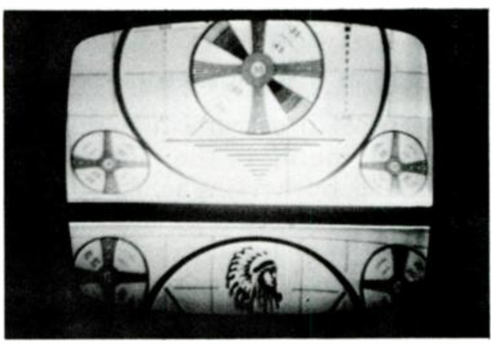


Figure 26 — Unstable vertical sync lock.

When the IF amplifier has poor low frequency response, the vertical blanking bar (hammerhead) appears weak, washed out, and often smeared. This was explained previously, but should be repeated here because of its basic importance in trouble analysis. Figure 27 shows the normal appearance of the vertical blanking bar. The blanking bar is invisible in Figure 26 because the vertical blanking pulse to the picture tube is not disabled, and the brightness control is not advanced. When the vertical blanking bar is distorted or absent, an IF sweep generator and scope should be used to check the IF alignment. Correct alignment, of course, cannot be obtained until after defective capacitors have been replaced.

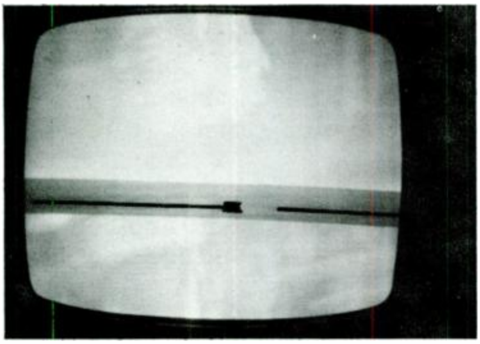


Figure 27 — Normal appearance of the vertical blanking bar.

Picture Pulling

Picture pulling (Fig. 28) can be caused by defects in various sections of the receiver. Therefore, localization tests are necessary. If picture pulling occurs when an IF pattern signal is injected at the input of the IF amplifier, but the symptom disappears when a video

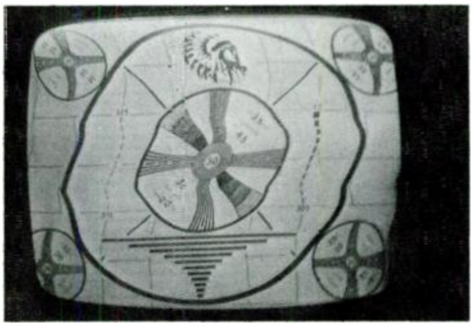


Figure 28 — A symptom of picture pulling.

frequency pattern signal is injected at the input of the video amplifier, the trouble will be found in the IF amplifier. In the case of hybrid receivers or line operated, all-transistor receivers, picture pulling may be associated with hum bars. Brightness modulation may be associated with picture pulling; it is caused by rapid changes in the AGC voltage as the horizontal sync pulse falls into or out of step with the flyback keying pulse.

It is helpful to check the video waveform at the output of the picture detector with a scope and low capacitance probe. For example, if the sync pulses are clipped or compressed we know that overload is occurring in an IF amplifier stage. The AGC line can be clamped to check for the possibility of AGC trouble. When hum modulation is present, and the scope is operated on 30-Hz horizontal deflection, we observe that the sync pulses are not leveled, but instead, ride up and down from one point to the next in the pattern.

Possible causes of picture pulling due to IF amplifier defects are:

a. Leaky capacitor that causes the AGC voltage to have an incorrect value.
b. Open neutralizing capacitor, such as C_{220} in Figure 23, which causes regenerative ringing and distorts the sync signal. The picture pulling and ringing symptoms then appear as shown in Figure 29.
c. Open capacitor that causes a highly distorted IF frequency response.
d. Hum in the supply line (hybrid receivers and AC operated all-transistor receivers only).
e. Gassy IF amplifier tube (hybrid receivers only).
f. Defective transistor, or incorrect type of replacement transistor.

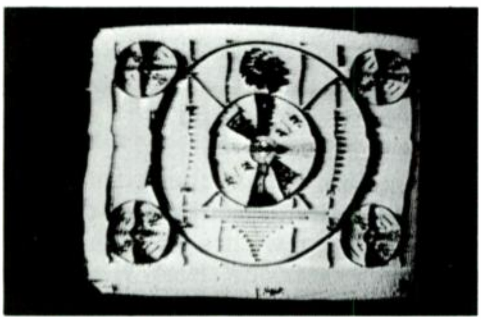


Figure 29 — Picture pulling caused by regeneration in the IF amplifier.

Poor Contrast

Poor contrast (Fig. 30) can be caused by defects in sections other than the IF amplifier. A TV analyzer is very helpful to localize the receiver section that has low gain. If normal contrast is obtained when a video frequency pattern signal is injected at the input of the video amplifier, but poor contrast occurs when an IF signal is injected at the input of the IF amplifier, the trouble will be found in the IF strip. The AGC line should be clamped to eliminate the possibility of AGC trouble. Note that the video detector should be checked, because a poor front to back ratio will cause a low contrast picture.

Common causes of a low contrast picture due to a defect in the IF amplifier are as follows:

a. Subnormal supply voltage to the IF section.
b. Incorrect IF AGC voltage.
c. Defective video detector diode.
d. Open bypass or decoupling capacitor in an IF stage.
e. Open or leaky capacitor shunting an IF coil.
f. Defective transistor.
g. Off-value resistor (rare cases only).

Open capacitors cannot be pinpointed by DC voltage measurements. However, the defective

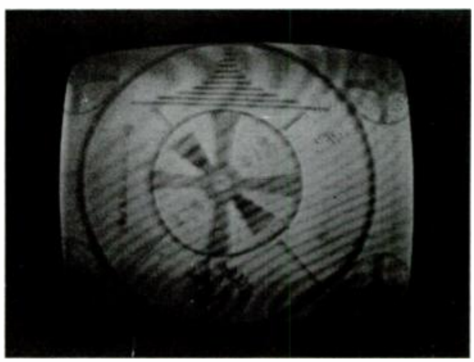


Figure 30 — A picture with low contrast.

stage can be localized by injecting an IF pattern signal at the base of each IF transistor in turn. For example, if the expected increase in contrast does not occur when the injection probe is transferred from the third stage to the second stage, we know that there is a defect in the second stage that is causing low gain. Leaky capacitors are indicated by incorrect DC voltages, unless the capacitor shunts a coil winding; in such case, the stage cannot be aligned correctly.

As an example of an open capacitor, if C_{219} in Figure 23 is open, the picture contrast will be very poor. Contrast remains poor when an IF test signal is injected at the base of Q201 or Q202. However, contrast becomes normal when the signal is injected at the base of Q203. The trouble will be pinpointed to C_{219} when a test signal is injected at the left-hand terminal of the capacitor, and then at the right-hand terminal. Signal injection tests are more useful than signal tracing tests in tracking down low gain, because a demodulator probe tends to disturb high frequency circuit action and may lead to false conclusions.

Negative Picture

Negative picture symptoms (Fig. 31) occur in hybrid receivers, but not in all-transistor receivers. The trouble can occur in any section of the signal channel that employs tubes. If the symptom disappears when a video frequency pattern signal is injected at the input of the video amplifier, the next step is to inject an IF pattern signal at the input of the IF amplifier. Then, if a

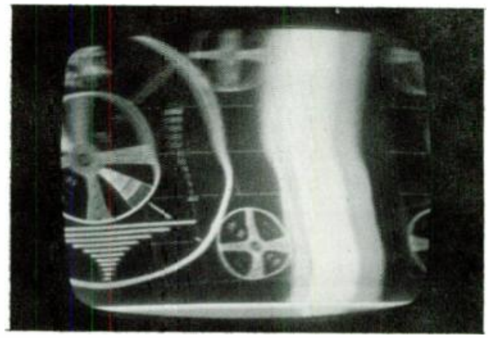


Figure 31 — A negative picture.

negative picture is displayed, the trouble will be found in the IF strip. Since a defect in the AGC system can cause a negative picture symptom, the AGC line should be clamped.

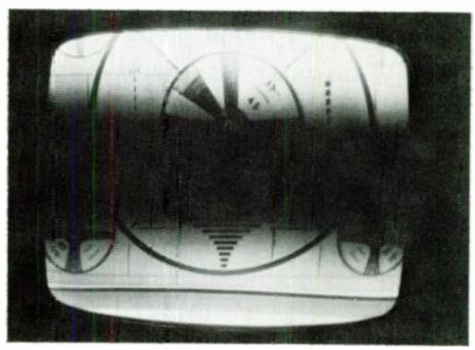


Figure 32 — Hum bar in the picture.

Common causes of a negative picture in a hybrid receiver are:

a. Leaky coupling capacitor that reduces the grid bias on an IF tube.
b. Open bypass or decoupling capacitor that produces regeneration in an IF stage.
c. Incorrect bias voltage from the AGC system.

d. Successive stages peaked to the same frequency, causing regeneration or marginal oscillation.
e. Gassy tube in an IF stage.
f. Missing or poorly grounded IF coil shields.

Troubleshooting tube-type IF amplifiers in hybrid receivers is the same as in tube type receivers; therefore, it is not explained in detail here.

Hum Bars

Figure 32 illustrates a severe case of power supply malfunction such as an open filter capacitor. A similar symptom in DC operated portable sets can be due to a decoupling capacitor. This permits vertical pulses to enter the signal circuits.

Intermittent Reception

Intermittent reception due to IF defects can be localized by suitable monitoring procedures. Technicians often find that an intermittent symptom disappears when a test instrument is connected into a circuit; the logical procedure is to leave instruments connected at key points, and wait for the intermittent symptom to recur. It may also be possible to speed up the intermittent. A typical monitoring test setup is made as shown in Figure 33. The VTVM's are used with RF probes connected at the collector terminals of the IF transistors; the scope monitors the picture detector output. Since the reading is comparatively low at the second IF stage, the most sensitive VTVM should be used at this position.

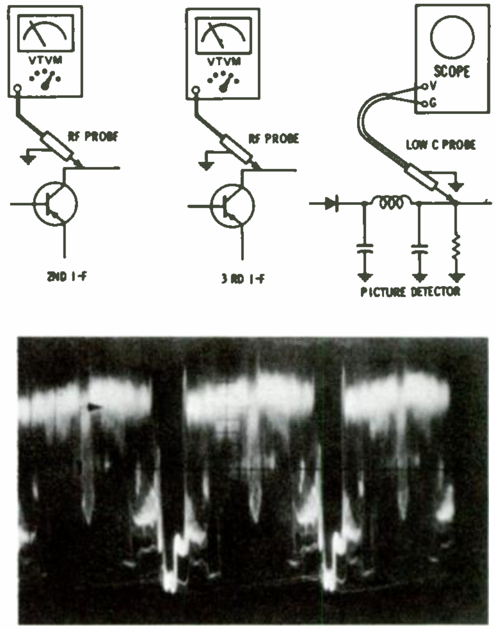


Figure 33 — Testing for intermittent reception.

Let us suppose that the symptom is intermittent loss of both picture and sound. When the intermittent occurs, the waveform may disappear from the scope screen, while the VTVM readings remain unchanged. Evaluation of readings is improved by clamping the AGC line during the monitoring test. If the VTVM readings are unchanged, we know that the trouble will be found in the picture detector section. On the other hand, if the waveform disappears from the scope screen and the reading of the VTVM at the third IF stage falls to zero, the trouble will be found in the third IF stage. Again, if the scope screen goes blank and both VTVM readings fall to zero, we know that the trouble will be found in the first IF stage, or in the RF tuner. The latter possibility can be checked by injecting an IF pattern signal at the input of the IF strip.

Common causes of intermittent reception due to a defect in the IF amplifier are:

a. Cracks in printed circuit wiring.
b. Cold solder joints.
c. Intermittent short or open in a capacitor.
d. Intermittent picture detector diode.
e. Intermittent IF transistor.
f. Defective IF coil or transformer.
g. Intermittent resistor (rare cases only).

Smeared Picture

A smeared picture can be caused by a defect in the video amplifier, as well as in the IF amplifier. Therefore, signal injection should be used at the beginning to localize the defective section. After it has been determined that the trouble is actually in the IF amplifier, check the IF response curve with a sweep generator and scope. It may be found, for example, that a trap has been misadjusted and is distorting the response curve shape. When the IF amplifier cannot be brought into correct alignment, there is a component defect that must be pinpointed. Voltage measurements will usually indicate leaky capacitors or defective transistors. An open capacitor in an IF stage can be localized to the particular stage by injecting an IF pattern signal at the base of each IF transistor.

Picture smear can also be caused by regeneration in the IF strip. The smear often disappears when a strong input signal is applied, and the IF amplifier is operating at comparatively low gain. If a weak input signal is applied, the amplifier operates at high gain, which tends to distort the response curve due to regeneration. In the case of hybrid receivers smear can be caused by a gassy tube in the IF strip.

Possible causes of a smeared picture in an all-transistor receiver due to a defect in the IF amplifier are:

a. Open neutralizing capacitor, such as C_{220} in Figure 23.
b. Open capacitor across an IF coil (C_{215}, or C_{223} in Figure 23.
c. Misadjusted IF trap.
d. Open bypass or decoupling capacitor.
e. Defective transistor.
f. Defective IF coil or transformer (infrequent, but possible).

The distinction between a bypass capacitor and a decoupling capacitor is one of function in circuit action. A bypass capacitor provides a low AC impedance around a resistor which is used in the circuit to drop a DC voltage, as shown in Figure 34. That is, the emitter resistor is employed both to obtain the necessary emitter bias voltage and to stabilize the stage with respect to temperature variation. An emitter bypass capacitor is used to eliminate current feedback. On the other hand, a decoupling capacitor is connected across a resistor to provide low pass filter action and to prevent high frequency signals from entering the power supply, or other common impedance, as seen in Figure 34. A common impedance between stages leads to feedback and operating instability.

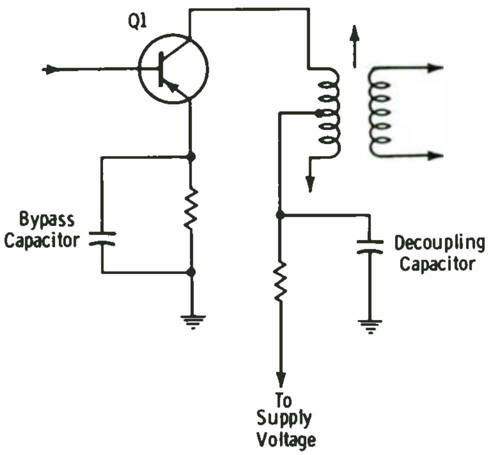


Figure 34 — Typical bypass and decoupling capacitors.

Overloading in the IF Amplifier

Overloading in the IF amplifier causes excessive contrast, often with a muddy, filled-up appearance in the picture. Since a defect in the AGC system can be the cause, the AGC line should be clamped. In case the symptom persists, signal injection at the input of the video amplifier and at the input of the IF amplifier is helpful to localize the trouble. After it has been determined that overloading is actually occurring in the IF amplifier, tests must then be made to pinpoint the defective component. Leaky coupling capacitors are prime suspects, because leakage causes a base bias shift and results in excessive emitter current. This defect is easily tracked down by DC voltage measurements.

Common causes of overloading due to an IF amplifier defect are as follows:

a. Leaky coupling capacitors such as C_{209} and C_{219} in Figure 23.
b. Leaky bypass capacitor, such as C_{221} in Figure 23.
c. Replacement transistor with an excessively high beta value.
d. Distorted IF response curve, with a high peak at the picture carrier end. (Can be caused by an open neutralizing capacitor.)
e. Off-value resistor, such as R_{208} in Figure 23. (Infrequent, but possible.)
f. Replacement of a silicon transistor by a germanium transistor.

Note that old model transistor TV receivers may produce overload symptoms when high level input signals are applied. This is a result of inadequate dynamic range in the AGC system. The practical solution to this problem is to use a resistive pad in the antenna lead, and thereby reduce the signal level. If the pad causes objectionable attenuation on the weaker channels, a switch must be provided to cut the pad in or out as required.

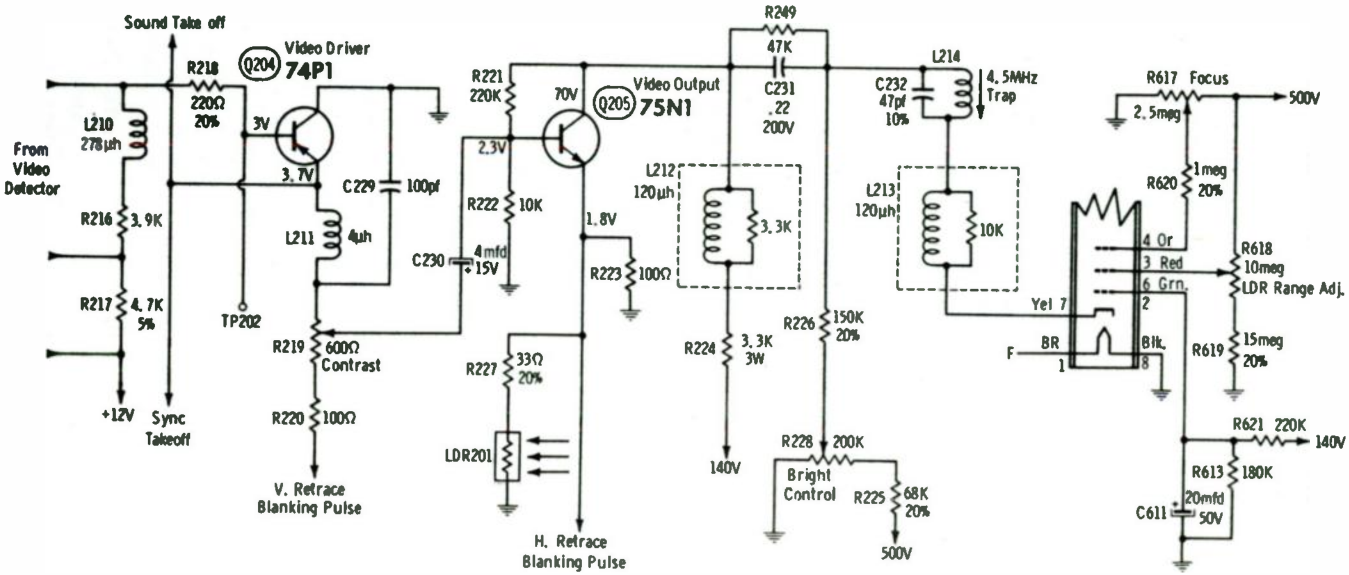


Figure 35 — A transistor video amplifier circuit.

VIDEO AMP PROBLEMS

DC Voltage Distribution

Some of the DC voltages in a transistor video amplifier are very different from those in receivers employing tubes. Other DC voltages are somewhat similar to those in tube type receivers. Comparative DC voltage distributions for the two types of receivers are given in Figure 36. The emitter follower stage in Figure 36 operates at a collector voltage of 10.2 volts, compared with a plate voltage of 115 volts for a video amplifier tube. On the other hand, the video output stage in Figure 36B operates at a collector voltage of 90 volts, which is somewhat comparable to a plate voltage of 115 volts for a video output tube. The four fundamental bias circuits are shown in Figure 37.

Picture tube electrode voltages depend on whether a low voltage or a high voltage tube-type is used. For example, pin 3 (grid No. 2, sometimes called the first, or accelerating, anode) in Figure 36A operates at 460 volts, while grid No. 2 (pin 6) of the picture tube in Figure 36B operates at 95 volts. Picture tubes used in transistor-TV receivers are designed for fast warm-up in some cases, and you will occasionally find small-screen picture tubes that have special heater-cathode units designed for a 4- to 5-second warm-up time. Most picture tubes require a minimum peak-to-peak video drive of 50 volts for full contrast. However, the small-screen picture tubes may require only 25 or 30 volts p-p of signal drive. In such cases, the DC voltage at the collector of the video output transistor is comparatively low. For example, the video output transistor of a small-screen receiver that requires only 25 volts p-p of drive signal for the picture tube operates from a 40-volt DC source.

ANALYSIS OF COMMON SYMPTOMS

Loss of Picture, No Snow

A blank raster with no snow can be caused by defects in circuits prior to the video amplifier. Therefore, make a localization test by checking with a scope at the picture detector output, or by injecting a video frequency, test pattern signal at the input of the video amplifier.

Possible causes of loss of picture, with no snow, due to a defect in a transistor video amplifier are as follows:

a. Open coupling capacitor, such as C_{230} in Figure 35.
b. Shorted bypass capacitor, such as C_{229} in Figure 35.
c. Defective transistor.
d. Defective picture detector diode.
e. Break in printed circuit wiring.
f. Cold solder joint.
g. Short circuit due to solder splash.
h. Open peaking coil, such as L_{211} in Figure 35.
i. Resistor off value (infrequent, but possible).

Suspected open capacitors can be checked by signal tracing with a

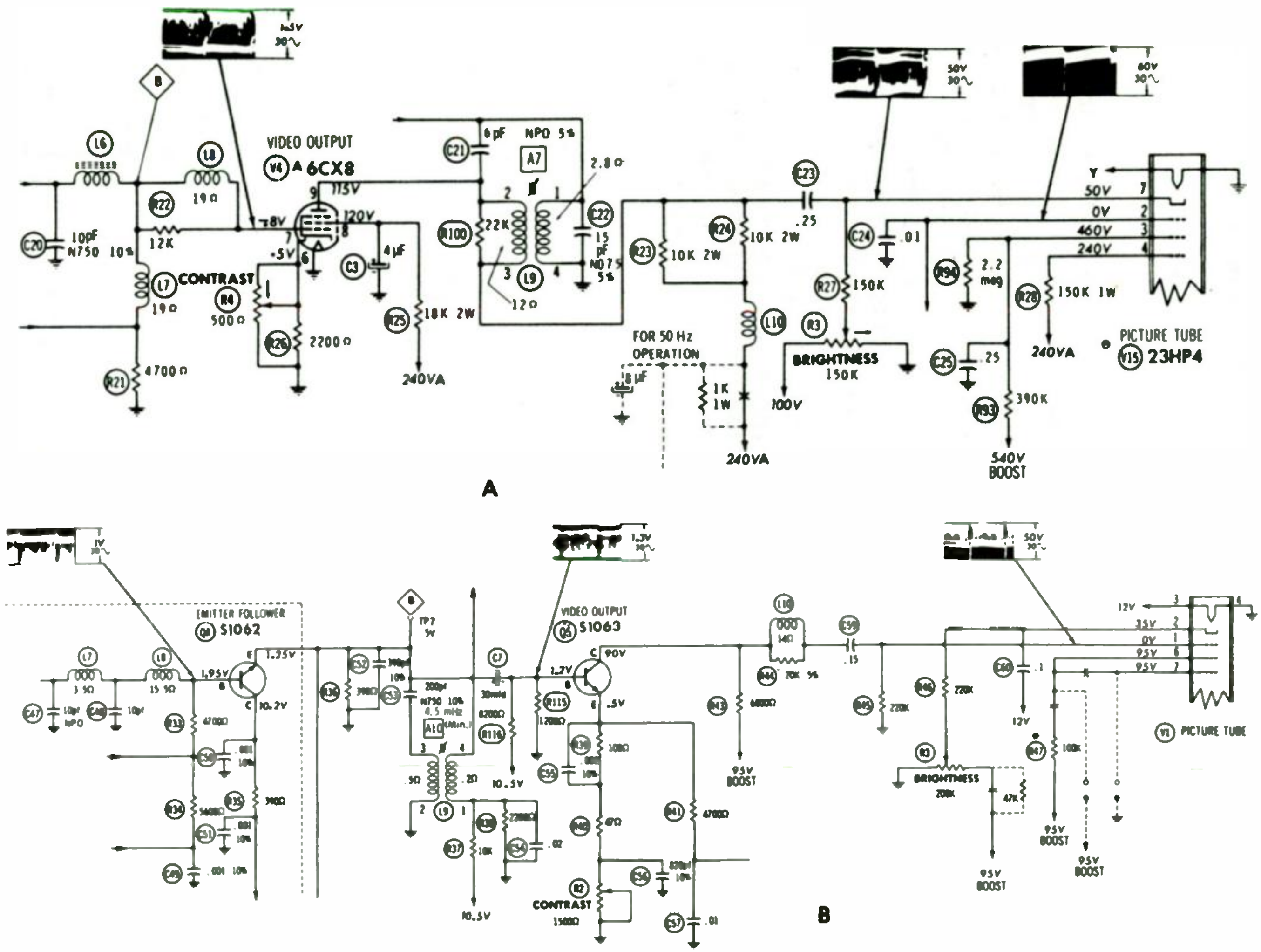


Figure 36 — Comparison of electrode voltages in tube and transistor video output stages.

scope, or the suspect can be bridged with a known good capacitor.

Weak Picture

Lack of contrast can be caused by defects in the signal channel prior to the video amplifier. Therefore, the signal level should be checked with a scope at the output of the video detector; if 1 volt p-p or more is measured, the trouble will be found in the video amplifier or the picture tube. The voltage gain of a normally operating video amplifier is easily checked with a scope, and will fall in the range from 25 times to 50 times, depending on the particular type of receiver (check the service data for input and output p-p voltages in the video amplifier).

Possible causes of a weak picture due to a defect in a transistor video amplifier are as follows:

a. Leaky bypass capacitor, such as C_{229} in Figure 35.
b. Defective coupling capacitor, such as C_{230} in Figure 35.
c. Subnormal supply voltage to the video amplifier section.
d. Excessive collector to base leakage in a transistor.
e. Worn and defective contrast control.
f. Off-value resistor (rare cases only).
g. Defective video detector diode.

Preliminary trouble localization can be made by signal tracing with a scope and low capacitance probe. If the output waveform at a stage has definitely subnormal amplitude, we know that the trouble will be found in that stage. Follow up with DC voltage measurements to close in on a defective component or transistor.

Hum Bars

Hum bars may occur in hybrid receivers, or in all-transistor receivers that are line operated. In hybrid receivers, 60-Hz hum bars result from heater to cathode leakage in a video amplifier tube, or from a poorly filtered half wave power supply. Similarly, 120-Hz hum bars can be caused by a poorly filtered full wave power supply, in either hybrid or all-transistor receivers. Hum bars can be caused by external interference (Fig. 40). In such case, the interference disappears when the receiver is switched

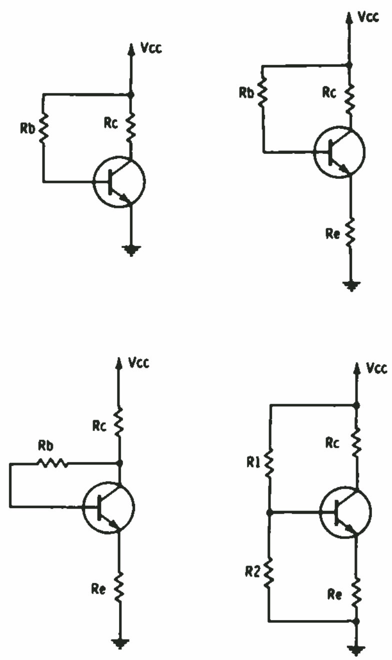


Figure 37 — Bias stabilizing circuits.

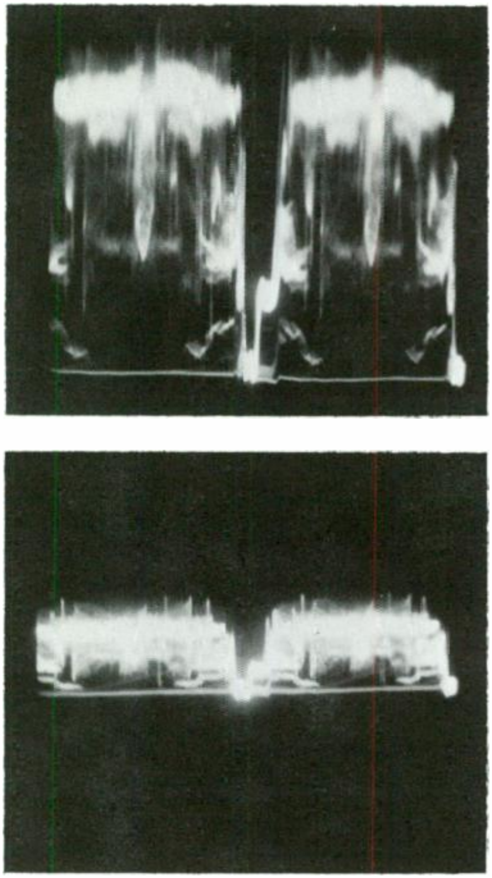


Figure 38 — Scope waveforms at the video detector output.

to another channel. In exceptional cases, 60-Hz hum bars are caused by an open decoupling capacitor in the vertical sweep section of the receiver.

Excessive Contrast

When the picture has excessive contrast check the peak to peak voltage of the video waveform at the output of the picture detector. If the amplitude is approximately 1 to 2 volts p-p, the trouble will be found in the video amplifier. Excessive video amplifier gain is commonly caused by a defect in the contrast control circuit. For example, if C_{56} in Figure 36B is shorted, the video amplifier operates at maximum gain, and the contrast control has no effect. Again, if C_{56} is leaky, there is a lack of normal control range.

Another contrast control configuration is shown in Figure 41. The potentiometer is connected in the collector circuit instead of the emitter circuit. Excessive contrast and lack of normal control range occur if C_{248} is leaky or shorted. Note that the video amplifier depicted in Figure 41 is direct coupled. As in a tube type video amplifier, the advantage of direct coupling is better reproduction of dimly and brightly illuminated backgrounds. The DC coupling diode will always conduct at all times, unless it becomes defective. The diode has a nonlinear forward-resistance characteristic, as depicted in Figure 42. This nonlinearity compensates for the curvature in the transistor characteristic and thereby provides better reproduction of the range of gray shades in the picture.

Common causes of excessive contrast due to defects in a transistor video amplifier are:

a. Leaky or shorted bypass capacitor.
b. Replacement transistor that has an excessive beta value.
c. Worn or noisy contrast control.
d. Shorted compensating capacitor, such as C_{246} in Figure 41.

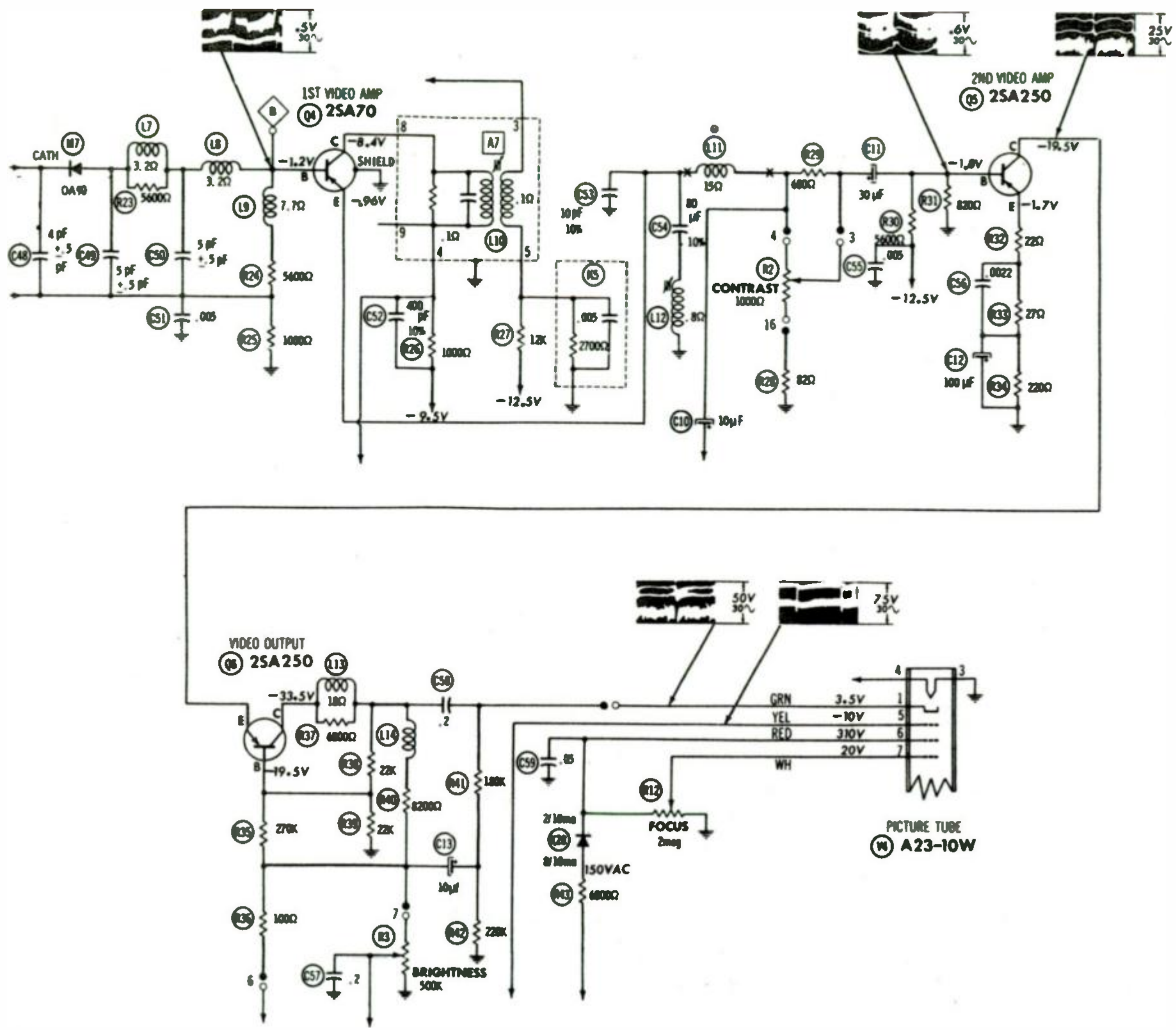


Figure 39 — A three stage video amplifier.

e. Off-value resistor that causes incorrect base-emitter bias (infrequent, but possible).

Note that the gain (beta) of a transistor increases rapidly with rising temperature, as shown in Figure 43. Therefore, when the setting of the contrast control must be progressively reduced to avoid excessive contrast, check the operating temperature of the video output transistor—it is possible that the heat sink is defective. If the transistor temperature is permitted to rise excessively, the collector junction will burn out.

To protect the video output transistor against damage in case the temperature increases abnormally, some manufacturers provide a protective diode connected between the base and emitter as shown in Figure 44. When the transistor starts to heat up, current increases and the bias voltage between base and emitter tends to increase. However, since the diode is a nonlinear resistance, it draws current out of proportion to its increasing terminal voltage. Therefore, the base emitter bias voltage can rise but slightly, and thermal runaway is prevented.

When a video output transistor has been damaged, a defective component is usually responsible. Accordingly, the circuit should be checked carefully before a new transistor is placed in operation. A protective diode (Fig. 44) sometimes fails, with resulting transistor burn out. Note that hybrid video amplifiers such as shown in Figure 45 are used in black and white and color receivers. In this arrangement, if the transistor develops a shorted collector junction, the signal feeds through from one tube to the next without 180° phase shift. In turn, we obtain a negative picture at comparatively low contrast.

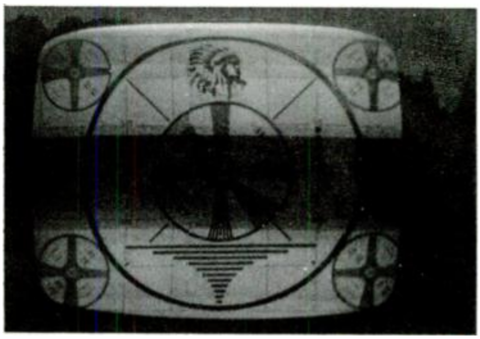


Figure 40 — Hum bars caused by external interference.

The blanking diodes in Figure 45 are actually part of the sweep system. However, since they are placed in the video amplifier section, a mention of their function is made in this chapter. In case the horizontal blanking diode short circuits, the screen will be shaded. Or, if the vertical blanking diode short circuits, the raster will be shaded vertically, with the darkest portion at the top of the screen.

Sound in Picture

Sound interference can be caused in sections prior to the video amplifier. Therefore, a preliminary check of the video signal should be made at the output of the picture detector with a wide band scope and low capacitance probe. If the video signal looks "fuzzy" with noticeable 4.5-MHz voltage riding on the sync pulses, we will not waste time

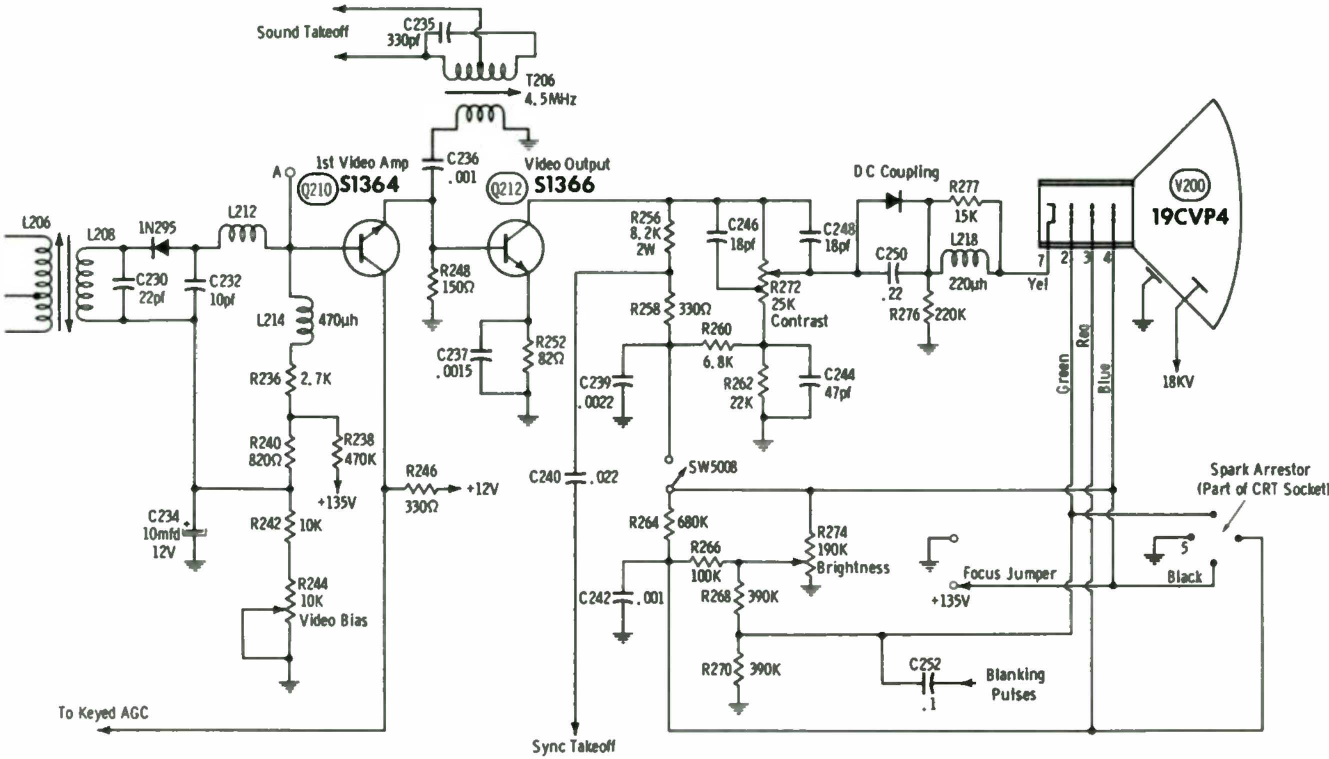


Figure 41 — Another type of transistor video amplifier circuit.

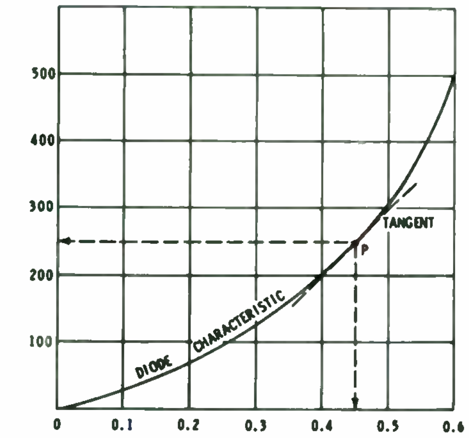


Figure 42 — A DC coupling diode has a nonlinear resistance characteristic.

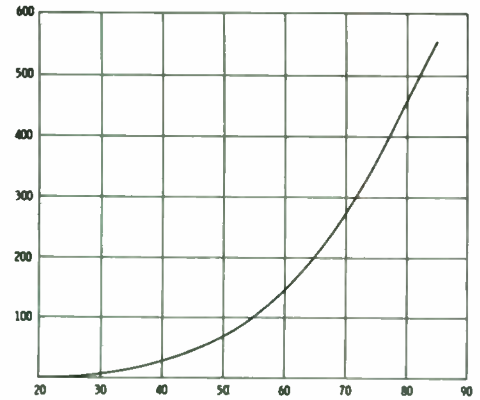


Figure 43 — Increase of gain (beta) of a transistor with rising temperature.

checking the video amplifier. On the other hand, if a normal video signal is displayed, the trouble will be found in the video amplifier. Note T_{206} in Figure 41. The primary of T_{206} forms a series resonant circuit with C_{236}. When T_{206} is tuned exactly to 4.5-MHz, the sound signal "sees" a low impedance to ground and is thereby prevented from entering the base of Q212. Therefore, adjustment of the sound trap should be checked first when sound appears in the picture. If the trap will not tune, C_{236} is a prime suspect.

Possible causes of a 4.5-MHz beat frequency in the picture due to defects in a transistor video amplifier are:

a. Defective sound takeoff transformer (or sound trap).
b. Defective capacitor in the sound transformer or trap circuit.
c. Break in printed circuit wiring in the sound takeoff section.
d. Cold solder joint.
e. Solder splash causing a short circuit.
f. Defective winding on sound transformer or trap (less likely than other defects).

Sound signal interference in the picture appears as sound bars that fluctuate with the audio transmission. The bars are not straight, but curved in various directions, and their curvature changes with the audio signal modulation. In large screen receivers, a 4.5-MHz dot pattern or "grain" is also observed during modulation.

Negative Picture

A negative picture at reduced contrast can be caused by a shorted collector junction in a hybrid receiver. In exceptional cases, a shorted collector junction results in a weak negative picture in an all-transistor video amplifier; however this is rare.

Smeared Picture

Picture smearing can be caused by defects in sections prior to the video amplifier. Therefore, it is necessary to make a localization test. For example, a video frequency test pattern signal can be injected at the input of the video amplifier. Another method is to inject a square wave signal at the video amplifier input. Picture smear is associated with square wave distortion, as shown in Figure 46. A comparatively low frequency square wave (such as 60 Hz) is employed.

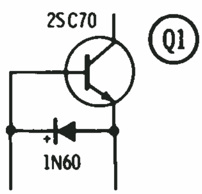


Figure 44 — The 1N60 diode protects the transistor against thermal runaway.

Possible causes of a smeared picture due to defects in a transistor video amplifier are as follows:

a. Open bypass capacitors, such as C_{239} and C_{244} in Figure 41.
b. Open peaking coil, such as L_{218} in Figure 41.
c. Open peaking capacitor, such as C_{246} or C_{248} in Figure 41.
d. Incorrect replacement transistor with excessive junction capacitance.
e. Off-value load resistor, such as R_{256} in Figure 41. (Rare cases only.)

Suppose that L_{218} in Figure 41 becomes open, due to mechanical damage, break in the printed circuit wiring, or a cold solder joint. In such cases, the high frequency response is impaired. Moreover, R_{277} then works into the cathode input capacitance of the picture tube. This forms an integrating circuit that distorts the video waveform and produces a smear symptom. If a bypass capacitor is open, the effective value of the collector load resistance is increased. This upsets the RCL balance of the high frequency compensating system, and can cause picture smear.

Poor Definition

Poor definition (lack of picture detail) results from poor high frequency response. To localize the trouble, a video frequency, test pattern signal can be injected at the input of the video amplifier. If the vertical wedges in the test pattern are blurred and poorly reproduced, the trouble will be found in the video amplifier. If a TV analyzer is not available, a sweep generator may be used to check the overall RF/IF response curve. In case this response curve is normal, we know that lack of picture detail is caused by a defect in the video amplifier.

Possible causes for poor picture definition due to defects in a transistor video amplifier are:

a. Open bypass capacitor, such as C_{234} in Figure 41.
b. Defective shunt capacitor in picture detector circuit.
c. Shorted turns in a peaking coil, or replacement peaking coil with incorrect inductance value.

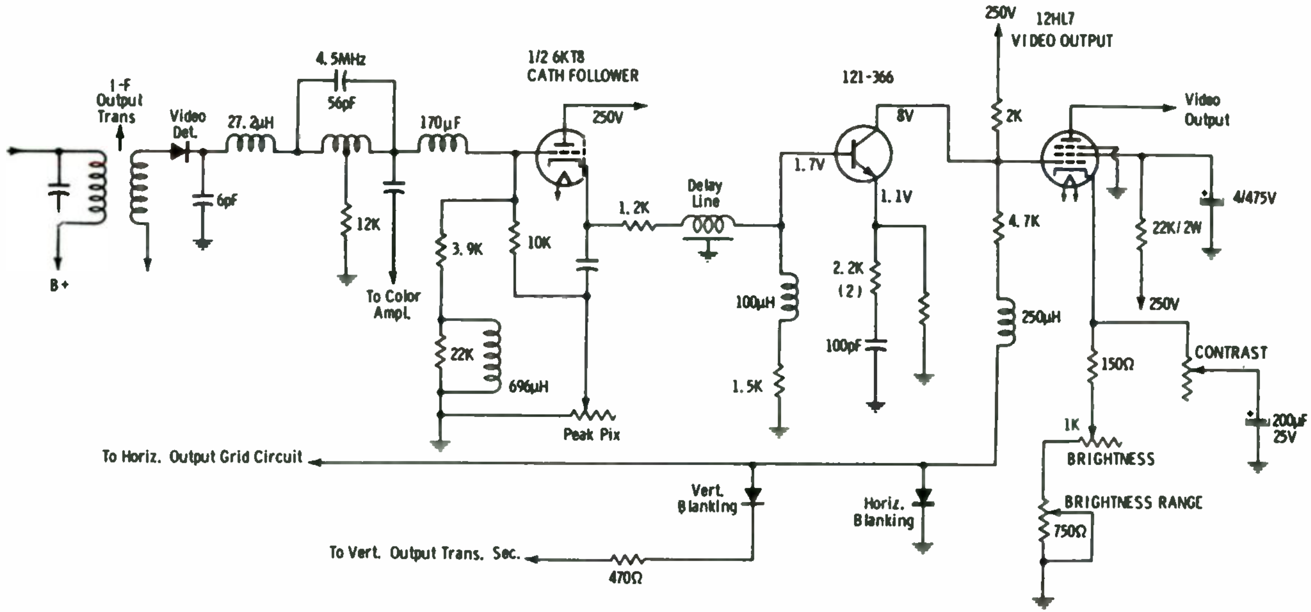


Figure 45 — A hybrid video amplifier.

d. Incorrect type of replacement transistor.
e. Off-value load resistor (less likely than other defects).

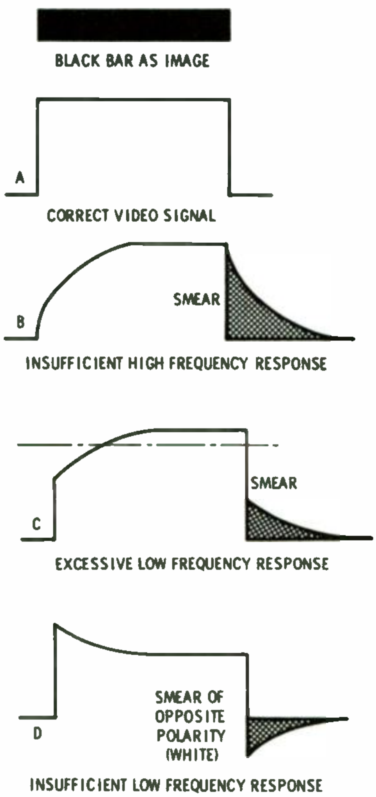


Figure 46 — How square wave reproduction indicates video amplifier deficiencies.

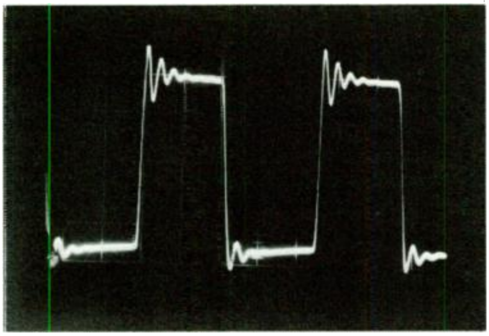
Ringing in the Picture

When ringing (circuit ghosts) are present in the picture, a localization test is required. The same methods can be used as described previously for poor definition. Another method is to apply a square wave signal at the input of the video amplifier, and observe the waveform at the amplifier output with a scope and low capacitance probe. A moderately high frequency square wave such as 50 or 100 kHz, is suitable. If the reproduced square wave rings, as illustrated in Figure 47A, circuit ghosts are produced. Ringing is basically caused by a rising high frequency response, as shown in Figure 47B. The frequency response of the video amplifier can be checked with a scope and a video frequency sweep generator, if available.

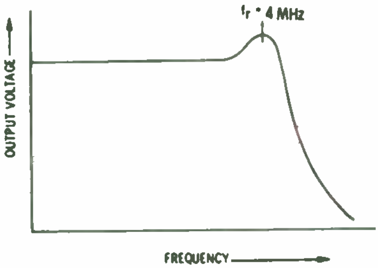
Common causes of picture ringing due to defects in a transistor video amplifier are:

a. Open damping resistor, such as R_{277} in Figure 41.
b. Replacement peaking coil L_{218} with incorrect inductance value.
c. Damaged or otherwise defective peaking coil.
d. Incorrect type of replacement transistor.
e. Shorted capacitor, such as the 56-pF trap capacitor in Figure 45.
f. Defective delay line (color receivers only).
g. Off-value collector load resistor (infrequent, but possible).

A damping resistor might be in good condition, but still be open circuited because of a cold solder joint. Incorrect inductance in a replacement peaking coil distorts the video frequency response curve, and if a rising high frequency response results, circuit ghosts will be displayed. A peaking coil from a tube type receiver cannot, in general, be used to replace a peaking coil



(A) Oscilloscope display.



(B) Video-amplifier response curve.

Figure 47 — Ringing caused by a peaked video amplifier response.

in a transistor receiver. Collector and emitter junction capacitances are very different from plate and grid input capacitances. By the same token, junction capacitances for various types of transistors are not the same. For this reason, the correct type of replacement transistor must be used.

Retrace Lines Visible

In theory, vertical retrace lines are invisible because the sync pulses are on pedestals that supposedly blank the retrace lines. However, in practice, there are several factors that can defeat the purpose of the pedestals in a video waveform. If the video amplifier is AC coupled, the blanking pedestals do not maintain a constant level, but vary in peak voltage with the average illumination of the televised scene. In turn, retrace lines appear in some scenes, and not in others. Viewers sometimes set the brightness control abnormally high; this defeats the function of the blanking pedestals, even in a DC coupled video amplifier. When the picture tube weakens, it is necessary to turn the brightness control beyond its normal setting to obtain a satisfactory display.

Therefore, we commonly find vertical blanking pulses coupled into the video amplifier to ensure that vertical retrace lines will be invisible at all times. This function has been previously noted for hybrid receivers (Fig. 45). With reference to Figure 35, a vertical retrace blanking pulse is fed from the vertical sweep section to the base of the video output transistor. Similarly, a horizontal retrace blanking pulse is fed from the horizontal sweep section to the emitter of the video output transistor. If a circuit defect kills a blanking pulse, retrace lines become visible. A scope is the best instrument to use for signal tracing the blanking pulse to the point at which it is stopped.

Note the vertical pulse coupling capacitor in Figure 48. If this capacitor is open, the blanking pulse will be stopped. A shorted capacitor such as C_{211} in Figure 48 will also stop the blanking pulse; in this case, the DC voltage distribution in the video amplifier is changed. However, it is unlikely that this change will be discovered in DC voltage measurements, because the contrast control will have been reset to compensate for the change.

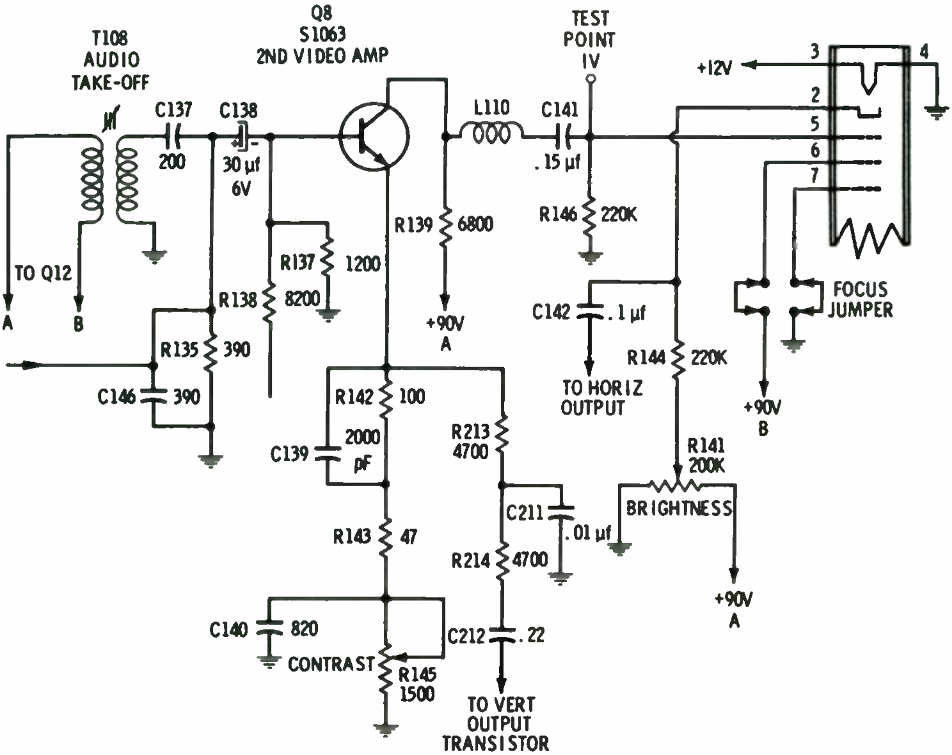


Figure 48 — C212 couples the vertical blanking pulse to the vertical amplifier.

Common causes for visible retrace lines are as follows:

a. Open coupling capacitor in blanking pulse circuit.
b. Shorted wave shaping capacitor in blanking pulse circuit.
c. Cold solder joint that opens the capacitor circuit.
d. Break in printed circuit wiring.
e. Short circuit due to solder splash.

No Raster

We know that absence of a raster is commonly caused by high voltage failure, or by a defect in the horizontal sweep system. However, a no-raster symptom can also result from certain defects in the video-amplifier section. It is assumed that the picture tube is known to be in operating condition. In such case, the trouble can be tracked down by checking the DC voltage distribution at the picture tube terminals. With reference to Figure 48, it is advisable to start by checking the heater voltage. If this voltage is low, the picture tube will have low emission, although a heater glow may be visible. Note that low emission can result from a poor contact in the picture tube socket, although the supply voltage is normal.

When there is no raster, and the trouble has been localized to the video amplifier, the brightness control is a ready suspect. A worn and noisy control can cause excessive bias voltage to be applied to the cathode of the picture tube, thus cutting off the electron beam. For example, suppose that R_{141} in Figure 48 is badly worn or open near the grounded end. Then, the picture tube will remain cut off, regardless of the control setting. Again, consider a situation in which R_{146} in Figure 48 is open. This results in a floating grid, which charges up to a substantial negative potential due to grid current, and cuts the picture tube off.

Common causes of a no-raster symptom due to defects in a transistor video amplifier are as follows:

a. Subnormal heater voltage at picture tube.
b. Defective brightness control.
c. Shorted pulse coupling capacitor (symptom may be raster shading in some configurations).
d. Defective picture tube socket.
e. Floating grid in picture tube (grid resistor open—infrequent, but possible).
f. Cold solder joint or break in printed circuit wiring.

Note that if C_{142} in Figure 48 is shorted, DC voltage from the horizontal-output section may be applied to the picture tube cathode. In some receivers, this DC voltage is comparatively high, causing picture tube cutoff regardless of the setting of the brightness control. This defect shows up as a substantial positive voltage on the cathode of the picture tube, even when the brightness control is set to minimum.

Intermittent Reception

Troublesome intermittents can be localized to best advantage by monitoring DC and signal voltages in the video amplifier section. A scope may be connected at the output of the picture detector, and if a second scope is available, it can be connected at the output of the video driver. The picture tube serves to monitor the signal from the video output stage. The DC voltages may be monitored by connecting voltmeters across the emitter resistors. Any of the video amplifier trouble symptoms that have been discussed can occur in intermittent form.

The picture tube can become intermittent, and if monitoring tests throw suspicion upon the picture tube, a replacement test should be made. Tapping an intermittent component will sometimes localize the trouble and speed up the intermittent condition. Heat can be applied to the pigtails of suspected capacitors from a soldering gun. Switching the power off and on, and switching the input signal off and on will occasionally speed up an intermittent. After monitoring tests have localized the intermittent to a particular stage, further DC voltage measurements will help to pinpoint the defective component.

Common causes for intermittents caused by defects in a transistor video amplifier are:

a. Intermittent capacitor (thermal or mechanical).

b. Intermittent picture detector diode.
c. Intermittent blanking diode.
d. Erratic contrast or brightness control.
e. Poor contact of socket to picture tube base pins.
f. Intermittent transistor.
g. Intermittent picture tube.
h. Cold solder joint.
i. Microscopic break in printed circuit wiring.

If you suspect that there is a marginal break in the printed circuit wiring, flex the board slightly to see if there is a sudden change in picture reproduction. Press suspected leads or pigtails from side to side to check for cold solder joints. The entire receiver may be operated in a cooler in difficult situations, but a hotbox must not be used to speed up an intermittent.

COMMON SYMPTOMS— TROUBLES IN AGC SYSTEMS

Negative Picture

Negative pictures due to defects in the AGC section are encountered only in hybrid receivers. In a hybrid receiver, AGC control may be obtained from a transistor AGC system. This arrangement employs an AGC circuit that provides more negative bias voltage when the IF signal level increases. Let us consider the configuration shown in Figure 49. Transistor Q_1 operates as a keyed AGC stage. The emitter is driven by video signal from the picture detector, and the base is fixed biased at 3 volts. The collector is pulsed from a winding on the flyback transformer. When the applied video signal is strong, the transistor conducts an appreciable amount of current in 15.75-kHz pulses. However, when the video signal is weak, little pulse current occurs.

Note in Figure 49 that the normal 5 volts DC at the collector of Q1 is produced by pulse rectification via diode X4. When a video signal is applied to the emitter, the horizontal sync pulses (negative-going) increase the forward bias on the transistor. In turn, collector current increases and electrons flow into the IF AGC line and into R_{14}. Thereby, the negative AGC voltage is increased. Pulse output voltage from X4 is filtered by C_3, R_{14}, and C_2. A preliminary check of circuit action is made by connecting a DC voltmeter to the IF AGC line, and observing the change in control voltage when the input signal to the receiver is varied.

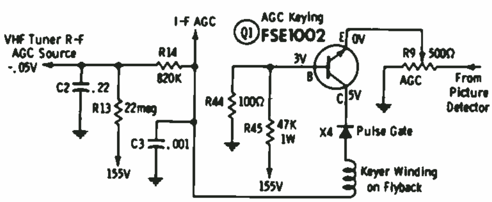


Figure 49 — Transistor keyed AGC stage used in a hybrid receiver.

Common causes for a negative picture are:

a. Shorted C_2 or C_3 in Figure 49.
b. Open X4.
c. Defective transistor.
d. Leakage from keyer winding to core of flyback transformer.

e. Worn or noisy AGC control.
f. Off-value resistor (infrequent, but possible).

In addition to DC voltage measurements, waveform checks are helpful in pinpointing a defective component. For example, if X4 is open in Figure 49, the keying waveform will appear only on the input side of the diode. Again, if there is leakage from the keyer winding to the core of the flyback transformer, the keying pulse will be weak or absent. In case the AGC control is worn and defective, the video waveform at the emitter of Q1 will be weak or absent. The video signal has a normal amplitude of 0.2 volt p-p, and the collector pulse waveform has a normal amplitude of 35 volts p-p in this circuit.

No Sound, No Picture, Raster Normal

A preliminary localization test is made in this situation by measuring the AGC voltage, or clamping the AGC line. If clamping restores normal operation, the trouble will be found in the AGC system. Defective capacitors are the most common troublemakers. Possible causes of no sound and no picture with a normal raster are as follows:

a. Shorted AGC capacitor.
b. Defective diodes.
c. Defective transistor.
d. Short circuits in the supply voltage.
e. Cold solder joint.
f. Break in printed circuit wiring that opens the supply voltage.

Overloaded Picture, Often With Intercarrier Buzz

An overloaded picture (Fig. 50) appears muddy and filled up; when due to AGC trouble, the symptom disappears when the AGC line is clamped. Scope checks of the circuit waveforms are the best preliminary approach, followed by DC voltage measurements. Note that inter-carrier buzz may accompany picture overload, because the IF amplifier operates at high gain and

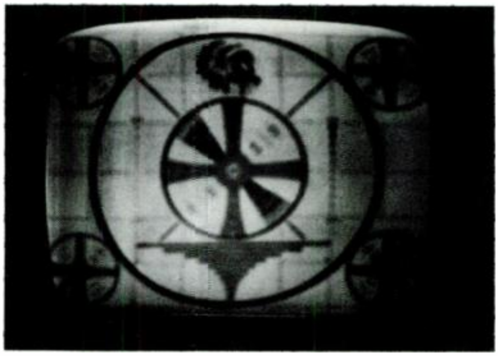


Figure 50 — An overloaded picture.

abnormal signal levels are processed by circuits that are operating nonlinearly. In turn, the picture signal can be modulated excessively on the sound signal.

Possible causes of an overloaded picture due to AGC defects are:

a. Pulse diode open or shorted.
b. Rectifier filter capacitor shorted.
c. Defective keyer winding.
d. Defective transistor.
e. Mistuned transformer.
f. Off-value resistor (rare cases only).

Weak Picture

When a low contrast picture (Fig. 51) is caused by AGC trouble, the picture becomes normal when the AGC line is clamped. In an all transistor receiver that uses forward AGC, the trouble is due to an AGC voltage that is greater than normal for the reference input signal level. A systematic test procedure is then required to pinpoint the defective component. Measurement of DC voltages is the best approach, supplemented by scope waveform checks.

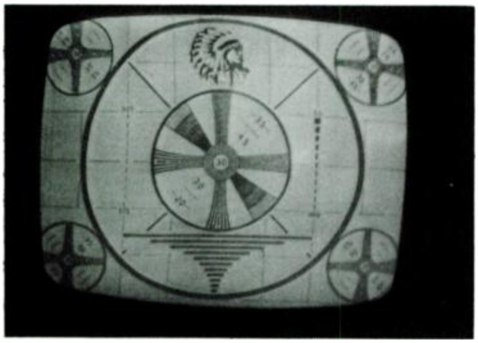


Figure 51 — A low contrast picture.

Possible causes of low contrast due to AGC trouble are:

a. Defective AGC amplifier transistor.
b. Open neutralizing capacitor.
c. Incorrect type of replacement transistor.
d. Replacement of flyback transformer with excessive keyer voltage.
e. Off-value resistor (less likely than other defects).

Germanium and silicon transistors have different characteristics; therefore, an incorrect type of replacement transistor can cause AGC trouble. If the neutralizing capacitor is open, the keying stage becomes regenerative and may develop excessive output, depending on the peaking frequency. Oscillation causes the same trouble, and strong oscillation makes the AGC system unresponsive to changes in input signal level.

With reference to Figure 49, a weak picture symptom can be caused by a defective AGC control. For example, if the control is worn or open near its grounded end, inadequate range results and abnormal video signal is applied to the emitter of the transistor. Another possibility of unsuspected trouble can be caused by an incorrect replacement flyback transformer that has excessive output from the keyer winding. Off value resistors are less common than other component defects, but they are occasional troublemakers.

Picture Pulling and Brightness Modulation

When picture pulling is caused by AGC trouble, contrast is usually excessive, although there are occasional exceptions. Clamping the AGC line will restore normal picture reproduction, if the trouble is in the AGC section. Brightness modulation (Fig. 52) often accompanies picture pulling. The cause of brightness modulation is a result of the sync pulses and the keying pulses falling more or less out of step with each other when the picture pulls. In turn, the AGC voltage varies over the vertical scanning

Figure 52 — Overloaded picture with horizontal pulling.

interval, and a scope check will show an AC ripple on the AGC line.

Possible causes of picture pulling and brightness modulation due to defective components in the AGC section are:

a. Pulse diode open or shorted.
b. Shorted rectifier filter capacitor.
c. Defective transistor or incorrect replacement type.
d. Incorrect type of replacement flyback transformer.
e. Break in printed circuit wiring.
f. Off-value resistor (less likely than other component defects).

When picture pulling is accompanied by brightness modulation, the variation in picture brightness changes with the setting of the horizontal hold control. The reason for this response is that the timing of the keying pulses is changed when the picture is shifted horizontally. For example, in the illustration of Figure 52, the picture is darker through the portion of maximum pulling. However, with a change in setting of the horizontal hold control, the picture shading may be reversed. In any case, the light and dark portions of the picture will shift vertically to some extent.

Note that this picture symptom could be confused with trouble in the horizontal AFC section. However, the excessive contrast and overload shown in Fig. 52 throw suspicion on the AGC system. Next, if the symptom clears up when the AGC line is clamped, it is logical to turn our attention to the AGC section. As in tube type receivers, AGC trouble is often difficult to cope with, because the circuits are comparatively complex.

COMMON SYMPTOMS— TROUBLES IN SYNC circuits

Loss of Vertical and Horizontal Synchronization.

The complete loss of both vertical and horizontal synchronization, illustrated by the photograph in Figure 53, is very often a result of a defective component located in the sync section. This symptom may be accompanied by other trouble symptoms that might give a clue as to what section of the receiver is at fault. A check of the tubes, coupling capacitors, and B+ voltages should be among the first troubleshooting procedures for this symptom.

Possible causes for loss of vertical and horizontal synchronization are:

a. Defective tube in sync or noise limiter stages.

b. Video coupling capacitor shorted, leaky, or open.
c. Plate or screen resistors open or too high in value.
d. Shorted or leaky coupling capacitor.
e. Shorted screen bypass capacitor.
f. Sync isolation resistor open or too high in value.
g. Resistance of voltage divider changed in value.
h. Improper cathode bias.
i. Open decoupling or B+ filter capacitor.
j. Improperly adjusted grid bias control.

It is possible for a negative picture or an overload condition to result from an inoperative sync circuit especially when the AGC network obtains its bias from this section. The loss of synchronization, a distorted picture, and buzz in the sound may indicate a shorted or leaky capacitor between the AGC and sync circuits. In many receivers, these two circuits have interlocking actions and can produce similar trouble symptoms. The service technician should never underestimate the influence of the noise eliminator stage. A defective component or an inoperative tube in this circuit can seriously affect sync stability.

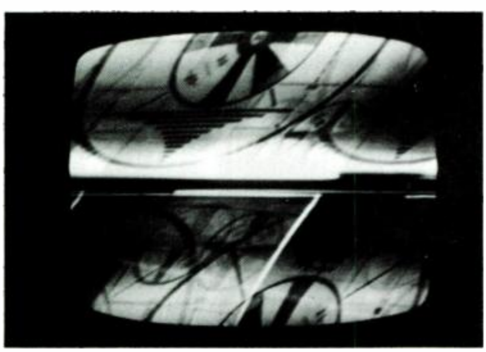


Figure 53 — Picture showing loss of vertical and horizontal synchronization.

A leaky coupling capacitor in the grid circuit of a typical sync separator will not retain a large enough charge to develop the proper grid leak bias. This trouble may be detected by an abnormal voltage reading on the grid of the tube.

Loss of Vertical Synchronization.

The photograph of Figure 54 represents a trouble symptom in which the picture moves either up or down at a rapid rate and thus produces an appearance of multiple images. In many such cases, the range of the vertical hold control will not be sufficient to lock in only one picture.

The symptom shown in Figure 55 illustrates another degree of poor vertical synchronization. In this instance, the picture may either tend to move slowly downward or to have an occasional flopover. These conditions can result from an inadequate or distorted sync pulse reaching the vertical oscillator circuit.

Possible causes of loss of vertical synchronization are:

a. Defective tube in the sync or noise limiter stages.
b. Defective integrator component.
c. A 60 Hz hum present in the sync signal.

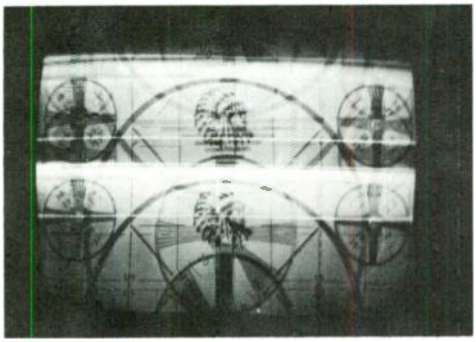


Figure 54 — Picture showing loss of vertical synchronization.

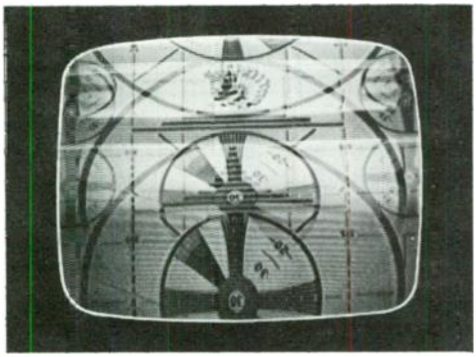


Figure 55 — Picture taken during sudden or periodic vertical flopover.

d. Leaky, shorted, or open coupling capacitor to vertical oscillator.
e. Open cathode bypass capacitor.
f. Voltage divider changed in value.
g. Plate load resistor decreased in value.

Another severe case of vertical sync trouble which is accompanied by a reduction in the height of the raster is pictured in Figure 56. One of the most common causes for a condition of this nature is a shorted, open, or leaky coupling capacitor located between the sync and vertical oscillator circuits.

If a plate load or voltage divider resistor overheats and changes value for no apparent reason, the replacement should always have a higher wattage rating than that of the original. This is a good practice to follow when any section of the receiver is being serviced.

In some of the older TV receivers, the sync take off point is located at the DC restorer diode and any sudden change in over-all picture brightness may result in a corresponding shift in the level of the sync signal. This condition often causes the vertical oscillator to skip and produce a momentary vertical roll.

Loss of Horizontal Synchronization.

Loss of horizontal synchronization, as illustrated by the photograph in Figure 57 is usually a direct result of a failure in the horizontal AFC or oscillator circuits. In many cases, however, this symptom can develop from a defective tube or component in the sync section. Trouble originating in the horizontal oscillator circuit usually produces a number of dark diagonal or horizontal bars on the screen. When the trouble is affecting the sync pulses fed to the oscillator, the picture often tends to drift back and forth. In this case, the hold control may be capable of stopping the picture; but the synchronization will still be very erratic.

Figure 56 — Picture showing loss of vertical synchronization accompanied by height reduction.

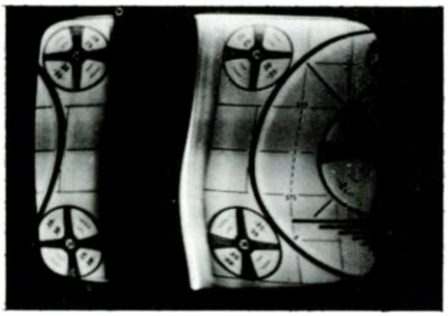


Figure 57 — Picture showing loss of horizontal synchronization.

In some instances, the trouble symptom will not appear until the receiver has been on for a certain period of time. This difficulty usually indicates that the heat generated in the receiver is affecting some component and is causing the oscillator frequency to drift out of range. A common offender causing a trouble of this kind is one or both of the mica or ceramic capacitors coupling the sync signal to the horizontal AFC circuit.

Possible causes of loss of horizontal synchronization are:

a. Defective tube in sync or noise limiter stages.
b. Open grid leak resistor.
c. Open or leaky coupling capacitor to horizontal AFC.
d. Plate resistor open or too high in value.
e. Open or leaky cathode bypass capacitor.
f. Open signal path in horizontal sync circuit. (Check tube sockets for corrosion or broken connections.)
g. Improper grid bias on horizontal sync tubes.

An open resistor in the grid leak network of a sync separator will sometimes result in the development of a train of oscillations when the contrast control is advanced. In a few other cases, it has been noticed that a Christmas tree effect can result when the contrast is reduced. This trouble symptom is shown in the photograph of Figure 58. An open filter capacitor located in the B+ circuit of the sync section is capable of producing this effect. The open capacitor will permit hum or vertical sync pulses to reach the AFC stage and thus cause erratic triggering of the oscillator.

Horizontal Pulling in the Picture.

The trouble symptoms shown in Figures 59 and 60 represent different degrees of horizontal pulling or bending. This trouble is encountered when the horizontal oscillator is trying to lose synchronization momentarily. Troubles of this nature are usually caused if some sort of sync pulse distortion or some hum modulation

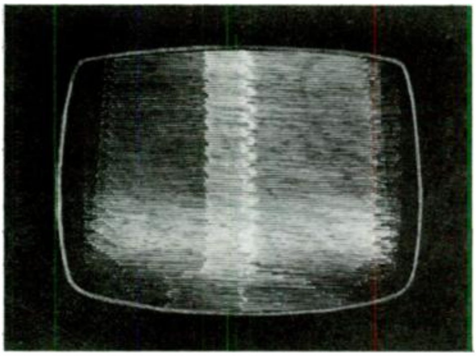


Figure 58 — "Christmas Tree" effect resulting from erratic operation of the horizontal oscillator.

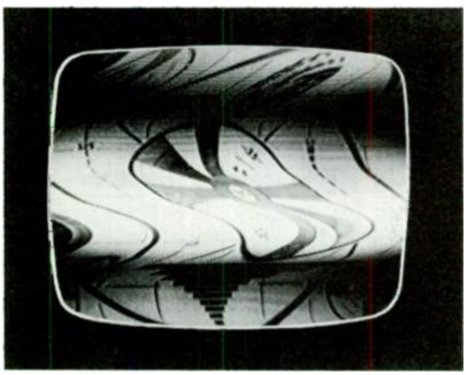


Figure 59 — Extreme horizontal pulling shown in the picture.

reaches the oscillator stage. One of the more common causes of picture pulling is insufficient filtering in the sync or AGC sections.

Possible causes of horizontal pulling in the picture are:

a. Defective tube in the sync or noise limiter stages.
b. Incorrect time constant in grid leak network.
c. Defective component in horizontal sync takeoff network.
d. Improper value of plate load resistor.
e. Improper filtering of bias supply. (Check all filter capacitors.)
f. Open screen bypass capacitor.
g. Leaky coupling capacitor in horizontal sync circuit.

If the time constant is too long in the grid leak network of the sync separator, the horizontal sync pulses immediately following the vertical sync pulse will be reduced slightly in amplitude. This is because the grid capacitor charges to a higher negative voltage during the vertical pulse than it does during the horizontal pulses. A greater negative voltage will then be present on the separator grid when the first horizontal pulses appear at the grid than when the last ones appear. During this first instant, the horizontal pulses will be of a lower amplitude and will often cause the picture to bend at the top. The top of the picture is rather sensitive to variations in the amplitude of the horizontal sync pulses especially when the control of the oscillator changes from the equalizing pulses back to the horizontal sync pulses.

Vertical Jitter.

The nature of vertical jitter will not permit a pictorial illustration, but undoubtedly the service technician has encountered this condition sometime in the past. The vertical oscillator acts as if it were about to lose synchronization. Instead of rolling, the picture tends to have a vertical jitter or bounce. With some troubles of vertical jitter, poor interlacing may also appear.

Possible causes for vertical jitter are:

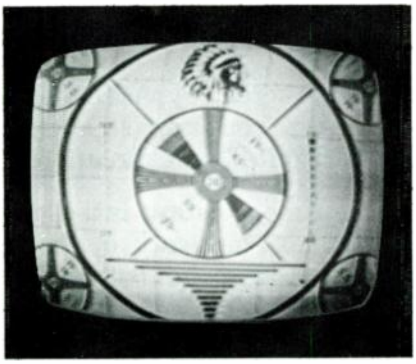


Figure 60 — Picture shows horizontal bending at the top.

a. Defective tube in the sync or noise limiter stages.
b. Defective component in the vertical integrator network.
c. Improper lead dress. (Check yoke and other leads near sync or oscillator stages.)
d. Open plate or screen bypass capacitor.

Horizontal pulses or portions of the video signal reaching the vertical oscillator stage will also produce this symptom. Remember to check for improper lead dress and for poor shielding.

Many sync troubles which have an intermittent characteristic can develop in a receiver. This type of trouble is usually difficult to isolate, and probably a great deal of the technician's time will be consumed in doing so. In these cases, the possibility of an intermittent tube should never be overlooked. Other causes of intermittent operation may include loose connections, cold solder joints, or drops of solder or other foreign particles causing shorts. If the trouble should result from one of these sources, the technician may be able to detect the fault by tapping the components in the suspected area. A visual inspection of the foil pattern employed in the newer printed wiring boards will usually reveal any broken signal path or possible short circuit.

An intermittent trouble may also occur only after a receiver warms up. This usually indicates that heat is affecting one or more of the components.

A soldering iron or heat lamp may prove very helpful when trouble occurs from increased temperatures in a certain section. The lamp or iron should be placed close to the components in question, and a voltage or resistance measurement should be taken. Exercise care if heat is being applied to a printed wiring board. Excessive heat may cause the printed wiring to pull away from the board. In order to save time when an intermittent trouble is encountered, many technicians prefer to change a number of capacitors and resistors in the defective section at one time. The receiver can be left on while the technician attends to other work, after which the check can be made.

SUMMARY

As you have seen in this lesson, troubleshooting is a little more complicated than merely looking at the picture tube screen display and listening to the sound. In this lesson the common symptoms and the possible causes have been listed for your reference. The process of troubleshooting the related sections requires a knowledge of all the circuitry involved and a logical troubleshooting procedure.

For instance, the symptom is *no raster, normal sound.* Turning to the section on picture tube problems we find a *no raster* condition listed. Reading this section we find the first check is the check for sound. If sound is present we can generally eliminate the low voltage power supply. The next suspect area is the high voltage power supply. By measuring the high voltage with a high voltage probe we find that the voltage is correct. We should next check the picture tube bias and filament supply circuits. If all of the voltage readings are correct we can assume the problem is in the picture tube. The picture tube may then be checked with a CRT tester.

By using a logical troubleshooting procedure the technician can save a lot of time. Some problems will not be as simple as the example given. Some problems will require voltage readings, waveform analysis and a careful circuit analysis before the defective component is located. Speed in servicing TV receivers is the result of logical troubleshooting and experience.

TEST

Lesson Number 94

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-094-1.

1. **If the condition of raster - no sound - no picture, and no snow is isolated to the tuner, you might logically suspect a defective**
   A. RF coil.
   2 B. mixer circuit.
   C. antenna.
   D. RF amplifier.

2. **No-picture and no-sound accompanied by a great deal of snow indicates**
   A. AGC trouble.
   4 B. trouble in the video amp.
   C. trouble in the RF or antenna.
   D. a blanking problem.

3. **When separation of picture and sound occurs in the RF tuner, check for a**
   A. blown fuse.
   B. crack in the CRT.
   8 C. defective flyback transformer.
   D. short circuit between adjacent switch contacts.

4. **When poor contrast is due to a problem in the video IF amplifier it may be due to**
   A. a defective video detector diode.
   22 B. AC interference on the AGC line.
   C. prior substitution of a high beta transistor.
   D. too many IF stages.

5. **Intermittent reception due to problems in the IF often are caused by a/an**
   A. shorted transistor.
   25 B. open power supply filter.
   C. broken PC foil line.
   D. open (collector-base) junction in a transistor.

6. **Aside from failure of the high voltage, loss of raster can be caused by defects in the**
   A. tuner.
   B. video amp.
   C. video IF amp.
   D. none of the above.

7. **While servicing a television receiver, the AGC line is clamped, thus restoring the receiver to normal operation. The trouble will be found in the**
   A. low voltage power supply.
   B. high voltage power supply.
   C. video amplifier.
   D. AGC system.

8. **An overloaded picture accompanied by a buzz from the sound system is caused by**
   A. a high voltage rectifier opening.
   43 B. a shorted winding in low voltage power supply transformer.
   C. the AGC system not operating.
   D. an open picture tube filament.

9. **When a television receiver loses both horizontal and vertical sync it may be assumed the problem is**
   A. in the video amplifier shunt peaking coil.
   45 B. in the sync section.
   C. an open filament in the horizontal oscillator tube.
   D. an extremely high high voltage.

10. **The symptom shown in Figure 57 could be caused by**
    A. an open signal path in the horizontal sync circuit.
    48 B. an open vertical hold control.
    C. an extremely low voltage power supply.
    D. the loss of sound.

Notes

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Portions of this lesson from
Transistor-TV Servicing Guide
by Robert G. Middleton
TV Servicing Guide
by Leslie D. Deanne and Calvin C. Young, Jr.

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"School Without Walls"
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CAUTION!
PROCEED WITH CARE!

You would most probably see this sign at the beginning of a stretch of road under construction.

It might be good to put a mental sign, such as this one, in front of you as you begin to "construct" your path in the business world.

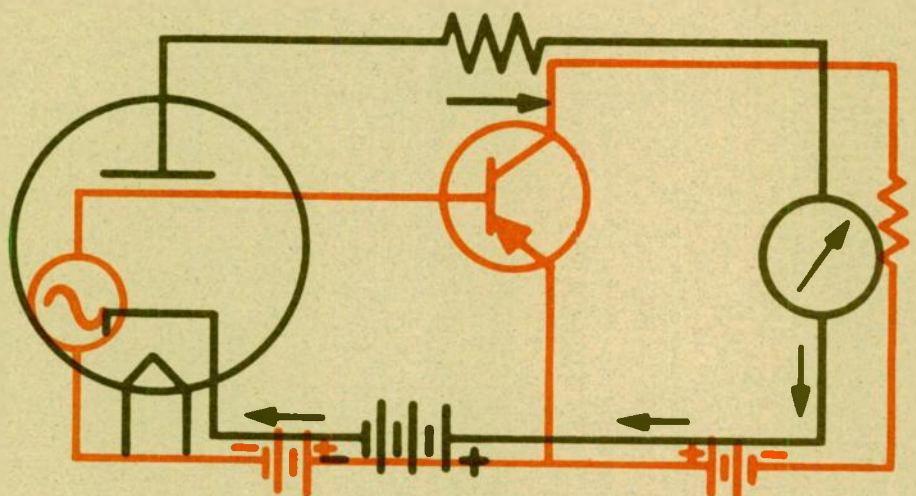
Remember, the sign says to be cautious, but in no way does it infer that you should not go ahead with any plans you wish to make. Rather, keep in mind the problems you will face—make your plans—and be careful to avoid the "ruts and grooves" that are most certainly there but, with foresight and alertness, can be avoided.

To "care" is to be concerned with how you will proceed. Be thorough, consider every phase of your business, approach it with confidence, and proceed with care.

S. T. Christensen

LESSON NO. 95

ADVANCED TELEVISION SERVICING-PART 2



RADIO and TELEVISION SERVICE and REPAIR

.ESSON CODE
\O. 52-095
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ADVANCE SCHOOLS, INC.
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CHICAGO, ILL. 60631

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Contents

ADVANCED TELEVISION SERVICING PART 2

INTRODUCTION

The previous lesson covered advanced troubleshooting of all the circuits that handle the video signal from the tuner to the picture tube cathode. In this lesson we will study the troubles that could occur in the sweep circuits, high-voltage power supply, low-voltage power supply and the sound system.

As in the previous lesson, the troubleshooting portions will be divided into problems relating to a particular circuit. This circuit will be further divided into the common symptoms and their probable cause. Pictures of the common symptoms that will occur have been included in this lesson. These lessons should be extremely helpful to the repair technician as he acquires

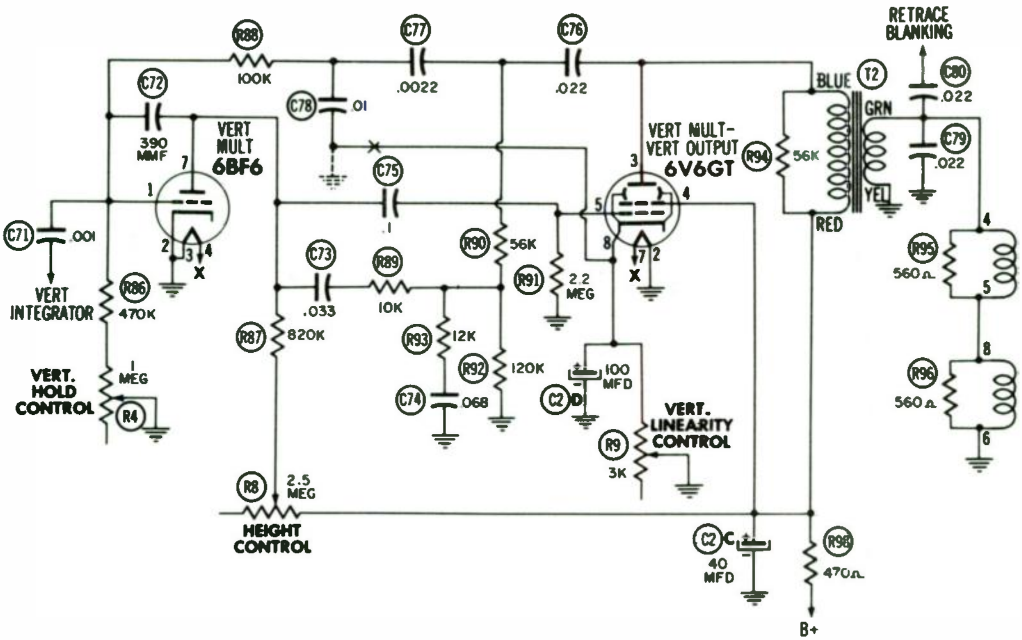

Figure 1 — A vertical sweep circuit in which the output tube is part of the multivibrator.

the skill necessary to become a highly qualified technician. These lessons will also be a helpful reference for the experienced service technician in solving some of the elusive problems that occur in the television receiver.

VERTICAL SWEEP SYSTEMS

The vertical sweep section of a television receiver functions to *sweep* the electron beam down the face of the picture-tube. The vertical section requires an oscillator (operating at 60 Hz), an output stage, and vertical deflection coils. A synchronizing signal is applied to the vertical oscillator to maintain synchronization with the transmitting station.

Trouble in the vertical sweep section of a television receiver can normally be detected by observing the picture on the picture-tube screen. Some of the common symptoms of troubles and their possible causes are listed below. A general discussion of each symptom is included. Also a picture of the symptom is shown as it would appear on the picture-tube screen.

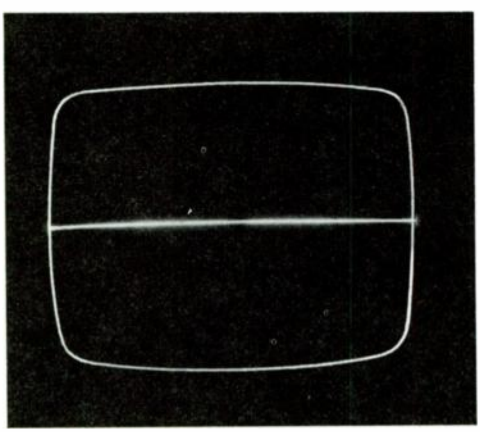

Figure 2 — Appearance of the screen when the vertical sweep has failed.

Loss of Sweep.

Loss of vertical sweep is indicated in Figure 2. This trouble symptom is present when there is no driving signal to the vertical deflection coils and when the horizontal scanning is normal.

Possible causes of a loss of sweep are:

a. Defective oscillator or output tubes.
b. Open coupling capacitor. See C_{75}, C_{76} and C_{77} in Figure 1.
c. Open linearity control.
d. Open height control.
e. Open output transformer.
f. Defective blocking oscillator transformer.

If substitution of tubes has failed to indicate the source of trouble, then the plate, screen, cathode, and control grid voltages should be checked to make sure that the trouble is not caused by a loss of B+ voltage due to a faulty decoupling network or height control. The next step is to check the waveform on the output grid. If it is defective, a check of the oscillator is the next step. If the grid waveform is satisfactory, a check of the output stage should reveal the trouble.

Insufficient Sweep.

Insufficient vertical sweep is the condition that exists when a linear picture cannot be made to fill the screen. The picture may not be compressed at the bottom or top.

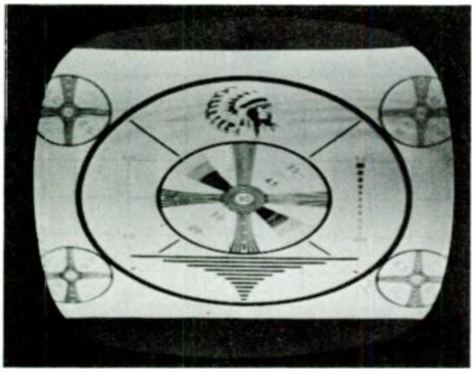

Figure 3 — Test pattern showing a reduction in height.

The illustration in Figure 3 shows a picture that fails to fill the screen at the top or bottom because of misadjustment of the height and linearity controls. You will notice that the picture is linear even though it is lacking in height.

Possible causes of insufficient vertical sweep are:

a. Improper adjustment of the height and linearity controls.
b. Weak oscillator or output tube.
c. Low B+ voltage.
d. Defective decoupling network in a plate circuit.
e. Low boosted B+ voltage.

Weak damper tubes have been known to cause insufficient sweep because they do not generate sufficient boost voltage. In most cases of this type, the high voltage will also be low; and as a result, the picture will be dim. Insufficient sweep also appear on receivers that employ selenium rectifiers if these rectifiers are defective. In these receivers, the B+ voltage may only be 25 or 30 volts low and still cause insufficient sweep.

Poor Linearity.

Poor linearity is the condition that exists when the picture tube screen cannot be covered vertically with a normal linear picture. Under some conditions, it may not be possible to cover the screen completely even with a nonlinear picture.

There are various degrees and types of nonlinearity that may occur in vertical sweep systems. The types of nonlinearity are: compression at the bottom, compression at the top, and foldover.

The illustration in Figure 4A shows a picture compressed at the bottom. During the servicing of this

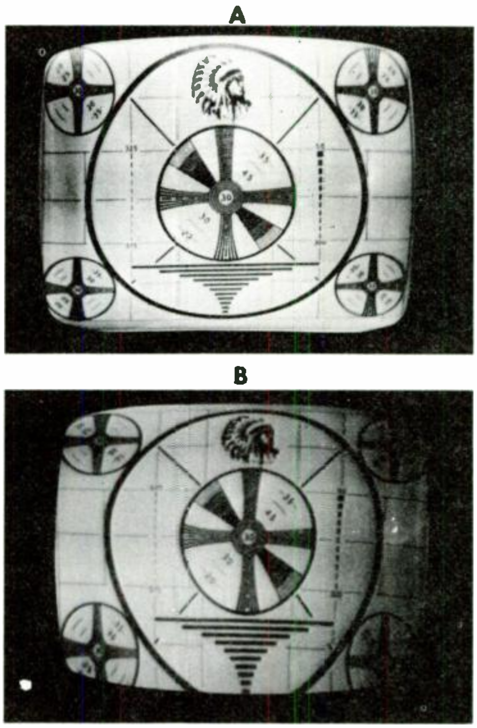

**Figure 4 — A.-Test pattern showing compression at the bottom.
B.-Test pattern showing compression at the top.**

receiver, the cathode of the output tube was checked with an oscilloscope. A distorted waveform was found. A check of the bypass capacitor revealed that it was open. After the capacitor was replaced, a normal waveform was observed at the cathode.

Possible causes of compression at the bottom of the picture are:

a. Improperly adjusted controls.
b. Open cathode bypass capacitor.
c. Defective output tube.

The illustration in Figure 4B shows a picture compressed at the top. This trouble symptom resulted when the grid resistor of an output stage opened.

Possible causes for compression at the top of the picture are:

a. Improperly adjusted controls.
b. Insufficient bias voltage in those circuits in which a fixed voltage biases the output stage.
c. Defective output tube.
d. Open grid resistor in output stage.
e. Changed value of resistors in the cathode of the output stage.

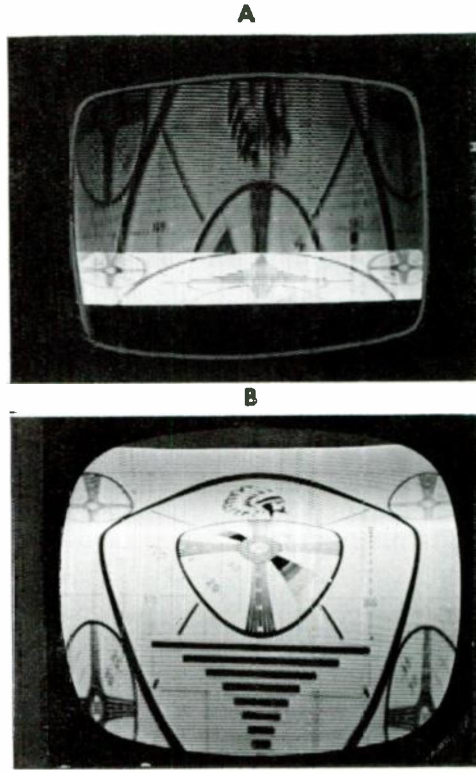

Figure 5 — A.-Test pattern showing foldover caused by capacitor leakage.
B.-Test pattern showing foldover caused by heater-to-cathode leakage.

The illustrations in Figures 5A and 5B are two examples of picture foldover caused by troubles in the vertical sweep section. The picture in Figure 5A is the result of leakage in the coupling capacitor between the oscillator and output stages. The degree of foldover will be a function of the amount of leakage in the capacitor. The picture in Figure 5B was caused by heater to cathode leakage in the output tube. The degree of foldover will be a function of the amount of leakage in the tube.

Possible causes of foldover are:

a. Defective output tube.
b. Leakage in coupling capacitor to output stage.
c. Defective output transformer.
d. Leakage in discharge capacitor. See C_{73} and C_{74} in Figure 1.

Loss of Synchronization.

Complete loss of vertical synchronization is indicated in Figure 6. There are two basic causes of loss of vertical synchronization: (1) lack of a sufficient sync signal and (2) change in the natural frequency of the vertical oscillator. It is the function of the vertical sync pulses to trigger the vertical oscillator into conduction in step with the sweep oscillator of the transmitter. This can be accomplished only if the natural or free running frequency of the oscillator in the receiver is a little lower than 60 Hz.

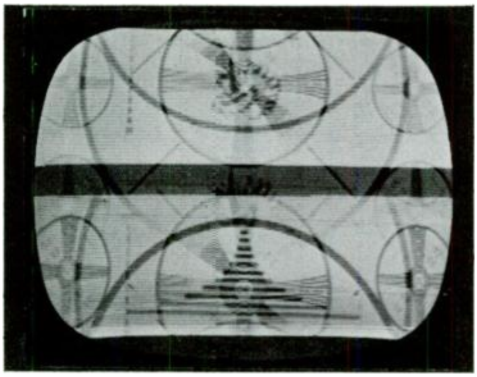

Figure 6 — Test pattern showing loss of vertical synchronization.

Possible causes of a loss of synchronization are:

a. Defective oscillator tube.
b. Defective hold control or series resistor. See R_4 and R_{86} in Figure 1.
c. Defective oscillator grid capacitor. See C_{71} in Figure 1.
d. Defective oscillator transformer.
e. Defective resistor in feedback loop. See R_{88}, R_{90}, and R_{92} in Figure 1.
f. Defective capacitor in feedback loop. See C_{72}, C_{76}, C_{77}, and C_{78} in Figure 1.
g. Insufficient or distorted sync signal from integrator network.

A check of the natural frequency of the vertical oscillator can be a great help in isolation of the source of trouble. To make this check, either remove the sync separator tube or disconnect one end of the integrator network and check the signal on the grid or plate of the vertical oscillator. The signal should have a frequency of slightly less than 60 Hz. A check with an oscilloscope of the line voltage will give a basis for comparison.

One-Way Sync or Critical Synchronization.

One-way sync is the condition that exists when it is necessary to turn the vertical hold control to one extreme of its rotation in order to synchronize the picture. The picture will roll in only one direction when the hold control is rotated from one end of its rotation to the other.

Possible causes of critical or one-way synchronization are:

a. Defective oscillator-grid capacitor. See C_{71} in Figure 1.
b. Changed value of hold control or grid resistor. See R_4 and R_{86} in Figure 1.
c. Defective oscillator transformer.
d. Defective resistor in feedback loop. See R_{88}, R_{90}, and R_{92} in Figure 1.

e. Defective capacitor in feedback loop. See C_{72}, C_{76}, C_{77}, and C_{78} in Figure 1.
f. Defective oscillator tube.

If critical synchronization exists in a receiver and the oscillator stage cannot be definitely identified as the source of the trouble, then it is probable that the trouble is due to some defect in the sync stages.

Poor Interlacing.

In most cases, poor interlacing is caused by trouble in the transmitter. To check on this possibility, switch to a different channel. Good interlacing on this channel would indicate trouble at the transmitter of the first channel.

Possible causes of poor interlacing are:

a. Pickup by the vertical oscillator of 15,750 Hz pulses from the horizontal oscillator stage or the horizontal output and high-voltage stage.
b. Defective integrator network.
c. Hold control set at critical point.

A condition of poor interlacing should be corrected whenever it is encountered because it indicates that the vertical oscillator is operating under critical conditions. It can also cause the loss of about 50 per cent of the picture detail, even though the poor interlacing itself is seldom noticeable.

Keystone Effect.

This trouble is illustrated in Figure 7. Keystone effect is caused by trouble in the deflection coils. The example shown is caused by a short across one coil. An open vertical deflection coil will produce a keystone effect, and there will be very little deflection; there will be deflection only as long as the damping resistor connected across the open coil is good. If this resistor should open, no current would flow through the other half of the coil and vertical sweep would disappear. If one deflection coil and both damping resistors should open, then a single bright horizontal line with damped oscillations would be produced.

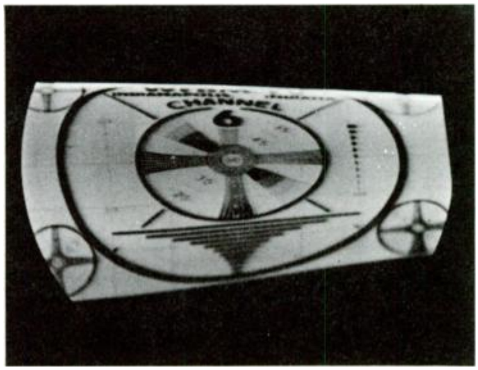

Figure 7 — An example of Keystone effect.

The example in the photograph shown in Figure 8 was caused by an open discharge capacitor. This illustration has many of the characteristics of "Christmas Tree" effect caused by the horizontal section. A check of the grid waveform at the horizontal output grid will reveal that the trouble is not in that section, and the technician familiar with this indication will know at once that the discharge capacitor is open. This capacitor corresponds to C_{73} and C_{74} in Figure 1.

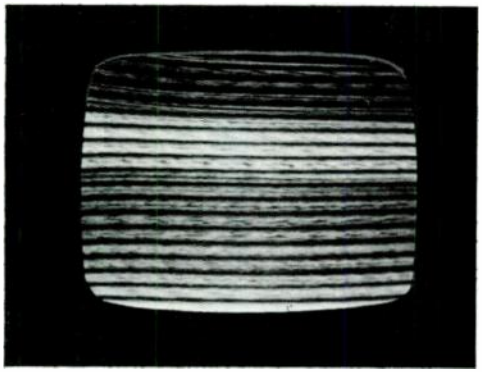

Figure 8 — A trouble symptom which resembles the "Christmas tree" effect.

HORIZONTAL AFC AND OSCILLATOR SYSTEMS

The horizontal sweep section must *sweep* the electron beam across the picture-tube screen. The horizontal sweep section consists of an oscillator (operating at 15,750 Hz), an output section, deflection coils, and a method of controlling the oscillator frequency. A synchronizing pulse is applied to the AFC circuit where it is compared with an output pulse from the horizontal sweep system. The difference between the two pulses produces a DC correction voltage which is applied to the horizontal oscillator to control its frequency and maintain synchronization with the transmitted signal.

Troubles in the AFC circuit or horizontal oscillator can produce symptoms that will appear in the picture on the picture-tube screen or could result in the complete loss of raster. In this section some of the more common symptoms are listed. Also included are the visual indications these problems produce on the picture-tube screen.

Loss of Raster.

A blank screen usually indicates that the high voltage on the second anode of the picture tube is missing. When the trouble symptom of no raster but normal sound is encountered, the first logical step is usually to check for the presence of high voltage. If it is excessively low or is missing, the next step would be to check for an open fuse and to substitute tubes in the horizontal and high-voltage circuits.

Many technicians are able to determine by ear whether or not the oscillator is running. If it is, the chances are that the trouble exists in the output or high-voltage circuits. If it is suspected that the oscillator is inoperative and tube substitution is unable to restore the raster, the chassis should then be removed and further tests made in the shop. A meter or oscilloscope can be put to work so that the trouble can be isolated to the defective stage.

Possible causes for loss of raster are:

a. Defective tube in the horizontal AFC or oscillator stages.
b. Plate resistor open or too high in value. See R_{83}, R_{86}, and R_{87} in Figure 9.
c. Defective coupling capacitor. See C_{67} in Figure 9.
d. Shorted filter or bypass capacitor. See C_{3A} and C_{61} in Figure 9.
e. Open horizontal hold control.
f. Open capacitor across horizontal waveform coil.
g. Defective oscillator coil.

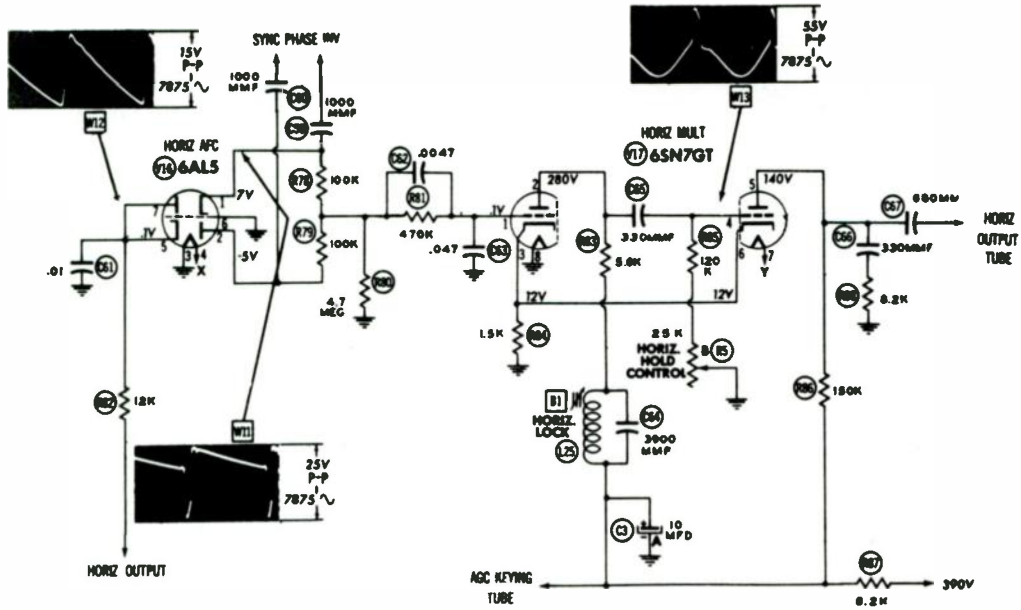

Figure 9 — Schematic drawing of a typical horizontal AFC and multivibrator circuit.

h. Defective tube socket and shorted or broken leads.
i. Shorted waveforming capacitor. See C_{66} in Figure 9.
j. Open grid resistor. See R_{85} in Figure 9.

The listed causes for no raster do not represent all the possible defects which could produce this symptom. They represent some of the more common defects in the horizontal AFC and oscillator circuits only. The technician may find it expedient to check the waveform present on the grid of the horizontal output tube first. If there is insufficient drive at this point, the horizontal oscillator or discharge circuit may be at fault. A voltage and resistance check should then be taken in these circuits.

Troubles developing in the AFC circuit will not usually result in a total loss of raster. In some cases, however, a shorted capacitor or open resistor in this circuit may reduce the B+ voltage or throw the oscillator too far off frequency to produce a raster. It is even possible for a defective AGC stage to render the horizontal oscillator inoperative when a normal signal is being received. With the antenna disconnected or the tuner in an off channel position, the oscillator may return to operation. This condition can result when the incoming sync pulses produce an AFC correction voltage capable of holding the oscillator tube above the grid cutoff level. When the incoming sync pulses are no longer present, the oscillator grid bias will decrease and the stage will resume oscillation.

Loss of Horizontal Synchronization.

The loss of horizontal synchronization is a common trouble symptom encountered rather frequently in the field of servicing. This symptom is usually caused by faulty tubes or components in the horizontal AFC or oscillator stages. It is also possible for a defect in the sync or horizontal output circuits to produce this condition.

In many instances, the loss of horizontal sync can become intermittent or it may occur only during the warm up period. A trouble of this nature is often caused by some component that changes value as the temperature of the receiver varies. The appearance of dark diagonal bars across the screen, as shown in Figure 10, indicates that the frequency of the horizontal oscillator is slightly different from the frequency of the incoming sync pulses. The raster and picture are still present, but the picture is not distinguishable on the screen. When the raster and picture are present, this should indicate to the technician that the flyback and video sections of the receiver are operating. In the majority of sync circuit failures, the stability of the vertical sync will also be affected. If horizontal synchronization is poor but the vertical is normal, the trouble is probably in the horizontal AFC circuit.

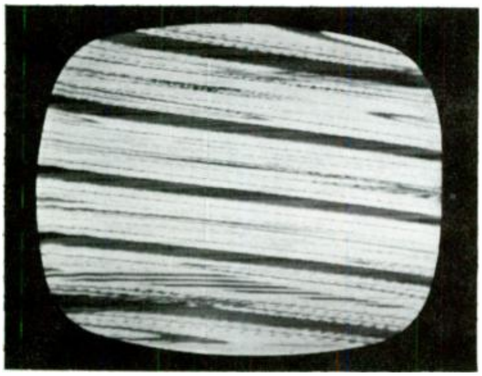

Figure 10 — Picture showing loss of horizontal synchronization.

Another degree of this trouble symptom can cause the results illustrated in the photograph of Figure 11. In this instance, a number of overlapping pictures can be seen; this indicates that the frequency of the oscillator is much lower than the repetition rate of the picture. This condition can be caused by an inoperative AFC stage or by defective components in the oscillator circuit itself.

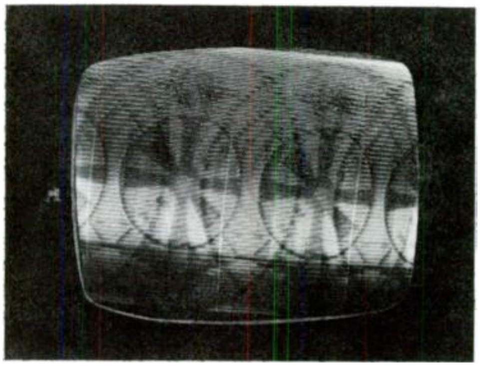

Figure 11 — A number of overlapping pictures produced by a loss of horizontal synchronization.

Possible causes for loss of horizontal synchronization are:

a. Defective tube in the horizontal AFC or oscillator stages.
b. Capacitor in the oscillator circuit changes value. See C_{64} and C_{65} in Figure 9.
c. Improper alignment of the horizontal system.

d. Improper value of resistor in the AFC network. See R_{78}, R_{79}, R_{80} and R_{81} in Figure 9.
e. Defective sync coupling capacitor. See C_{59} and C_{60} in Figure 9.
f. Incorrect value of resistor in the cathode circuit of the horizontal multivibrator. See R_{84} in Figure 9.
g. Vertical sweep or power supply frequencies enter the oscillator circuit. (Check the lead dress and all filter capacitors.)
h. Defective horizontal hold control or locking-range trimmer.
i. Defective capacitor in feedback network. See C_{61} in Figure 9.
j. Open filter capacitor in AFC network. See C_{62} and C_{63} in Figure 9.
k. Defective horizontal frequency coil. See L_{25} in Figure 9.

If the horizontal synchronization is unstable when contrast settings are low or when you are switching from one channel to another and if it tends to improve as the contrast control is advanced, the trouble may lie in the sync coupling or AFC circuits. Should the trouble symptom become more apparent as the contrast is increased, the AFC filter network should be checked. Inadequate filtering of the DC correction voltage applied to the oscillator stage will usually cause loss of horizontal synchronization.

Horizontal jitter or tearing in the picture is often due to interaction between stages or to external interference.

Improper adjustment of the horizontal waveform slug will also produce this trouble symptom. In a few remote cases, the permeability of the slugs used to tune the horizontal frequency and waveform coils has been known to change. If any of these conditions become too extreme, they may result in what is frequently referred to as the Christmas-Tree effect. An example of this trouble symptom is pictured in Figure 12.

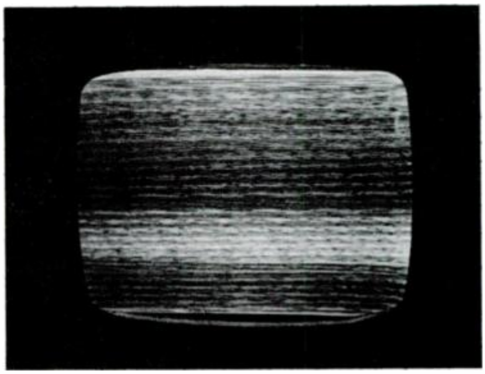

Figure 12 — The "Christmas tree" effect as it may appear on the picture tube.

The Synchroguide system possesses an excellent noise immunity characteristic; but at the same time, the circuit is very susceptible to microphonic conditions. Some receiver manufacturers employing this type of circuit will shock mount the tube in order to reduce microphonic effects. Any erratic oscillations occurring in the horizontal circuit will usually upset the operation of the oscillator stage.

When tubes or other components are replaced in the horizontal AFC or oscillator circuits, a recheck of the frequency and phase alignment should become standard procedure.

Improper Horizontal Phasing.

Another trouble symptom closely related to poor horizontal synchronization is improper phasing. This trouble usually originates in the horizontal AFC system. An out-of-phase condition will often produce a split picture like that shown in Figure 13. The right half of the picture will appear at the left of the screen, and the left portion of the picture will appear at the right side. The dark vertical bar in the center is produced by the horizontal blanking signal. Under normal conditions, a small portion of this blanking signal is present on each side of the picture and can be seen if the picture is shifted off center and is increased in brightness. The remainder of the blanking signal occurs during horizontal retrace time.

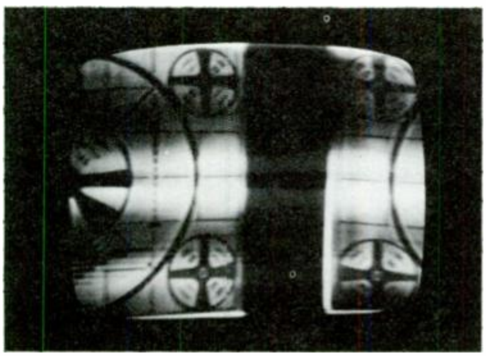

Figure 13 — Picture showing improper horizontal phasing.

The trouble symptom of Figure 13 usually indicates that the trace time is starting in the middle of the horizontal sweep and finishing at the beginning of the sweep. This pattern may tend to shift back and forth or intermittently lock into sync. If the phasing trouble is less extreme, a phasing ghost like the one in Figure 14 may appear on the screen. This symptom will occur when the video signal appears on the screen during horizontal retrace time. The phasing ghost usually takes the form of a white cloud superimposed on part of the picture, and it often causes the picture to shift or pull to one side.

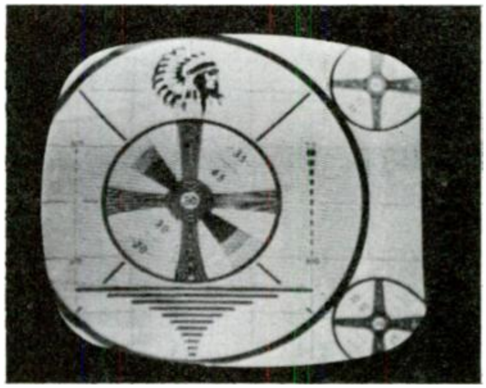

Figure 14 — A horizontal phasing ghost accompanied by a slight picture shift.

Possible causes for improper phasing are:

a. Defective tube in the horizontal AFC or oscillator stages.
b. Improper horizontal sweep alignment.
c. Defective capacitor in feedback network. See C_{61} in Figure 9.
d. Open or leaky AFC filter capacitor. See C_{62} and C_{63} in Figure 9.
e. Oscillator plate resistor open or too high in value. See R_{83}, R_{86} and R_{87} in Figure 9.
f. Defective resistor in feedback circuit. See R_{82} in Figure 9.
g. Defective horizontal lock trimmer.

h. Wave shaping component changed in value. See C_{66} and R_{88} in Figure 9.
i. Incorrect value of resistor in the AFC network. See R_{78}, R_{79} and R_{81} in Figure 9.

Many of the phasing problems can be solved by proper alignment of the horizontal system. In some designs, it may be necessary to place a jumper across the ringing coil before the other adjustments are made. The alignment procedure should not only include the frequency and phasing coils but also adjustment of the horizontal drive, width, and linearity. The pulse voltage fed back to the AFC stage from the output circuit must have the proper peak-to-peak value. Adjustment of the horizontal drive, width, and linearity may affect the amplitude of the feedback pulses; and these should therefore be checked for proper settings. The critical balance required in the horizontal AFC system should always be maintained. If a dual-diode tube is employed as a phase detector, both diode sections should test approximately equal to ensure correct frequency and phasing. In the horizontal circuit, resistors having a tolerance rating of 5 per cent should be checked for correct value and capacitors having a temperature compensation characteristic should be replaced if for any reason they are suspected of being faulty.

Horizontal Pulling.

The service technician has undoubtedly heard customers complain that the vertical lines in the picture are bent, curved, or pulled out of shape. This is a very common trouble symptom and in some cases the cause may be traced to the horizontal AFC or oscillator circuits. Horizontal pulling and horizontal bending are terms used frequently to describe picture distortion occurring in the horizontal plane. A weaving condition usually occurs when the extent of pulling varies. The presence of picture pulling indicates that the horizontal oscillator is attempting to lose synchronization but only momentarily.

Perhaps the most common type of horizontal pulling is a slight bending of the lines at the top of the picture. In most instances, the bent portion of the picture will shift back and forth or straighten when various settings of the horizontal hold or contrast controls are made. The trouble symptom pictured in Figure 15 illustrates a slight bending near the top of the picture.

Figure 15 — Horizontal pulling or bending at the top of the picture.

Another condition of horizontal pulling is shown in the photograph of Figure 16. The distortion seen in this shows that the center portion

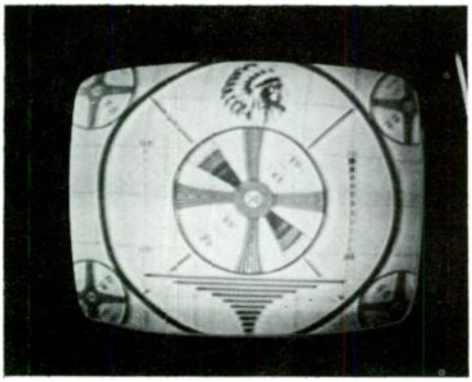

Figure 16 — Horizontal pulling near the center of the picture.

of the picture tends to pull to the left. The trouble which causes this type of distortion often causes a more severe case of distortion, but the other troubles which usually cause severe pulling are much easier to locate and correct.

The troubleshooting procedure to be followed for isolating the cause of horizontal pulling should include a number of basic checks. The technician should first check for the symptom on all operating channels. By increasing the brightness and misadjusting the centering, he can determine whether the pulling is in the raster or only in the picture. Picture pulling or poor sync phasing will not affect the edges of the raster.

The next step will be to check the relative amplitude of the sync signal on the picture tube screen. If the signal appears normal at the picture tube, the RF, IF, and video circuits can usually be eliminated.

Another logical procedure would be to remove the incoming sync signal from the horizontal AFC stage. This may be done by disconnecting the sync coupling capacitor or capacitors at the input to the AFC tube. With the horizontal hold control set at mid position, adjust the frequency coil until a momentary picture can be seen on the screen. It usually requires only a glance to determine whether or not the trouble has disappeared. If the trouble is still present, the fault may be originating in the horizontal AFC or oscillator circuits. Should no defective components be found in these circuits, it is also possible that an extraneous signal is affecting the AFC circuit. Since it is possible for the vertical sweep signal to affect the horizontal circuit, the sync section should be isolated from the vertical circuit. Disconnect the coupling capacitor between the integrating network and the vertical oscillator, and adjust the vertical hold control so that the picture can be observed. If the trouble symptom disappears, additional isolation is necessary between the vertical oscillator and the horizontal sync section.

Possible causes for horizontal pulling are:

a. Defective tube in the horizontal AFC or oscillator stages.
b. Open or leaky sync coupling capacitor. See C_{59} and C_{60} in Figure 9.
c. Component of incorrect value in AFC filter circuit. See C_{62}, C_{63}, R_{80}, and R_{81} in Figure 9.
d. Improper alignment of horizontal frequency or phase slugs.
e. Incorrect value of resistance in AFC circuit. See R_{78} and R_{79} in Figure 9.

f. Poor regulation of B+ voltage supplied to horizontal section.
g. Defective capacitor in oscillator circuit.
h. External signals modulate the horizontal sweep frequency. (Check for an open filter capacitor, poor lead dress, or improper shielding.)

Insufficient Width or Foldover.

The signals that are generated in the horizontal oscillator drive the output tube which in turn energizes the horizontal winding of the deflection yoke. If the amplitude of the output signal from the horizontal oscillator is reduced, the width of the picture and raster may be insufficient to fill the face of the tube. A defective tube or component in this section of the receiver may produce the trouble symptom pictured in Figure 17. This symptom reveals itself as a narrow, dim picture which is slightly out of focus. In many cases, however, this type of trouble results from a defective horizontal output circuit, from low line voltage, or from a deficiency in the B+ supply voltage.

The picture in Figure 18 illustrates another symptom often produced by faulty components in the horizontal oscillator. It can be seen in the photograph that the center portion of the picture has a slight foldover. With the video signal removed, the raster will reveal a bright vertical line at the point of foldover. In some instances, a more noticeable reduction in picture width will accompany this type of horizontal trouble.

When insufficient width or horizontal foldover develops, it is a good idea to examine the waveform present on the grid of the horizontal output tube. If the amplitude of the pulse is lower than normal, or if it is distorted in some manner, a further check of the oscillator should be made.

Possible causes for insufficient width or foldover are:

a. Defective tube in the horizontal oscillator circuit.
b. Improper adjustment of the oscillator and AFC circuits. (Check the frequency, phase,

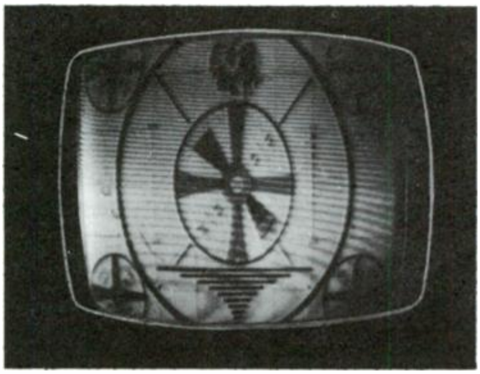

Figure 17 — Insufficient picture width.

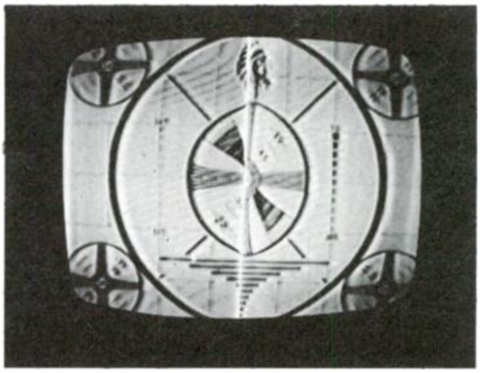

Figure 18 — Horizontal foldover near the center of the picture.

drive, width, and linearity adjustments.)

c. Oscillator plate resistor too high in value. See R_{83}, R_{86} and R_{87} in Figure 9.
d. Open or leaky capacitor in wave shaping network. See C_{66} in Figure 9.
e. Defective coupling capacitor. See C_{67} in Figure 9.
f. Incorrect value of resistor in wave shaping network. See R_{88} in Figure 9.
g. Open grid resistor in discharge circuit.
h. Low value of plate resistor in the discharge circuit.

A leaky capacitor in the wave shaping network usually produces foldover on the right side of the screen. This may appear as light drive lines which cannot be entirely removed by adjustment of the horizontal drive control or trimmer capacitor.

If the grid resistor in the discharge circuit should increase in value or should open, the width of the picture will be reduced considerably and the edge of the raster may appear jagged. In some cases, a loss of horizontal synchronization will accompany the symptoms mentioned.

Pie-Crust Effect.

The trouble symptom represented in Figure 19 displays what is commonly referred to as "pie crust" effect. The term is reflected in the wavy shape of the circles making up the test pattern—the circles resemble the edge of a pie crust.

The trouble is usually caused by an electrical hunting action in the horizontal AFC circuit. The amplitude and number of ripples may change with different settings of the horizontal hold control. If the effect of this condition is only slight, the symptom may appear as a pull or wiggle through the picture. An antihunting circuit is usually employed in the conventional Synchroguide system. This network provides a certain amount of correction in case the AFC circuit tends to overcontrol the oscillator. Defective components in this circuit will often produce a pie crust effect.

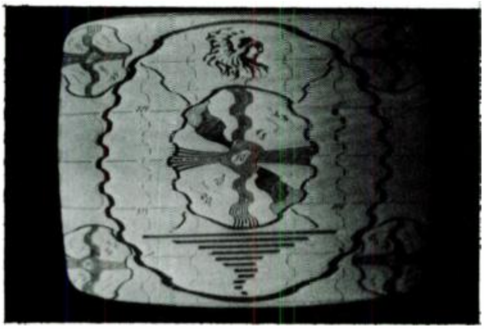

Figure 19 — "Pie Crust" effect in picture.

In a few instances, it is possible for the horizontal circuit to pick up the vertical signal or some 60 Hz interference from the power supply and to produce this condition.

Possible causes for this pie crust effect are:

a. Microphonic tube in the horizontal AFC or oscillator stages.
b. Defective component in the antihunting circuit.

c. Open capacitor in AFC circuit. See C_{62} and C_{63} in Figure 9.
d. Defective horizontal oscillator coil.
e. Vertical signal picked up by the horizontal AFC circuit. (Check the lead dress, the shielding, and the isolating and filtering components.)
f. Line frequency at the receiver out of phase with the line frequency used by the transmitter.
g. Open bypass capacitor.
h. Flux leakage from the power transformer. (Check the shielding and lead dress of the transformer.)

When a picture has horizontal ripple caused by a 60 Hz voltage which is entering the horizontal AFC or oscillator circuits, there are a few procedures which will help to eliminate this condition.

If changing component and lead positions fails to cure the trouble, it may be necessary to install a metal shield around the horizontal oscillator coil or to extend the leads of some of the associated components. If a can is used to shield the coil, make sure a good ground connection exists between the metal can and the chassis.

There are in the field today a number of television receivers which have certain inherent defects that may cause trouble in different areas or after given periods of operation. Each particular model produced will always have room for some slight design improvement. For this reason, many manufacturers issue production change bulletins giving information on modifications which will improve the operation of their receivers. It is recommended that the technician obtain this type of information whenever possible and keep it on file. It can save a great deal of time and effort when he services the same make and model from time to time.

Many technicians have learned through actual experience the different circuit modifications necessary to eliminate certain inherent troubles in various sets. It is also helpful in some cases for the technician to alter the value of different components in order to become more familiar with their resulting effects on the picture, the raster, or the sound. This statement should not, however, be taken as a recommendation for a change of component values to compensate for other defective components that have merely escaped detection.

HORIZONTAL OUTPUT AND HIGH VOLTAGE SYSTEMS

This portion of the lesson deals with the horizontal output and the high voltage circuits of television receivers. These circuits include the horizontal output stage, the flyback transformer, the deflection yokes, and the damper and high voltage rectifier. The symptoms resulting from these troubles are shown and described in the sections that follow.

No Raster.

Perhaps the most frequently encountered symptom of trouble stemming from the horizontal output and high-voltage system is loss of raster. This condition usually results from a lack of high voltage on the second anode of the picture tube. The presence of normal sound is an additional symptom pointing to difficulty in the horizontal sweep or highvoltage sections. The loss of horizontal sweep in most conventional receivers will result in a complete loss of light on the screen.

When the technician is confronted with symptoms of no raster and normal sound, the operation of the brightness control should be checked first. Then he should test for high voltage (Fig. 20). If sufficient voltage is found on the picture-tube anode, the trouble may be due to a defective picture tube, a faulty brightness-control circuit, or a misadjusted ion trap. When a lack of high voltage is encountered, the horizontal output and high-voltage circuits should be checked for an open fuse or a defective tube. If only a weak arc can be drawn from the plate cap of the high-voltage rectifier tube, disconnect the plate lead and recheck for an arc on the lead itself. If the arc is normal at this point, the rectifier tube may be defective.

A thorough visual inspection of the high-voltage section plays a definite part in the trouble-shooting procedure. Broken connections, burned components, and faulty insulation can often be detected in this manner. One might check to determine if the plate of the horizontal output tube appears red or overheated. If it glows cherry red or the tube appears gassy, the oscillator may be inoperative or there may be a short in the output stage.

When high voltage is lost because of a short somewhere along the boosted B+ line, the difficulty can sometimes be isolated if the various circuits supplied by this voltage are disconnected. Removing the tubes or disconnecting the supply lead to the vertical circuit may, for example, restore high voltage to the receiver. If this occurs, the trouble is undoubtedly in the vertical section and not in the flyback system.

Possible causes of no raster are:

a. Defective tube in the horizontal sweep or high-voltage circuits.
b. Open fuse in the flyback system.
c. Shorted or leaky high voltage filter capacitor. (See C_{114} in Figure 21, C_{127} in Figure 23, C_{101} in Figure 24, or C_{107} and C_{108} in Figure 25.
d. Defective component in a voltage-doubler network. See R_{98}, R_{99}, R_{100}, and C_{100} in Figure 24.
e. Shorted or leaky screen capacitor in the output stage. See C_{107} in Figure 21, C_{75} in Figure 22, C_{121} and C_{122} in Figure 23, C_{92} in Figure 24, or C_{99} in Figure 25.
f. Open screen resistor in the output stage. See R_{108} in Figure 21, R_{95} and R_{96} in Figure 22, R_{131} and R_{132} in Figure 23, R_{93} and R_{95} in Figure 24, or R_{107} in Figure 25.
g. Shorted or open coupling capacitor. See C_{104} in Figure 21, C_{74} in Figure 22, C_{120} and

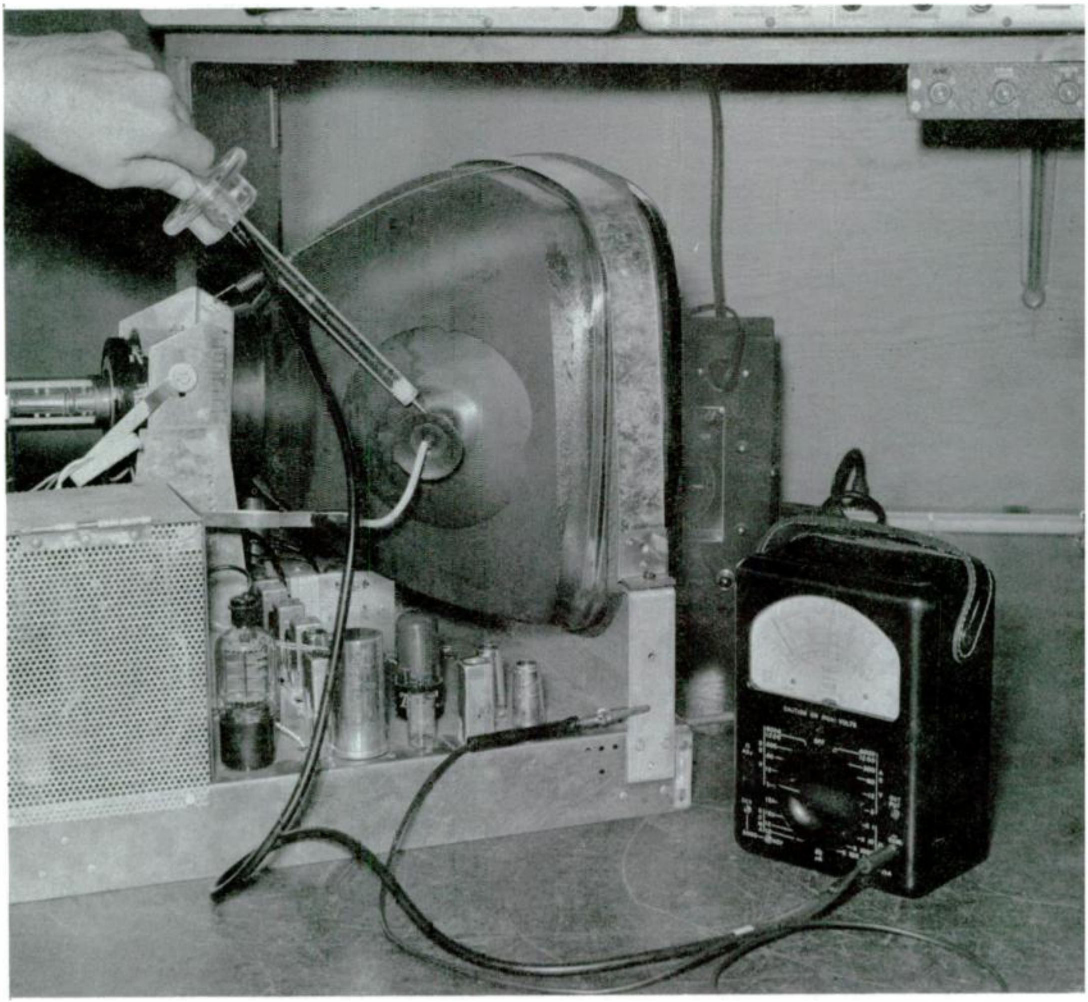

Figure 20 — Measuring second anode voltage with a high voltage probe.

C_{124} in Figure 23, C_{91} in Figure 24, or C_{96} and C_{101} in Figure 25.

h. Defective yoke or yoke socket.

i. Shorted or leaky boosted B+ filter capacitor. See C_{111} and C_{112} in Figure 21, C_{77} and C_{78} in Figure 22, C_{125} and C_{126} in Figure 23, or C_{93} and C_{94} in Figure 24.

j. Breakdown of high voltage insulation. Check high voltage leads, standoff insulators, and connectors.

k. Defective flyback transformer.

l. Open cathode resistor in the output stage. See R_{94} in Figure 22, R_{130} in Figure 23, R_{94} in Figure 24, or R_{105} in Figure 25.

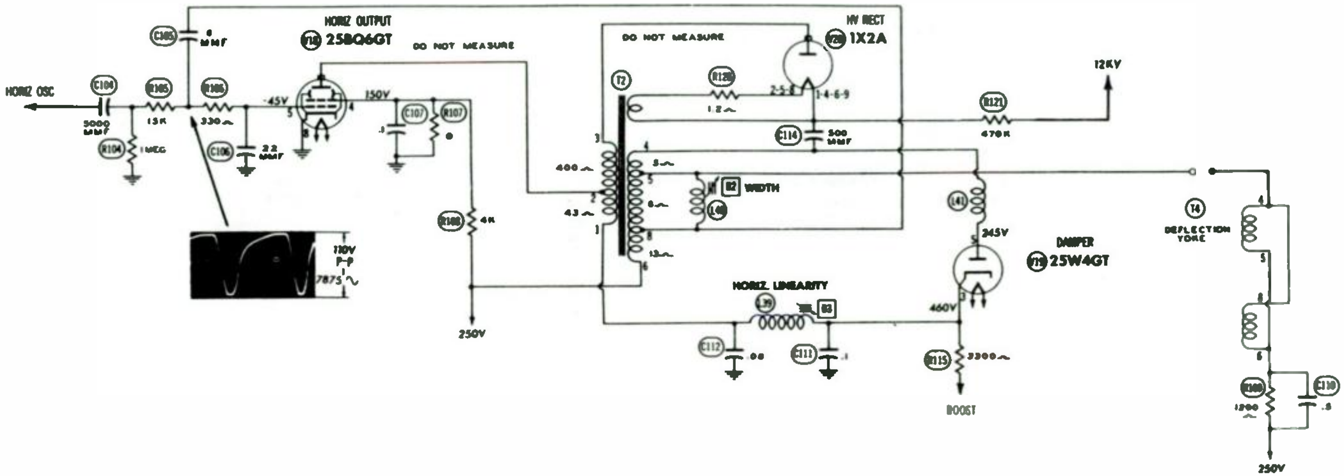

Figure 21 — Schematic diagram of a horizontal output and high-voltage system of the isolated secondary type.

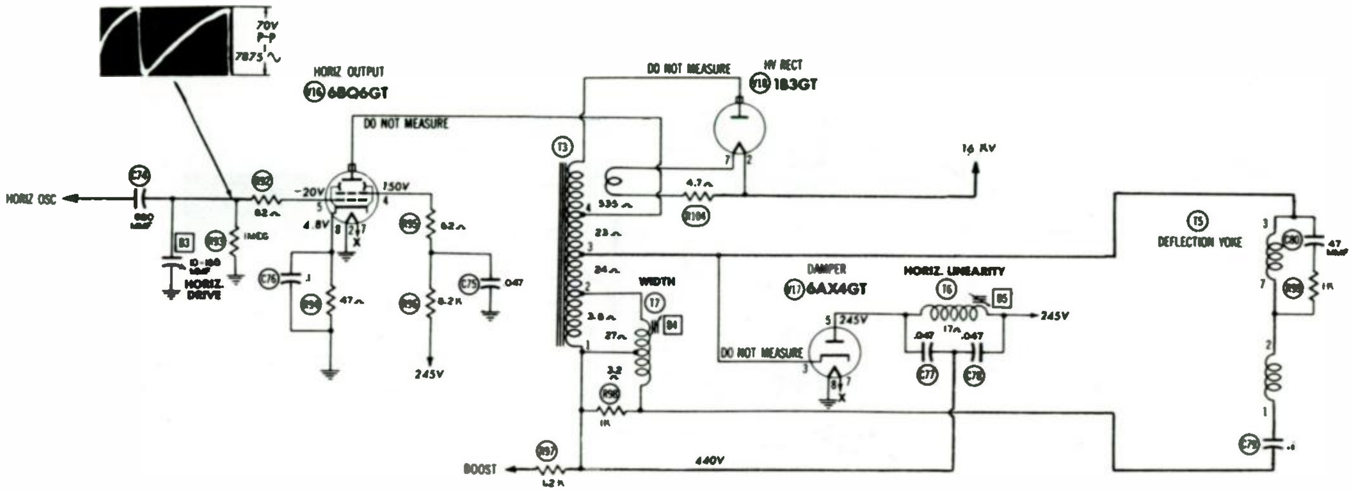

Figure 22 — Schematic diagram of a horizontal output and high voltage system employing an autotransformer.

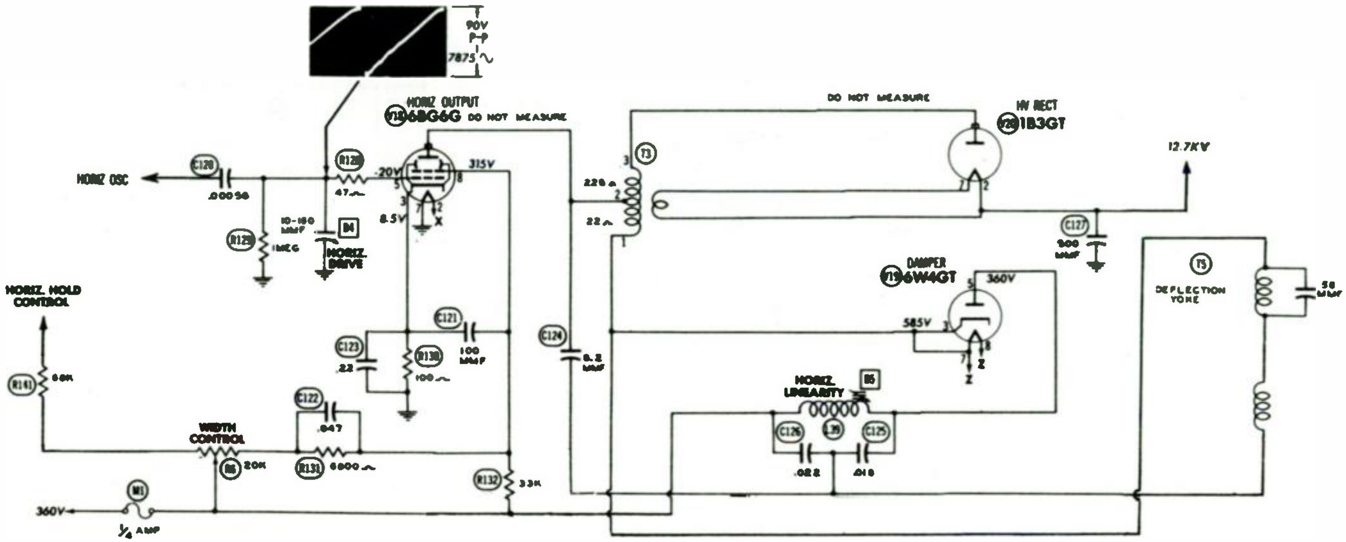

Figure 23 — Schematic diagram of a horizontal output and high voltage circuit employing the direct drive system.

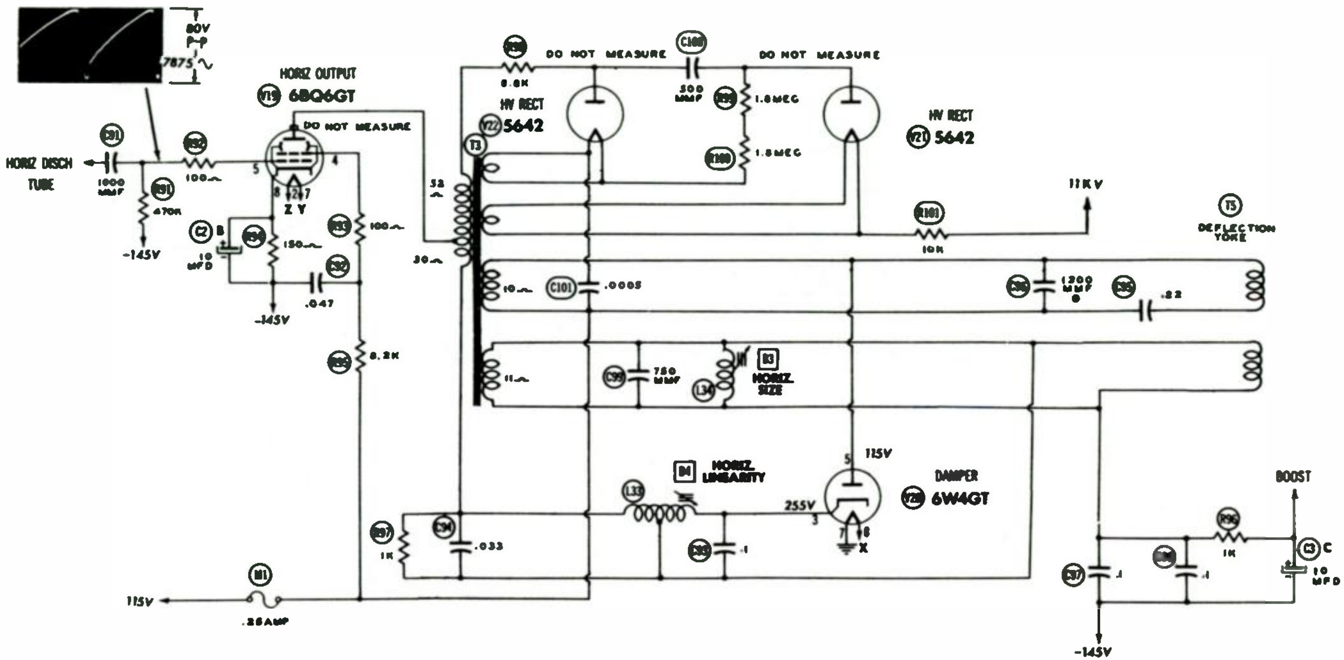

Figure 24 — Schematic diagram of a horizontal output and high voltage system employing a voltage doubler.

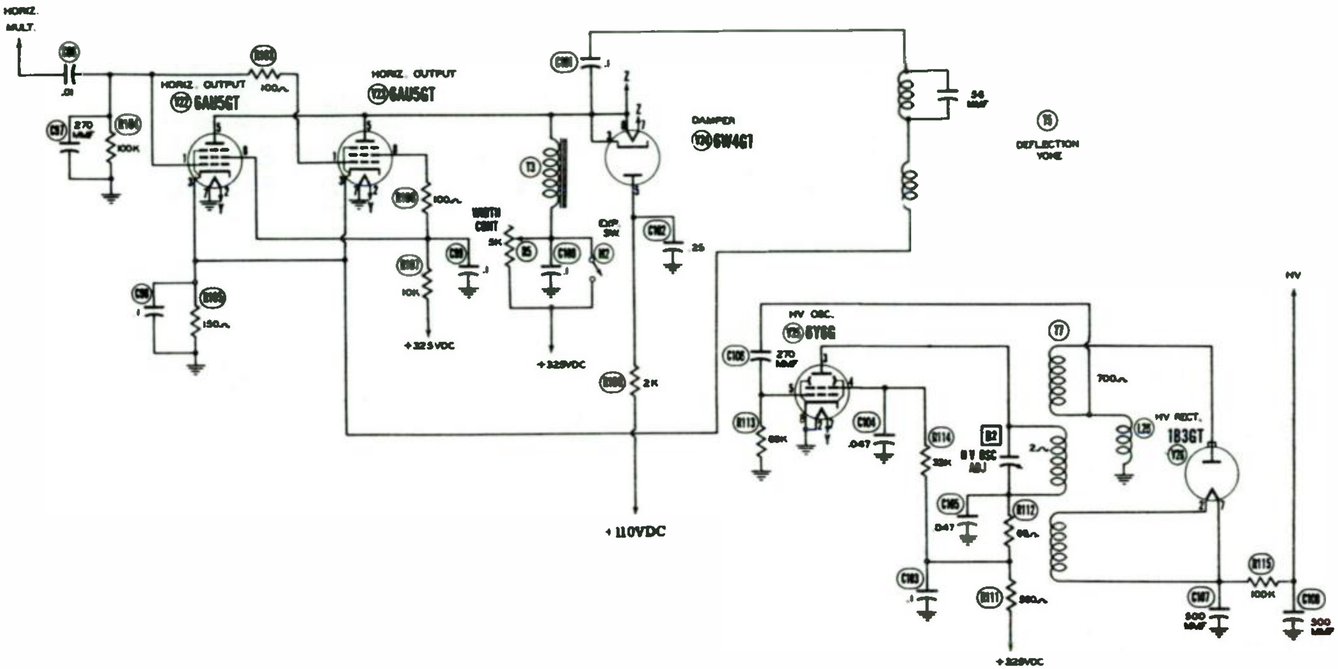

Figure 25 — Schematic diagram of a horizontal output circuit and separate RF type of high voltage system.

m. Shorted feedback capacitor. See C_{105} in Figure 21.
n. Open or shorted capacitor in the yoke return lead. See C_{110} in Figure 21 or C_{79} in Figure 22.
o. High voltage filter resistor increased in value or open. See R_{121} in Figure 21, R_{101} in Figure 24, or R_{115} in Figure 25.

Insufficient Width.

The symptom pictured in Figure 26 represents a trouble caused by insufficient horizontal sweep. Symptoms of this nature usually indicate to the technician that the trouble exists in either the horizontal sweep circuit or in the low voltage power supply. Although the present discussion deals only with those faults originating in the horizontal sweep circuit, it should be pointed out that a weak low voltage rectifier tube or selenium rectifier is also a very common cause for this condition. A deficiency of low voltage will often reduce the height of the picture.

Figure 26 — Reduced width caused by a defect in the horizontal sweep section.

The most frequent offender causing insufficient width is perhaps the horizontal output stage. This weakness may be due to the relatively large amount of power handled by this tube. The efficiency of the horizontal output stage is rather critical, and the slightest change in drive or bias voltages may result in width reduction.

Possible causes for insufficient width are:

a. Defective tube in the horizontal sweep or high-voltage circuits.
b. Misadjusted or defective drive control, width coil, or linearity coil.
c. Open or leaky boosted B+ filter capacitor. See C_{111} and C_{112} in Figure 21, C_{77} and C_{78} in Figure 22, C_{125} and C_{126} in Figure 23, or C_{93} and C_{94} in Figure 24.
d. Open or leaky screen capacitor in the output stage. See C_{107} in Figure 21, C_{75} in Figure 22, C_{121} and C_{122} in Figure 23, C_{92} in Figure 24, or C_{99} in Figure 25.
e. Horizontal output grid resistor low in value. See R_{104} in Figure 21, R_{93} in Figure 22, R_{129} in Figure 23, R_{91} in Figure 24, or R_{104} in Figure 25.
f. Horizontal output screen resistor increased in value. See R_{108} in Figure 21, R_{96} in Figure 22, R_{131} and R_{132} in Figure 23, R_{95} in Figure 24, or R_{107} in Figure 25.
g. Open or leaky coupling capacitor. See C_{104} in Figure 21, C_{74} in Figure 22, C_{120} and C_{124} in

Figure 23, C_{91} in Figure 24, or C_{96} and C_{101} in Figure 25.
h. Defective flyback transformer.
i. Leaky capacitor in the yoke return lead. See C_{110} in Figure 21, or C_{79} in Figure 22.
j. Horizontal output cathode resistor increased in value. See R_{94} in Figure 22, R_{130} in Figure 23, R_{94} in Figure 24, or R_{105} in Figure 25.

When trouble shooting a symptom of insufficient width, the technician should always check the amplitude of the drive voltage before delving too far into a suspected flyback circuit.

Blooming.

Picture blooming is a common term used when the entire raster expands as the brightness control is advanced. This trouble symptom is shown in the photograph of Figure 27 in which the picture detail appears out of focus. For proper focus, the brightness level must be reduced to below normal; and in such a case, the raster may not fill the screen. If this condition becomes extreme, the raster may disappear completely as the brightness control approaches its maximum setting. When these symptoms occur, the receiver is usually operating with insufficient high voltage.

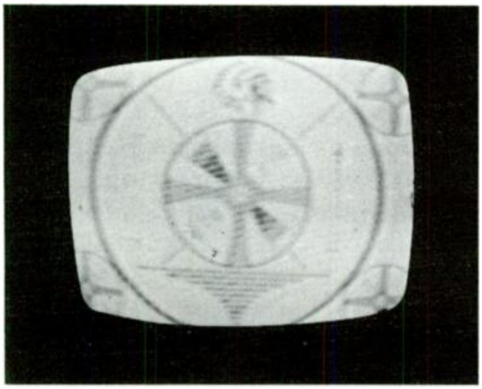

Figure 27 — Picture blooming caused by insufficient high voltage.

Possible causes for blooming are:

a. Defective tube in the horizontal sweep or high-voltage circuits.
b. High voltage filter resistor increased in value. See R_{121} in Figure 21, R_{101} in Figure 24, or R_{115} in Figure 25.
c. Defective component in a voltage-doubler network. See R_{98}, R_{99}, R_{100}, and C_{100} in Figure 24.
d. Leaky high-voltage filter capacitor. See C_{114} in Figure 21, C_{127} in Figure 23, C_{101} in Figure 24, or C_{107} and C_{108} in Figure 25.
e. High-voltage arcing or corona discharge. Check lead dress and solder connections.
f. Filament resistor of the high-voltage rectifier changed in value. See R_{120} in Figure 21, or R_{104} in Figure 22.
g. Defective component in the RF type of supply. See Figure 25.
h. Misadjusted horizontal drive control.
i. Defective flyback transformer.

Trouble in the low-voltage power supply may produce blooming, but a narrow raster with a decrease in picture brightness will usually accompany such a symptom. A gassy picture tube will also cause the picture to bloom. The picture may look slightly negative, or a discolored spot may appear on the screen. In either case, the tube would be gassy.

Horizontal Foldover.

Horizontal foldover can produce various symptoms on the picture-tube screen. These may appear as light drive lines near the left center of the picture, or large portions of the raster may sometimes be folded back at either the left or right side of the screen.

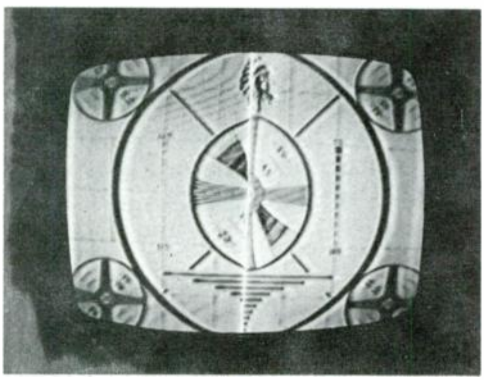

Figure 28 — Horizontal foldover affecting the center portion of the picture.

The trouble symptom pictured in Figure 28 represents horizontal foldover near the center of the screen. This condition and those in which the left side of the raster folds over are most often caused by defective components in the damper circuit. When the foldover occurs at the right side of the screen (as shown in Fig. 29), the trouble usually originates in the horizontal discharge or output circuits. This method of isolation will not always

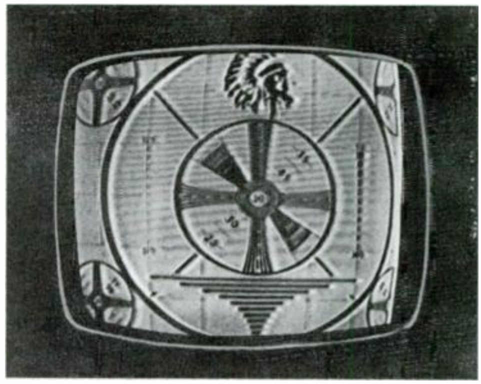

Figure 29 — Horizontal foldover on right side of the screen accompanied by an over all reduction in width.

hold true but should prove helpful at times. A waveform analysis of the horizontal sweep section is perhaps the quickest troubleshooting procedure to use when a fault of this nature is being localized.

Possible causes for horizontal foldover are:

a. Defective tube in the horizontal discharge or flyback circuits.
b. Leaky coupling capacitor. See C_{104} in Figure 21, C_{74} in Figure 22, C_{120} in Figure 23, C_{91} in Figure 24, or C_{96} in Figure 25.
c. Misadjusted or defective drive control.
d. Open or leaky cathode capacitor in the output stage. See C_{76} in Figure 22, C_{123} in Figure 23, C_{2B} in Figure 24, or C_{98} in Figure 25.
e. Grid resistor of incorrect value in the horizontal output stage. See R_{104} in Figure 21, R_{93} in Figure 22, R_{129} in Figure 23, R_{91} in Figure 24, or R_{104} in Figure 25.

f. Open or leaky screen capacitor in the output stage. See C_{107} in Figure 21, C_{75} in Figure 22, C_{121} and C_{122} in Figure 23, C_{92} in Figure 24, or C_{99} in Figure 25.
g. Defective width or linearity coil.
h. Open or leaky boosted B+ filter capacitor. See C_{111} and C_{112} in Figure 21, C_{77} and C_{78} in Figure 22, C_{125} and C_{126} in Figure 23, or C_{93} and C_{94} in Figure 24.
i. Cathode resistor of incorrect value in the horizontal output stage. See R_{94} in Figure 22, R_{130} in Figure 23, R_{94} in Figure 24, or R_{105} in Figure 25.
j. Open capacitor in deflection-yoke circuit.
k. Defective yoke or flyback transformer.

Horizontal foldover may be a result of improperly matched components in the flyback circuit. When it becomes necessary to replace such components as the yoke, flyback transformer, width coil, or linearity coil, it is imperative that these items duplicate the original part or that certain circuit modifications be performed to compensate for any mismatch.

Horizontal Nonlinearity.

The trouble symptom represented in the photograph of Figure 30 reveals a case of horizontal nonlinearity. In this particular example, the left half of the picture is stretched out of proportion because of a nonlinear sweep. Symptoms of nonlinearity are closely related to those of horizontal foldover. Defective components may cause horizontal foldover in some instances; and in others, the same components may produce some form of nonlinearity.

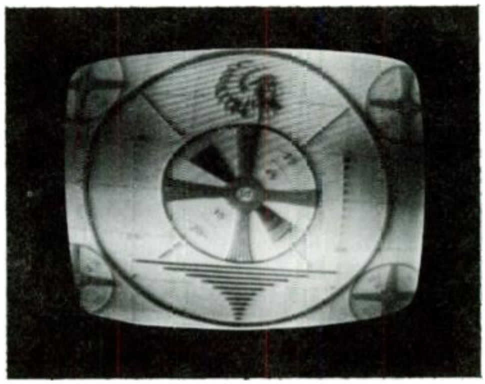

Figure 30 — A typical symptom of horizontal nonlinearity.

Possible causes for horizontal nonlinearity are:

a. Defective tube in the horizontal discharge or flyback circuits.
b. Defective or misadjusted linearity coil.
c. Open or leaky boosted B+ filter capacitor. See C_{111} and C_{112} in Figure 21, C_{77} and C_{78} in Figure 22, C_{125} and C_{126} in Figure 23, or C_{93} and C_{94} in Figure 24.
d. Open screen capacitor in the output stage. See C_{107} in Figure 21, C_{75} in Figure 22, C_{121} and C_{122} in Figure 23, C_{92} in Figure 24, or C_{99} in Figure 25.
e. Grid or cathode resistor changed in value. See R_{104} in Figure 21, R_{93} and R_{94} in Figure 22, R_{129} and R_{130} in Figure 23, R_{91} and R_{94} in Figure 24, or R_{104} and R_{105} in Figure 25.

f. Improper value of screen resistor. See R_{108} in Figure 21, R_{95} and R_{96} in Figure 22, R_{131} and R_{132} in Figure 23, R_{93} and R_{95} in Figure 24, or R_{107} in Figure 25.
g. Defective yoke or width coil.
h. Partially open or leaky coupling capacitor. See C_{104} in Figure 21, C_{74} in Figure 22, C_{120} in Figure 23, C_{91} in Figure 24, or C_{96} in Figure 25.
i. Shorted or leaky capacitor in the yoke return lead. See C_{110} in Figure 21, or C_{79} in Figure 22.

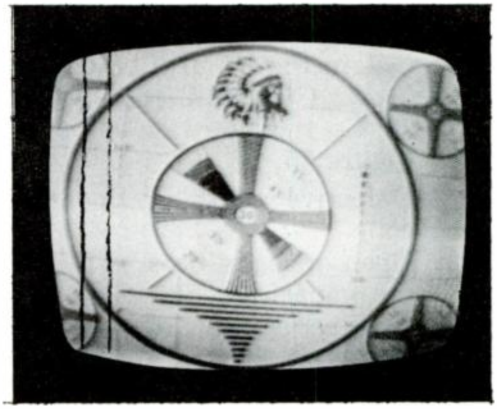

Figure 31 — Barkhausen oscillation as it may appear when a weak signal is being received.

When the test pattern is not on the air, the technician will find a crosshatch generator very handy for checking horizontal linearity. This instrument will give a true picture of the linearity of both vertical and horizontal sweep circuits.

In many receivers, the setting of the horizontal linearity coil is somewhat critical. If this coil is misadjusted, it can cause the flyback transformer to overheat or it can place an undue strain on the output tube.

Barkhausen Oscillation.

An interference known as Barkhausen oscillation is another common trouble symptom often encountered. This type of interference is illustrated in the symptom of Figure 31. In this example, a weak signal is being received and the oscillations show up as two vertical black lines near the left side of the screen. These oscillations actually occur within the horizontal output tube. When the signal voltage on the plate of the output tube drops to zero or becomes slightly negative, the electrons which have already passed the screen grid are attracted back toward the positive potential on its screen. When the plate voltage becomes positive, the electrons again change direction and are attracted toward the plate. Thus an oscillation is set up within the tube. These oscillations can radiate from a number of different sources in the flyback circuit. The radiation may be picked up by the antenna lead-in, by the tuner, or by the IF strip.

Barkhausen oscillation is most evident when no signal is being received. A strong local signal will usually override this type of interference or will cause the dark lines to appear much lighter.

Possible causes for Barkhausen oscillation are:

a. Defective output tube.
b. Misadjusted drive, width, or linearity controls.
c. Improper shielding.
d. Incorrect lead dress.

e. Excessive lead length in the flyback circuit.
f. A slight physical or electrical change in component values.

The procedure that may be followed in logically locating the trouble is listed below.

Several tubes may be substituted in each of the horizontal output, damper, and high voltage rectifier stages.

Dress the antenna lead-in wire away from the flyback section of the receiver.

Reset the horizontal drive adjustment, and vary the width and linearity coils.

Place a small magnet around the glass envelope of the horizontal output tube. A single magnet ion trap is ideal for this application.

Add tube shields to the RF and IF stages of the receiver if there are none.

Check the high-voltage cage for proper ground connections. Add additional shields if necessary.

Shorten or reposition all leads emerging from the high-voltage compartment.

Place carbon resistors of approximately 50 ohms each in series with the plate and screen leads of the horizontal output tube and in series with the plate lead of the high voltage rectifier.

Install RF chokes of 1 to 5 microhenries in the plate and cathode circuits of the damper tube, and add a 100-mmfd capacitor from the B+ side of the plate choke to chassis ground.

The technician should keep in mind the possibility of other faults that could produce a symptom similar to Barkhausen oscillation or horizontal ringing. As an example, a dark vertical line may appear on the screen because of internal arcing within some component in the flyback system.

Unstable Horizontal Synchronization.

Difficulties originating in the horizontal output section of the receiver can produce a wide variety of unusual synchronization troubles. A symptom of one of these is illustrated in Figure 32. In this particular instance, the erratic distortion would disappear as the brightness control was turned down; but at the same time, the entire raster shrunk and the brightness was below a normal viewing level. Some cases of arcing can cause a similar erratic tearing condition. The interference

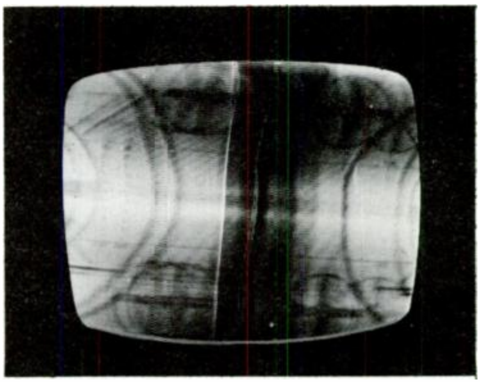

Figure 32 — Erratic horizontal synchronization.

generated by high-voltage arcing will often affect the stability of the horizontal oscillator.

A symptom of horizontal pulling is shown in the photograph of Figure 33. This trouble was a direct result of heater to cathode leakage within a defective horizontal output tube. Any low frequency modulation taking place in the horizontal output stage may produce horizontal pulling or bending.

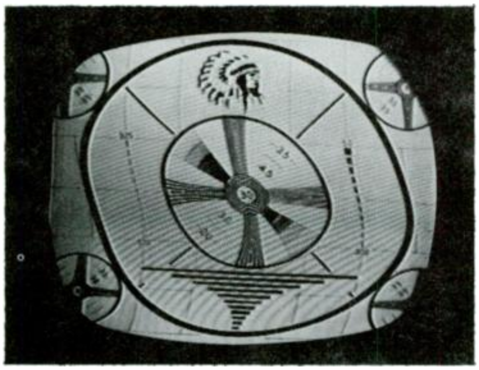

Figure 33 — Picture pulling caused by trouble in the horizontal output stage.

The operation of the horizontal AFC system can be upset by an improper feedback pulse from the horizontal output circuit. A trouble of this nature will often cause the picture to shift back and forth or the horizontal blanking pulse to appear near the center of the screen. Other trouble symptoms such as horizontal jitter, picture tearing, or multiple images may result from various defects in the horizontal output circuit.

Possible causes for unstable horizontal synchronization are:

a. Defective tube in the horizontal output or high voltage circuits.
b. Defective component in the AFC feedback network.
c. Internal arcing of a defective component. Check the screen and cathode bypass capacitors, the high-voltage filter capacitor, or the feedback components.
d. Open or leaky coupling capacitor. See C_{104} in Figure 21, C_{74} in Figure 22, C_{120} in Figure 23, C_{91} in Figure 24, or C_{96} in Figure 25.
e. Improper lead dress.

Corona Discharge and High Voltage Arc-over.

Corona manifests itself as a blue or violet discharge radiating from a source of high voltage and usually producing an audible hissing sound. The bluish haze results from the ionization of the air surrounding the point of high potential. Corona discharge will often precede an actual high voltage arc-over which is a complete breakdown of the insulation separating two points of different potentials.

Arcing in the high voltage system of a television receiver is frequently encountered because of the relatively high potentials involved. The trouble symptom pictured in Figure 34 represents the interference produced on the screen when arcing occurs in a high voltage rectifier circuit. The streaks in the picture are usually accompanied by a periodic or an erratic snapping sound. A close examination of the high voltage section may reveal a flashing at the point of breakdown, and the odor of ozone can sometimes be detected. In order to local-

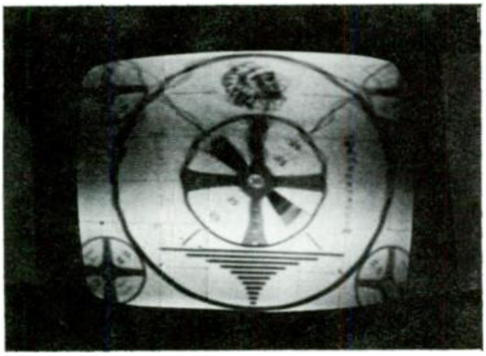

Figure 34 — The effects of high voltage arcing as they may appear in the picture.

ize corona or high voltage arc-over, it may be necessary to examine the suspected circuit in a darkened room.

When the probe contacts the source of breakdown, the hissing sound may be interrupted or may change in pitch. If this method fails to isolate the trouble, the line voltage may be increased and the condition may become more apparent and thus more readily detected.

Possible causes for corona discharge and high voltage arc-over are:

a. Improper lead dress. Check the positions of all leads in the flyback system.
b. Poor solder joint. Check the connections for sharp points, rosin joints, and jagged edges.
c. Defective insulation. Check the lead covering and the insulators for possible damage.
d. Excessive dust or moisture in the high-voltage compartment.
e. Defective tube or yoke socket. Check for breakdown between the socket connections.
f. Internal arcing of a component. Checking the high voltage filter network, damper tube, width and linearity coils, and flyback transformer.
g. Poor contact at the picture tube anode. The glass surface surrounding the anode connection must also be free of dust and moisture.

When corona is emanating from an insulation material, the surface of the object should be thoroughly cleaned and a coat of suitable lacquer or corona dope applied. If its source is difficult to locate, corona can often be eliminated if the entire high-voltage system is sprayed with some type of commercial varnish of high dielectric strength. Corona occurring in the tube socket of the high-voltage rectifier can sometimes be cured by application of a slight amount of Lubriplate on the tube pins and by reinsertion of the tube in the socket. The high-voltage rectifier circuit should also be kept free of dirt and grime which will usually collect over any long period of time.

Distortion Caused by Ringing in the Yoke.

The interaction between vertical and horizontal windings of a deflection yoke can often result in unwanted picture distortion. The result of one trouble originating in the yoke circuit is shown in the photograph of Figure 35. The raster width is reduced slightly, and a certain amount of yoke ringing can be seen at the left side of the picture. A more severe case of yoke ringing

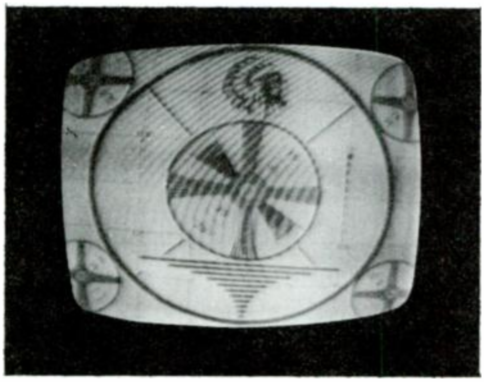

Figure 35 — A slight case of yoke ringing.

is represented in Figure 36. In this particular example, the over-all brightness has been reduced and the ringing tends to distort the entire left half of the test pattern.

A certain degree of stray pickup between the horizontal and vertical windings of the yoke is always present. Components that have incorrect values or damping and neutralizing elements that are defective will usually produce symptoms similar to those illustrated.

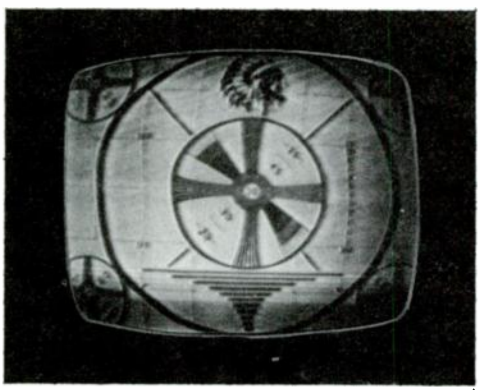

Figure 36 — Picture distortion and insufficient brightness resulting from a severe case of yoke ringing.

Possible causes for distortion caused by ringing in the yoke are:

a. Open capacitor across one half of the horizontal yoke winding.
b. Improper lead dress.
c. Open shunt resistor across one half of the horizontal winding.
d. Incorrect yoke replacement.

Many of the commercial receivers employ a capacitor of approximately 270 micromicrofarads connected between the vertical and horizontal windings of the yoke. This component tends to reduce the effects of the interaction (or cross talk) between windings. Should this capacitor open, a symptom of yoke ringing will usually result. If the capacitor becomes leaky or shorted, the width of the picture may be reduced or a slight Keystone effect may result. When the elimination of yoke ringing presents somewhat of a problem, a capacitor should be installed between the windings if the original circuit is without one.

High Frequency Whistle (Flyback Singing).

Another trouble symptom that warrants mention in this lesson is the whistle caused by flyback singing. Many people are capable of hearing beyond the normal range and may find the high pitched squeal emanating from the flyback circuit very annoying. The cause of this trouble is usually mechanical resonance in the flyback transformer. The following steps should be taken to eliminate this trouble.

1. Adjust the width, linearity, and drive.
2. Reposition all leads connected to the flyback transformer.
3. Replace the horizontal output tube.
4. Tighten all mounting nuts and screws associated with the transformer.
5. Install rubber shock mounts between the transformer and the chassis.
6. Drive small wooden wedges between the transformer winding and the core.
7. Saturate the entire transformer assembly with wax or lacquer.

A combination of two or more of the procedures listed may be needed before the whistling noise is eliminated. It may even be impossible to eliminate the singing completely without replacment of the flyback transformer, but it can be reduced to a level which can be tolerated.

AUDIO SYSTEMS

The audio systems used in TV receivers are similar to the audio systems used in FM receivers. As a rule, the troubles encountered in a television receiver will closely parallel the troubles that might appear in an FM radio.

General Isolating Procedure

Since the audio section of a receiver is made up of several stages that must all work together, any trouble must be traced or isolated to the defective stage or stages if it is to be rapidly located. This is best accomplished by the process of elimination.

It is possible to check the audio amplifier stage, output stage, and speaker system without removal of the chassis from the cabinet if the TV receiver has a phono switch and an input jack. This may be done if the switch is moved to the phono position and a record is played on the phonograph. If a phonograph is not available, you can insert a screwdriver into the phono jack and touch the shaft of the screwdriver with your finger. If the circuits following the phono input are operating satisfactorily, a buzz or hum should be heard from the speaker. The volume control should be set for a low level to prevent damage to the speaker, and the amount of hum should vary with the setting of the volume control.

This check is good only when the trouble concerns weak sound or when there is no sound. Distortion would obviously not be revealed if hum were being used for a test signal. If a phonograph or an audio signal generator were used for a signal source, any distortion caused by trouble in the audio section would be revealed. These checks will tell you that the trouble is either in the audio section or in the IF and detector section. During the troubleshooting procedure, you may then concentrate on the section known to be defective.

If the isolation procedure should reveal that the trouble is in the IF or detector stages, then you should check the voltages at the sockets of these tubes. If the plate and screen voltages are about normal, the next step would be to check the alignment of the audio IF and detector stages because the indications during the alignment can help in isolating the trouble.

Loss of Audio.

The condition of a loss of audio exists when there is no voice or music coming from the speaker. There may or may not be a low-level hiss. This would simply indicate that the audio amplifier and output tubes are operating because the hiss is thermal noise generated within them.

Possible causes of a loss of audio are:

a. Defective audio output, amplifer, detector, limiter, or IF tubes.
b. Defective volume control.
c. Defective coupling capacitor to the output or amplifier grids. See C_{57} and C_{58} in Figure 37; C_{44} and C_{46} in Figure 38; C_{59} in Figure 39; or C_{66}, C_{67}, and C_{68} in Figure 40.
d. Defective output transformer or speaker.
e. Open decoupling resistor. See R_{53} and R_{58} in Figure 37, R_{44} and R_{51} in Figure 38, R_{66} and R_{74} in Figure 39, or R_{71} in Figure 40.
f. Open plate or screen resistor. See R_{64} in Figure 37; R_{43} and R_{48} in Figure 38; R_{67}, R_{69}, and R_{70} in Figure 39; or R_{68} and R_{70} in Figure 40.

Complete loss of audio means that no sound, not even the hiss caused by thermal agitation, is being emitted from the speaker. This condition can exist only if the trouble exists in the last stages (the AF amplifier and output). If the thermal hiss is present, this is a good indication that the trouble is located ahead of the volume control. If the trouble should be ahead of the volume control, a popping noise should be heard from the speaker when the volume control is tuned to maximum and when each tube ahead of the volume control is removed and reinserted. If this procedure at any stage fails to produce the popping noise, the stage being tested has trouble in its plate circuit or the next stage closer to the volume control has trouble in its input circuit. This is a procedure that may be employed without removal of the chassis from the cabinet, and it should usually help in locating the defective section of the receiver.

Weak Audio.

The condition of weak audio exists when there is very little voice or music coming from the speaker even with the volume control set at maximum. This condition may or may not be accompanied by a hissing noise from the speaker. If such a noise is present, it is caused by thermal noise generated within the audio section. This can mean that the audio section is functioning satisfactorily. This type of indication will appear only in receivers that employ a high-gain amplifier stage to drive the output stage and only when the trouble is due to failure ahead of the audio amplifier stage.

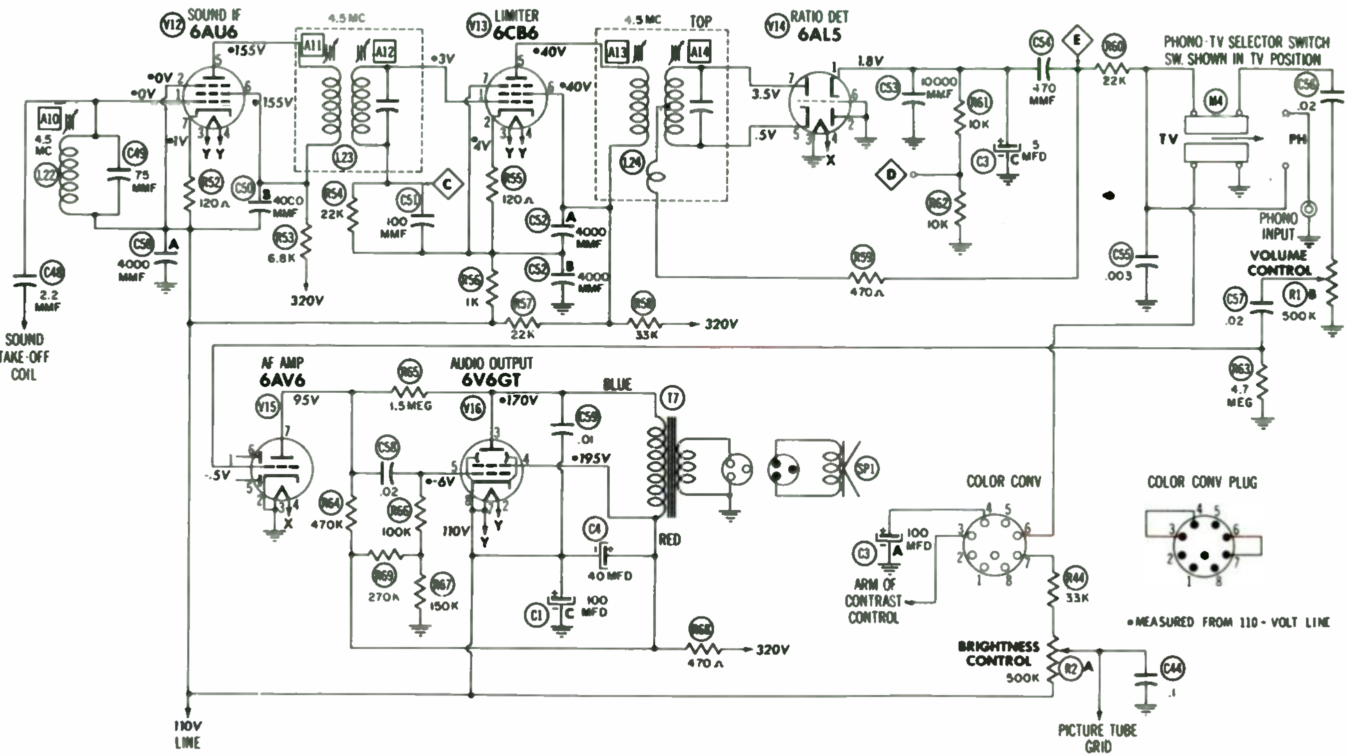

Figure 37 — An audio section employing a ratio detector.

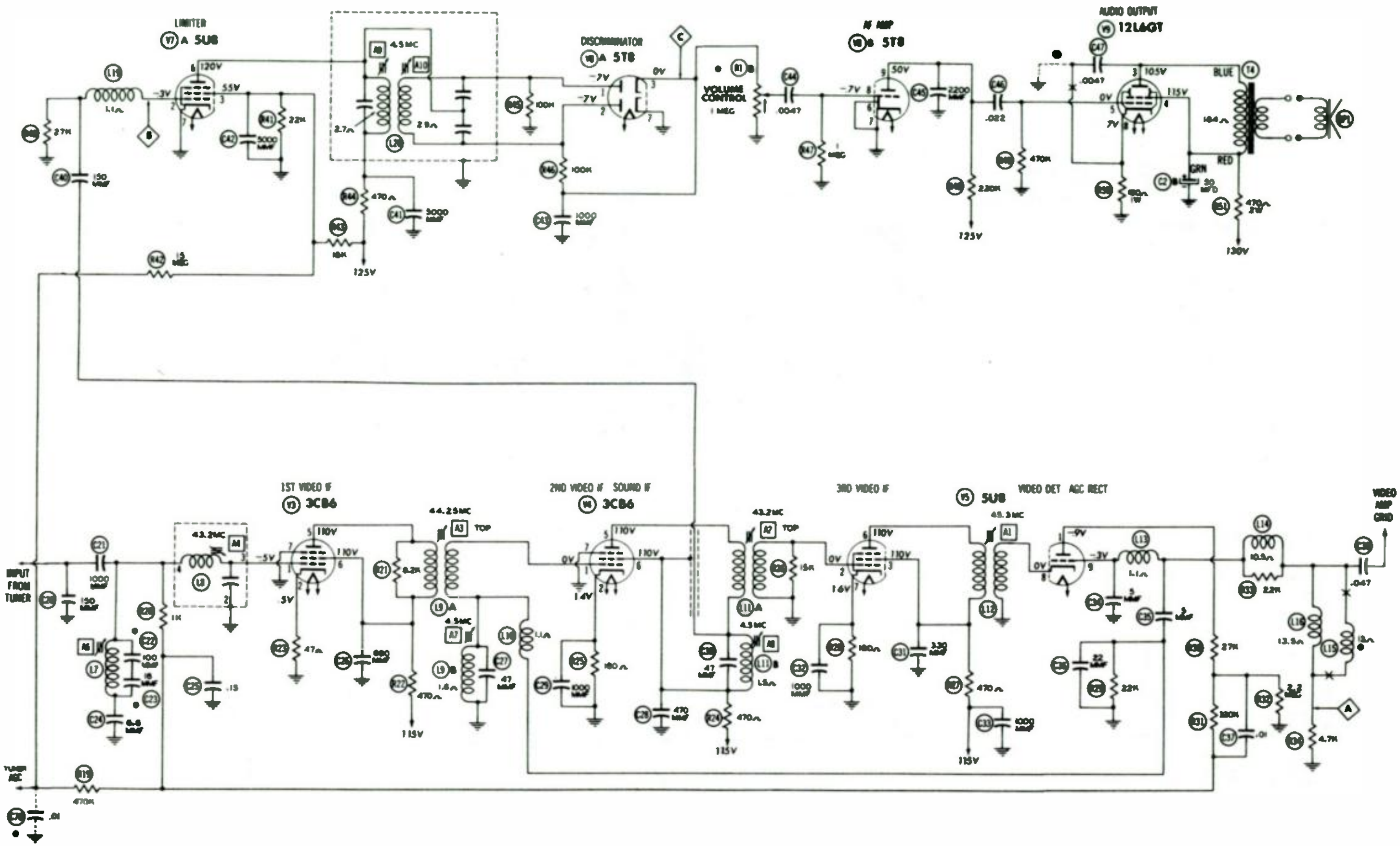

Figure 38 — An audio section employing a discriminator.

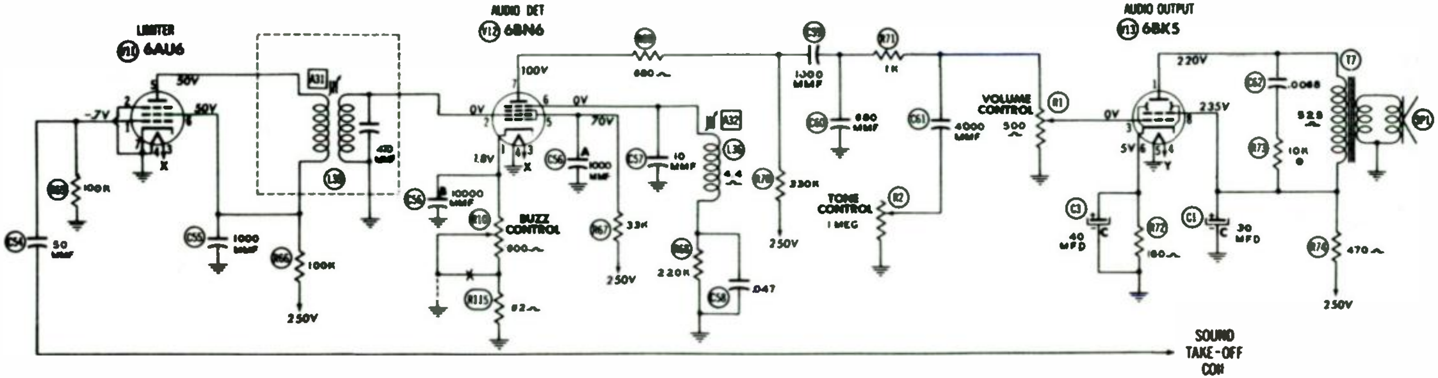

Figure 39 — An audio section employing a gated-beam detector.

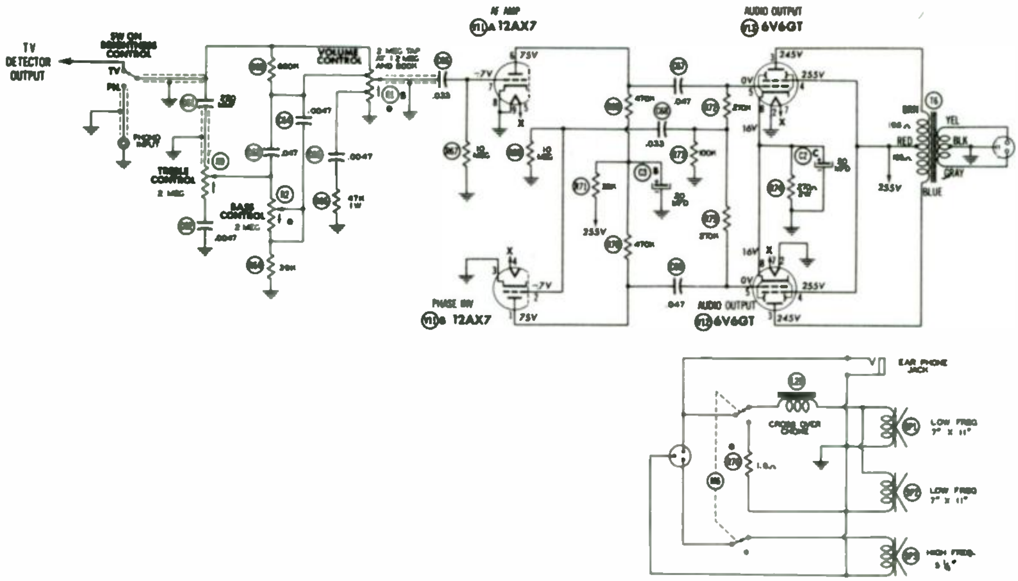

Figure 40 — The audio amplifier and output stages of a typical deluxe television receiver.

Possible causes of weak audio are:

a. Defective IF, limiter, detector, voltage amplifier, or output tubes.
b. Low voltage to the plate or screen grid of the limiter or IF amplifier tube caused by trouble in the decoupling network to that stage.
c. Defective tone compensation capacitor in the output stage. See C_{59} in Figure 37 and C_{47} in Figure 38.
d. Poor alignment of IF or detector stage.
e. Open coupling capacitor to one of the tubes in a push-pull output stage. See C_{69} in Figure 40.
f. Defective tube or component in phase-inverter stage. See V11B and its components in Figure 40.
g. Low B+ voltage.
h. Defective component in the tone-control network. See Figure 40.

When low B+ voltage is causing weak audio, the video and the high voltage stages will also be operating poorly; and the technician should immediately suspect power supply trouble.

Weak audio may be caused by a defect in one half of the push-pull output stage. A quick way to check for this condition would be to remove first one output tube and then the other. If there is a loss of audio when one of the tubes is removed and no effect when the other tube is removed, it is reasonable to assume that the stage which produced no difference when its tube was removed is defective. In a push-pull output stage which is operating normally, removal of either output tube should cause a reduction of the output.

Sync Buzz.

Sync buzz is the condition that exists when the desired audio signal is accompanied by a low-frequency buzz. This is a very annoying type of trouble and is one about which the average customer is very likely to complain.

Possible causes of sync buzz are:

a. Defective detector tube.
b. Improper alignment of the detector stage.
c. Improper tuning of the local oscillator in the tuner.
d. Poor lead dress between the audio and vertical or sync stages.
e. Overloading in the video IF or tuner stages.
f. Defective stabilizing capacitor in the ratio-detector stage. See C_3 in Figure 37.

Improper lead dress between the vertical or sync sections and the audio section causes the audio section to pick up the vertical pulses or sync pulses; and as a result, a problem of sync buzz that is very difficult to eliminate is created. When this trouble is due to design or construction practices, the manufacturer will usually issue a production change bulletin and tell how the trouble can be corrected. If improper lead dress has been caused by carelessness on the part of a technician when a component was being replaced or when a circuit was being traced in this section of the receiver, then locating the source of the trouble will probably be very difficult. For this reason, it is important that the original lead dress and component placement be disturbed as little as possible. This holds true for all sections of a television receiver.

Drift.

The problem of the sound drifting from the point of best reception is one that is usually associated with the split-sound system. In receivers employing this kind of system, it is normal for the sound to drift during the warm-up period (which is about 5 minutes). Drift occurring after this period would indicate trouble either in the tuner or in the audio IF strip.

If the drift is caused by a trouble in the audio IF strip, then this trouble will probably be due to improper alignment. Realignment of the audio IF and detector stages should help to eliminate the trouble. If the drift is still present after realignment of the audio IF and detector stages, then the trouble will be due to excessive drift of the local oscillator in the tuner. If the IF or detector stages cannot be properly realigned, trouble will be present in the IF or detector stage. A check of the stage in which proper adjustment cannot be obtained should reveal the trouble.

Garbled or Distorted Audio.

Distorted audio is the condition that exists when the audio signal is distorted or is noticeably changed. Garbled sound is a severe degree of distortion; and as a rule, the distortion is so great that the audio cannot be understood.

Possible causes of distorted or garbled audio are:

a. Heater to cathode leakage in an audio IF, detector, amplifier, or output tube.
b. Gassy tube in an audio IF, amplifier, or output stage.
c. Leaky coupling capacitor in the amplifier or output stages.
d. Defective speaker.
e. Improper alignment.

If an audio IF, detector, amplifier, or output tube has heater to cathode leakage that is severe enough, the audio could be completely blanked out and replaced by 60-hertz hum. Heater to cathode leakage in the tuner or a video IF stage which is ahead of the sound take-off point could also result in distorted or garbled audio. As a rule, heater to cathode leakage in the video IF and tuner stages will also cause a black bar across the screen, particularly when the picture brightness is low.

Gassy tubes cause grid current to flow, and thus distortion can be developed. This condition occurs most often in the output stage.

A leaky coupling capacitor would cause the bias on a grid to be disturbed, and the sound would become distorted or garbled. If the leakage through the capacitor is bad enough, the bias on the tube could be disturbed enough that the audio could be completely missing.

LOW VOLTAGE POWER SUPPLIES

The low voltage supplies used in TV receivers are similar in circuit design to many of the B+ supplies used in radio receivers and record players. The designs used in present day receivers are either the vacuum tube rectifier type or the solid state rectifier type. Even though there are only these two basic types, there are many variations of them.

As the power supply section delivers power to many parts of the receiver, the loss of power can create many different types of problems. The major symptoms that generally occur in a receiver are listed below.

No Raster and No Sound.

Loss of raster and sound usually result from a deficiency in the low-voltage supply. When these symptoms are encountered, the technician should first determine the type of supply employed and any design peculiarities that would aid in isolating the trouble.

If a set continues to cause line fuses to blow or if any smoke or burnt odor is detected, the chassis should be taken to the shop for a more complete checkup. The symptom of no raster and no sound in a receiver which employs a series filament circuit may result from an open filament in any one of the tubes. When the defective tube is replaced, the entire string will light up and the set should return to normal operation.

If the filaments do not light up after all tubes in the string have been substituted, there may be an open fuse or dropping resistor in the filament circuit.

If trouble is suspected in a low voltage supply using a power transformer, one of the first steps to be taken is the substitution of the rectifier tube. Then check to see if the plate elements glow red and appear overheated. If this condition is present, excessive current is usually being consumed by the receiver and a possible B+ short exists. Power should be removed from the receiver immediately to prevent any further damage to components, and a more complete examination should be made in the shop.

Possible causes for no raster and no sound are:

a. Defective low voltage rectifier tube or selenium rectifier.
b. Open tube filament in receivers employing a series filament arrangement.
c. Open fuse or fusible resistor in the power supply circuit. See R_{70} in Figure 43 or M2 and R_{89} in Figure 44.
d. Faulty connection. Check the line cord, interlock contacts, fuse holder, or the plugs for the speaker and yoke.
e. Open resistor in the B+ distribution system. See R_{109} and R_{110} in Figure 42 or R_{90} in Figure 44.
f. Shorted or leaky filter capacitor. See C_{1A}, C_{1B}, C_{2A}, and C_{2B} in Figure 41; C_{1A}, C_{1B}, C_{2A}, C_{2B}, C_{2C}, and C_{3A} in Figure 42; C_1 and C_{2A} in Figure 43; or C_{1A}, C_{1B}, and C_{2A} in Figure 44.

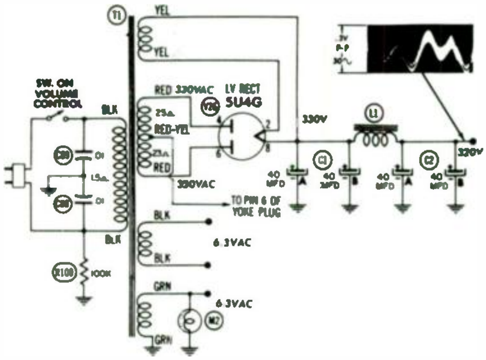

Figure 41 — Conventional power supply employing a power transformer and a single rectifier tube.

g. Defective ON-OFF switch.
h. Shorted or open focus coil or focus control in the B+ circuit. Check all shunt and series resistors in the focus network.
i. Open filter choke or speaker field coil. Check for a direct short in the B+ circuits that follow the burned out component.
j. Defective power transformer.

If components such as filter chokes or voltage dropping resistors are found open or burnt in the B+ circuit, the technician should always check for a possible short circuit before replacing the damaged parts and applying power to the receiver.

Insufficient Width or Height.

Another common trouble symptom resulting from a deficiency in the low-voltage power supply is illustrated in Figure 45. The symptom reveals a very dim raster and a reduction in both width and height. Poor focus or a reduction in sound may also accompany a trouble of this nature.

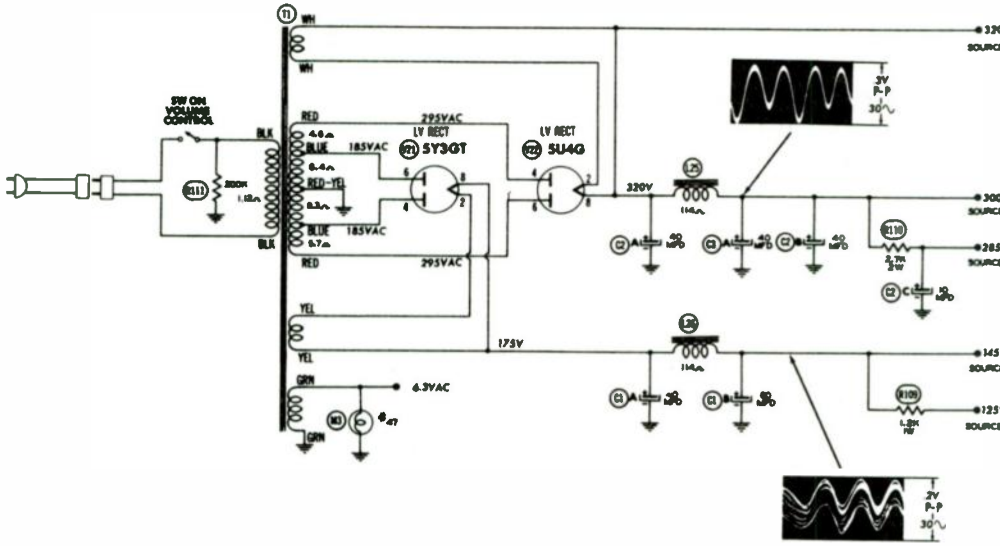

Figure 42 — Typical dual voltage supply using a power transformer and two rectifier tubes.

In a large number of cases, the brightness and height will appear relatively normal but the width of the picture will be insufficient to fill the screen. A decrease in picture height can usually be corrected by adjustment of the vertical height and linearity controls. The width of the picture is somewhat more susceptible to reductions in B+ voltage; and in many instances, the width, linearity, and drive adjustments will be unable to compensate for this deficiency.

Possible causes for insufficient width and height are:

a. Weak low voltage rectifier tube or selenium rectifier.
b. Defective tube or a short circuit overloading the low voltage supply.
c. Leaky filter capacitor. See C_{1A}, C_{1B}, C_{2A}, and C_{2B} in Figure 41; C_{1A}, C_{1B}, C_{2A}, C_{2B}, C_{2C}, and C_{3A} in Figure 42; C_1 and C_{2A} in Figure 43; or C_{1A}, C_{1B}, and C_{2A} in Figure 44.
d. Low line voltage.
e. Voltage dropping resistor too high in value. See R_{109} and R_{110} in Figure 42 or R_{90} in Figure 44.
f. Defective component in the focus coil circuit.

Weak selenium rectifiers often cause a receiver to take a long time

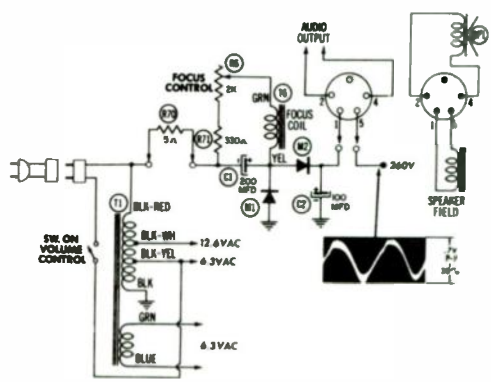

Figure 43 — Half-wave, voltage-doubler circuit using two selenium rectifiers and a separate filament transformer.

to warm up. In other cases, the set will operate normally at first; but after a short period of time, the picture may tend to shrink in size. Selenium rectifiers cannot be properly checked with an ohmmeter, but commercial testers for selenium rectifiers are available to eliminate the substitution test normally required to determine the condition of a selenium rectifier.

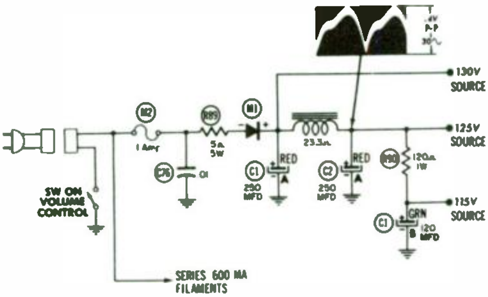

Figure 44 — Conventional half-wave rectifier system using a selenium rectifier.

Hum Bars in the Picture.

The trouble symptom shown in Figure 46 represents a hum bar in the picture. If the hum or AC ripple voltage is modulating the video signal, it may also be affecting other circuits in the receiver. In general, there are three possible sources of 60-Hz voltage in a TV receiver, namely: the vertical sweep circuit, the filament supply, and the AC ripple voltage which results from half-wave rectification. Perhaps the most common cause of 60-Hz hum is heater to cathode leakage in one of the RF, IF, or video tubes. When this trouble develops, the edges of the raster will usually remain straight and only the picture elements will appear distorted. This will be accompanied by brightness modulation.

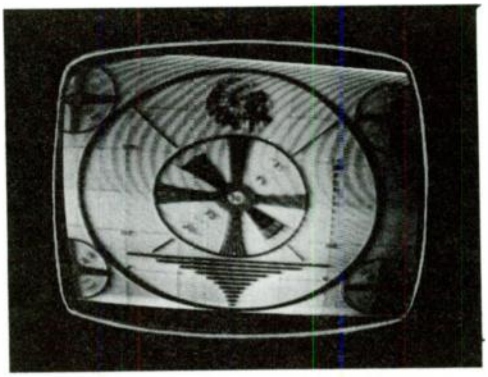

Figure 45 — Insufficient width and height and a loss of brightness caused by a decrease in the B+ supply voltage.

In the process of isolating the trouble causing 60-Hz hum in the picture, the technician should observe the edge of the raster to determine whether or not the horizontal sweep is also affected. If the edge of the raster tends to curve in the shape of a sine wave, hum is modulating the horizontal sweep.

The most frequent cause of AC hum in the B+ supply is a leaky or open filter capacitor. In order to check an electrolytic capacitor that has multiple sections without removing it from the circuit, shunt the individual sections temporarily with a suitable replacement.

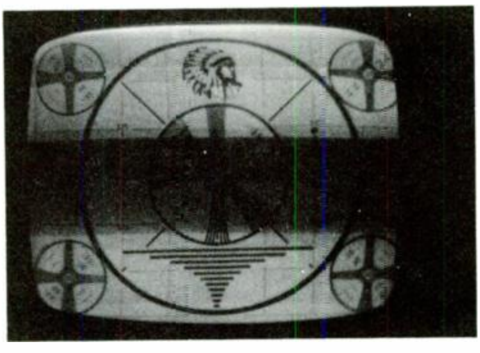

Figure 46 — Picture showing 120-hertz hum modulation.

Hum or Buzz in the Sound.

Hum or buzz which emanates from the speaker and which is unaffected by different settings of the volume control is often caused by trouble in the low voltage power supply or its associated circuitry. When a trouble of this nature is encountered, the technician should check to see if the undesired sound is tunable or if it is present when no station is being received. If the hum is relatively unchanged by these steps and the pitch of the sound remains constant when the vertical hold control is varied, then the hum modulation may be entering the sound through the B+ supply.

Possible causes for hum or buzz in the sound are:

a. Insufficient filtering. Check all filter capacitors in the B+ distribution system.
b. Open AC line filter capacitor. See C_{88} and C_{89} in Figure 41 or C_{76} in Figure 44.
c. Open filament bypass capacitor.
d. Defective isolation resistor. See R_{109} in Figure 41 or R_{111} in Figure 42.
e. Excessive flux leakage from the power transformer. Check the soldered connections of the copper band around the transformer.

No Picture.

A loss of the picture is another symptom that can be caused by trouble in the low voltage power supply. Additional symptoms such as poor focus or loss of sound may accompany this particular trouble. Although this symptom is not commonly caused by faults in the low voltage power supply, it is still possible for a defective component in one of the B+ branches to produce such a condition. A symptom of this nature, for instance, may result when an electrolytic capacitor in one of the B+ branches develops a short circuit or excessive leakage and causes a series resistor to open or increase in value. In such a case, the DC voltage at this point would be insufficient to supply certain stages of the receiver. If the RF, IF, or video sections should lack B+ supply voltage while the sweep circuits are operating normally, a symptom of raster with no picture will result. In many cases in which the focus coil network is located in the defective branch, the raster will appear out of focus and the focus control will have little or no effect in correcting the condition.

Horizontal Ripple in the Picture.

Another trouble associated with faults in the low voltage supply is shown in the symptom of Figure 47.

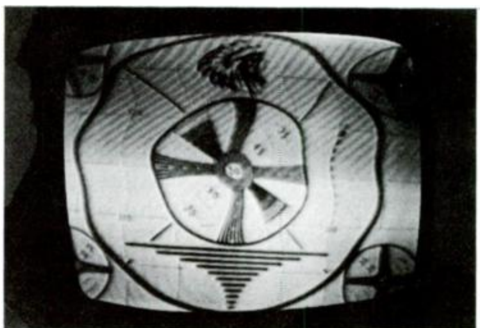

Figure 47 — Horizontal ripple resulting from an open filter capacitor in the B+ circuit.

This condition was a direct result of an open filter capacitor in the B+ supply. Because of insufficient filtering, a certain amount of AC ripple was able to modulate the horizontal oscillator and distort its output signal. The symptom illustrated in Figure 48 represents a more severe case of horizontal distortion also caused by poor filtering in the B+ circuit.

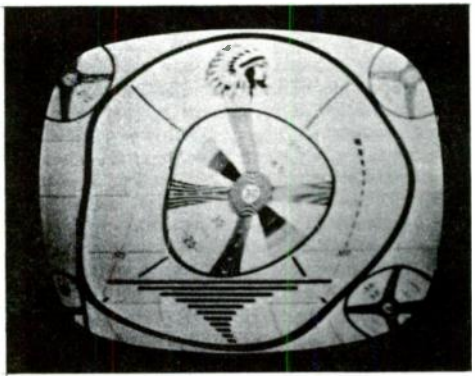

Figure 48 — A severe case of horizontal distortion originating from troubles in the low voltage power supply.

In some instances, the horizontal ripple may appear to move vertically through the picture. This condition often results from the difference between power line frequencies at the transmitter and at the receiver. The technician may test for this possibility by checking for the symptom on several operating channels if they are available. In a few rare cases, a similar horizontal ripple can result from excessive flux leakage from the power transformer. If this is the case, a check of lead dress and shielding should be made. Shielding the horizontal AFC or oscillator coils can sometimes reduce the coupling effect between the power supply and the horizontal sweep section.

Transformer Buzz.

Buzz is another annoying trouble symptom that may develop from a faulty power transformer. Transformer buzz is also common in other sections of the receiver. The horizontal and vertical output transformers frequently cause this condition.

When this symptom is encountered, the technician should determine whether the buzz is coming from the speaker or whether it is a mechanical vibration of some sort. One quick check for power transformer buzz is to listen for the symptom when the set is first turned on from a cold start. If the buzz starts before the rectifier tube reaches normal temperature, the trouble is evidently in the power transformer.

In most cases, it is rather difficult to isolate this type of trouble by merely placing the ear close to the different transformers in the receiver; but when a transformer is jarred, the buzz may be intermittent or may change pitch. If the technician suspects that the buzz originates in the power transformer, he should remove the rectifier tube or tubes from the circuit temporarily. The filament supply will usually furnish enough load on the unit to produce the trouble if the fault is in the power transformer itself. Removing the rectifier tube will usually eliminate all other possible sources.

If the power transformer is producing a buzz, the technician should tighten the bolts clamping the laminations together. Should this fail to cure the trouble, it may be necessary to remove the outer shell of the transformer and check to see if the windings are positioned securely on the core. If the windings are the least bit loose, a wood or fiber wedge can be driven between the core and the inside form of the windings. These operations will usually eliminate all sources of vibration within the transformer and will rid the unit of buzz.

SUMMARY

Some of the common troubles that occur in the vertical and horizontal sweep circuits, in the high and low voltage power supplies, and in the audio section have been reviewed in this lesson.

Linearity and vertical size troubles are the problems that are most frequently encountered in the vertical sweep circuits. The operation of the height, linearity, and hold controls should be operated, as clues to the source of the trouble can many times be determined from these controls.

The horizontal section of the receiver should be checked with a voltmeter or an oscilloscope to isolate a faulty stage. Proper adjustment must be made of the controls labeled: horizontal hold, frequency, phase, locking range, AGC, and at other points in the sync circuits.

High voltage problems are generally associated with vacuum tubes, or in hybrid receivers having solid state components that preceed and are associated with the high voltage circuit. Voltage checks, along with resistance measurements are generally used to localize the trouble.

Low voltage problems in vacuum tube sets are many times solved by replacing the rectifier tube. In solid-state power supplies it might be either the rectifier or the capacitor. If replacement does not correct the problem, low voltage might be caused by a shorted tube or a shorted component.

TV audio problems are similar to the problems in FM receivers, but with the additional problems created by the sync circuits causing buzz. Logical troubleshooting practices usually localize the cause of the difficulty.

TEST

Lesson Number 95

IMPORTANT

Carefully study each question listed here. Indicate your answer to each of these questions in the correct column of the Answer Card having Test Code Number 52-095-1.

1. A complete loss of vertical sweep would be indicated by
A. a vertical line on the picture tube screen.
2 B. a horizontal line on the picture tube screen.
C. a blank raster.
D. the screen being filled with diagonal lines.

2. If the frequency of the vertical oscillator is checked while the vertical oscillator is free running, the frequency would be
5 A. a little lower than 60 Hz.
B. a little higher than 60 Hz.
C. exactly 60 Hz
D. 15,750 Hz.

3. If horizontal synchronization is poor, but the vertical synchronization is normal, the trouble is probably in the
A. video IF amplifier.
B. picture tube.
C. integrator circuit.
D. horizontal AFC circuit.

4. Improper horizontal phasing is probably the result of
A. an open in the deflection coils.
B. a loss of vertical oscillation.
C. improper horizontal sweep alignment.
D. a loss of horizontal oscillation.

5. **If there is no raster but normal sound, and there is no high voltage, the trouble is probably in the**
   A. damper tube circuit.
   B. brightness control circuit.
   C. horizontal and high voltage circuits.
   D. low voltage rectifier tube circuit.

6. **Horizontal foldover (Fig. 28) is usually caused by**
   A. misadjusted horizontal drive control.
   B. corona discharge.
   C. incorrect lead dress.
   D. loss of picture.

7. **Sync buzz in the audio section is caused by:**
   A. an unbalanced amplifier stage.
   B. the audio circuit picking up vertical or sync pulses.
   C. a gassy tube.
   D. none of the above.

8. **Garbled audio may be caused by a**
   A. defective speaker.
   B. leaky coupling capacitor.
   C. gassy tube.
   D. all of the above.

9. **A loss of brightness and a reduction in picture size is generally caused by a**
   A. faulty antenna.
   B. low B+ voltage.
   C. bad audio amplifier.
   D. broken speaker.

10. **Hum bars in the picture due to the low voltage power supply can be caused by**
   A. an open fuse in the power supply.
   B. a bad line cord.
   C. either 60 or 120 hertz.
   D. a short circuit of the CRT.

Notes

Notes

Portions of this lesson from
TV Servicing Guide
by Leslie D. Deane and Calvin C. Young, Jr.
Courtesy of Howard W. Sams Co., Inc.

"School Without Walls"
"Serving America's Needs for Modern Vocational Training"

MODERN TESTING METHODS

Not too many years ago, a do-it-yourself radio repairman could keep the family radio running with "by guess and by gosh" methods. And some of these men did a good job.

But today's solid state, transistorized equipment needs precise test equipment and testing methods.

ASI provides you with this type of modern test equipment and testing methods by its series of kits and lab experiments. Build your equipment carefully. Learn to use it well. You will find it very valuable in your career as an electronic technician.

S. T. Christensen