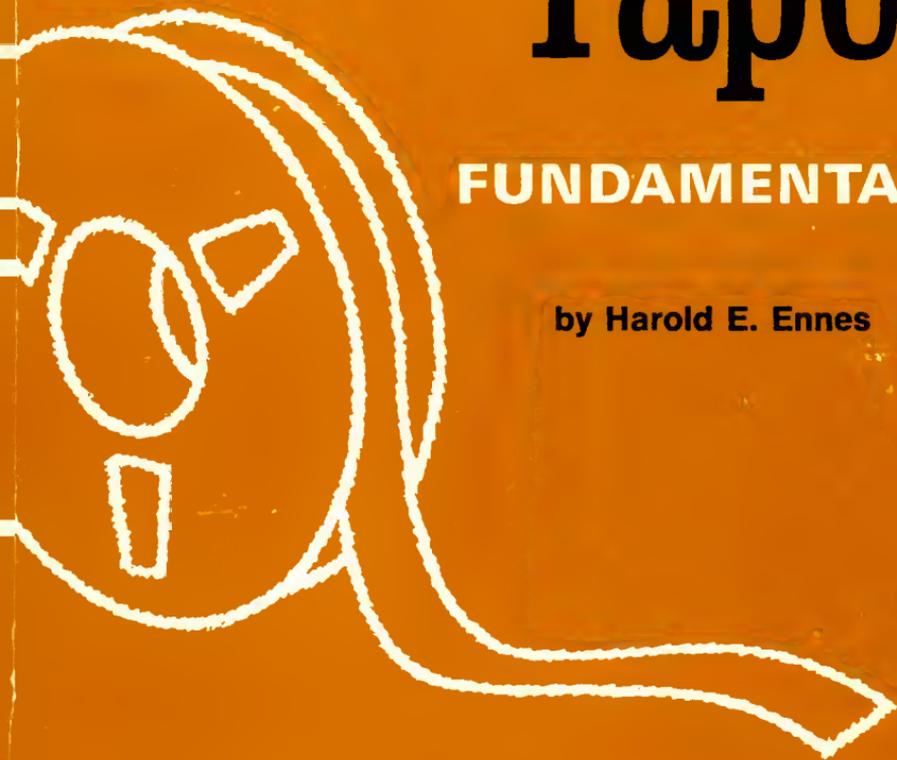


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# Television Tape

**FUNDAMENTALS**

by **Harold E. Ennes**





# TELEVISION TAPE FUNDAMENTALS

by  
Harold E. Ennes

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THE BOBBS-MERRILL COMPANY, INC.

Indianapolis • New York

FIRST EDITION

FIRST PRINTING — NOVEMBER, 1962  
SECOND PRINTING — NOVEMBER, 1966

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Library of Congress Catalog Card Number: 62-21970

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## PREFACE

Since the first television tape recorder was introduced in 1956, there has been a phenomenal growth in the application of video magnetic tape by telecasters and many independent production centers. It is difficult for the "old timer" to realize that many of his fellow workers do not remember the days before tape, when practically two-thirds of the nation watched TV programs at odd hours or from "hot kines" that carried little resemblance to modern programming. Video tape, from the very start, provided superior picture quality due to its clarity and life-like qualities, giving a presence that cannot be matched by film. In addition, this medium provided the telecaster, for the first time, with a spontaneous means of local spot commercial and program production well within the means of a modest budget.

In spite of, or because of, the rapid growth, information relative to basic recording systems of value to students and practicing engineers has been scanty. Having been privileged to attend training seminars at both Ampex and RCA, as well as having considerable practical experience with each system, I have humbly undertaken to fill this need. The primary purpose of this material is to provide fundamental knowledge, slanted for the practicing engineer who feels the need for a better understanding of his equipment, but also serving as an introduction to the subject for the beginner.

Specific circuitry will undoubtedly change in the immediate years ahead; this coverage is therefore general in nature, pointing up the primary functions of video-tape equipment. The scope of coverage is from basic theory to testing and maintenance of complete systems.

HAROLD E. ENNES



## ACKNOWLEDGMENTS

The complete cooperation of the two major suppliers of television-tape recorders in the United States—Ampex and RCA—has made this book possible. Liberal use has been made of material supplied in factory training programs of both manufacturers—in particular, descriptions of specific circuit functions in a given system which has been integrated into the text, as well as material gathered by the writer from various specialized departments.

*Credits to Ampex:* Much credit is hereby extended to Larry Weiland for making plant facilities available to the author, to Eldon Brown for his painstaking training seminar, to Tom Merson and Frank Gonzalez for their efficient scheduling of plant facilities tours, and to Joe Roizen for supplying much of the requested material and photographs.

*Credits to RCA:* Appreciation is expressed to John P. Taylor for supplying requested photographs and other material, to H. G. Wright for photos of the SMPTE tape response, to Norman Hobson and Roy Marian for their assistance in answering questions about problems which confronted the writer in actual practice, to Ed Hill for his most thorough scheduling of plant facilities inspection, and to John Wentworth for his inimitable training sessions.

The Author also extends his appreciation to the SMPTE and the *Journal of the SMPTE* for permission to reproduce the paper "Electronic Editing of Magnetic Television Tape Recording," by Norman F. Bounsall of Ampex, which appeared in the February, 1962, issue of the *Journal*, and the following proposed American Standards and Recommended Practices:

Proposed American Standard VTR 16.3 (then known as PH22.115) "Specifications for Monochrome Video Magnetic Tape Leader," from the May, 1961 issue of the *Journal of the SMPTE*.

Proposed American Standard VTR 16.5 (formerly PH22.121) "Characteristics of the Audio Records for 2-In. Video Magnetic Tape Recordings," from the February, 1960 issue of the *Journal of the SMPTE*.

Proposed SMPTE Recommended Practice RP 10 "Signal Specifications for a Monochrome Video Alignment Tape for 2-In. Video Magnetic Tape Recording," from the May, 1961 issue of the *Journal of the SMPTE*.



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SECTION 1

**BASIC  
CONCEPTS**

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## SECTION 1

# BASIC CONCEPTS

Television tape recording requires a magnetic-field manipulation which will adequately handle an 18-octave signal range at a satisfactory signal-to-noise ratio. This section states the basic problems and the approach to their solutions.

### 1-1. THE TIME-SPACE RELATIONSHIP

Although time-space relationship is important to all communication theory, television tape techniques are such as to exaggerate their interdependence. The familiar frequency-to-wavelength conversion, which is a fundamental time-space relationship, is given in Fig. 1-1.

For any given medium, time and space are one and the same. A *given medium* indicates a fixed velocity which is determined by the medium or system in question. On Waveform A of Fig. 1-1, point 1 of a passing wave is at reference point  $t_1$ . One second later (Waveform B), the passing wave has advanced to  $t_2$ , and point 2 is at the reference time. The unit distance between  $t_1$  and  $t_2$  is the wavelength, which also defines one cycle of the frequency.

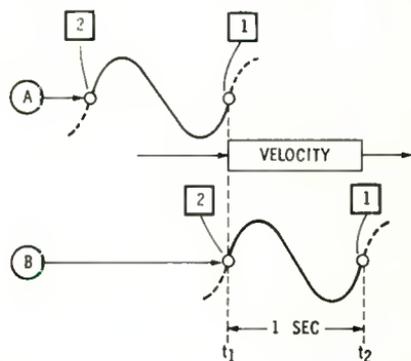


Fig. 1-1. Fundamental time-space relationship.

The velocity of sound waves, although influenced by temperature, humidity, and height above sea level, may be taken at approximately 1,088 feet per second. Since the wavelength is equal to the velocity divided by the frequency in cycles per second, a 1,000-cycle tone (in air) will have a wavelength of  $1,088 \div 1,000$ , or 1.08 feet. Doubling the frequency to 2,000 cycles results in a wavelength just one-half as long.

As the frequency is increased still further into the radio-frequency spectrum, the velocity of propagation in air also increases to practically the speed of light, or 186,000 miles (300,000,000 meters) per second. Thus, increasing the 1,000-cycle tone 1,000 times (1 megacycle) results in a wavelength of approximately 984 feet; the higher the velocity, the longer the wavelength for a given frequency.

The tape velocity of broadcast-type audio tape recorders is either 7.5 or 15 inches per second (ips). At 7.5 ips, the recorded wavelength of a 1,000-cycle tone is  $7.5/1,000$ , or 0.0075 inches (7.5 mils). (One mil is  $\frac{1}{1,000}$  inch.) At a tape speed of 15 ips, the recorded wavelength of a 1,000-cycle tone is  $\frac{15}{1,000}$ , or 0.015 inches (15 mils).

The magnetic head gap must have a certain minimum physical size to lay down adequate field strength on the tape. The relationship of head-gap size to frequency is illustrated in the drawing in Fig. 1-2.

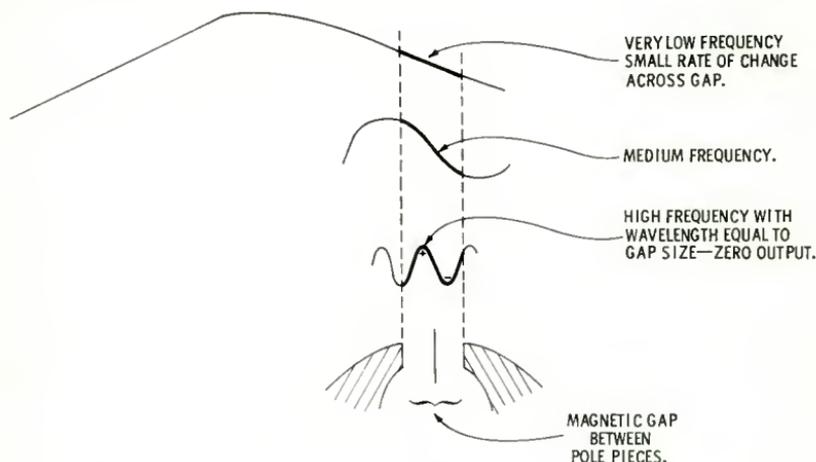


Fig. 1-2. Relationship between head-gap size and frequency.

As the frequency is increased and the tape speed held constant, the recorded wavelength approaches the physical size of the head gap. This results in north-south field cancellation of the signal and zero output. Therefore, the high-frequency limit of the system is fixed by head-gap size and tape speed.

The strength of the magnetic field is determined by the amplitude of the signal fed to the head and the rate of change of the magnetic field. For a given amplitude, as the frequency is increased (increased rate of change) the magnetic-field intensity is increased. As the frequency is doubled (increased by one octave) the voltage is doubled. This voltage increase, measured in decibels, is 6 db. Therefore a 6-db-per-octave rise occurs in magnetic recording with increasing frequency.

Conversely, as the frequency decreases from a given high-frequency limit, a 6-db-per-octave falloff in response occurs. At a certain low-frequency limit, the change rate of the magnetic recording is so low, compared to the gap size, that very little output exists. When the signal output falls to an objectionable signal-to-noise ratio, the lower frequency limitations of the system have been exceeded.

The frequency limitation of direct magnetic recording is about 10 octaves, or 30 to 15,000 cps in the audio range. If it is desired to increase the upper frequency limit to 30,000 cps, the lower frequency limit must also be doubled to maintain an adequate signal-to-noise ratio. The result is still a 10-octave range of 60 to 30,000 cps.

## 1-2. REQUIRED FREQUENCY RANGE FOR TELEVISION TAPE

The gamut of frequencies required in a video signal must extend into very-low-frequency regions for good picture shading, and comparatively high regions for satisfactory fine detail in the picture.

System requirements at the extreme low-frequency end (approaching zero frequency or DC) are aided by line-to-line clamps and DC restorers; however, the low-frequency AC response must also be very good. As a reference for this discussion, it will be arbitrarily stated that 10 cps is the low-frequency-AC-response requirement. Response in this region is directly related to the proper operation of clamps and DC restorers when these circuits are employed.

There are two resolution factors for a television picture, vertical resolution, which is independent of system bandwidth; and horizontal resolution, which is directly related to system bandwidth.

The vertical resolution determines how well the horizontal lines in a picture are resolved. The maximum vertical resolution is fixed by the number of active scanning lines. The United States standards call for a total of 525 lines. Vertical blanking time is approximately 7.5% of the total frame time, therefore:

$$525 \times 0.075 = 39.375$$

Thus, approximately 40 lines of the picture are blanked out. This leaves 485 active picture lines scanning from left to right and top to bottom of the image. This would appear to indicate that 485 vertically spaced horizontal lines would be resolved, but, in practice, this is not true. The slight spacing between the scanning lines, and the fact that the scanning spot straddles some of the lines, both tend to reduce the utilization of the maximum number of active lines. This reduction is usually considered as 0.7 times the total active lines. Thus,

$$485 \times 0.7 = 339.5$$

or, approximately 340 usable lines.

Fig. 1-3 shows the horizontal wedges of a test pattern. Here, the lines merge at a point which represents 340 black and white horizontal lines in the total image height. This is a typical value of vertical resolution at both studio and transmitter outputs; hence, the television-tape system should not limit it.

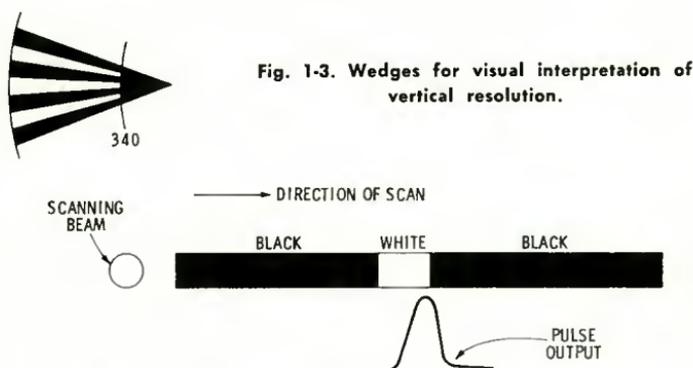


Fig. 1-4. Scanning beam encountering sharp vertical line.

Fig. 1-5. Wedges for visual interpretation of horizontal resolution.



Horizontal resolution is the ability to define vertical lines in the image. The essentially round shape of the scanning spot and the fact that it is not infinitely small places an immediate limitation on the ability to reproduce rapid picture transitions. Thus, when the beam suddenly encounters the sharp vertical line representing transition from black to white (Fig. 1-4), the resulting signal is not a square wave, but more nearly a sine wave.

Another factor contributing to the sine wave is the fact that a straight vertical line represents an infinite risetime and would require infinite bandwidth. Such a bandwidth, of course, is impossible in practice; the risetime of the signal, representing the instantaneous transition, is limited by the available bandwidth of the system.

Chart 1-1. Derivation of Rule of Thumb That 1 Megacycle = 80 TV Lines

1. The aspect ratio of the picture is 4 units wide to 3 units in height. This requires the horizontal resolution of a test chart to be related to the picture height.
2. This is to say, if black and white lines with the same thickness as those indicated at the 340 position on the horizontal wedge were placed adjacent to one another, a total of 340 could fit into the height of the chart. (Width of each line equals  $1/N \times$  picture height.) Or,  $340 \times 4/3$  or 452 of the same thickness lines could be placed in the width of the chart.
3. Lines of  $H$  resolution per cycle equals 2. One cycle consists of two alternations (positive and negative) therefore two picture elements—one white and one black.
4. Then the  $H$  resolution factor equals  $2/1.33$  (Note:  $4/3 = 1.33$ ).
5. Since  $2/1.33$  equals 1.5 the  $H$  resolution factor is 1.5, and this factor times the active line interval specifies the number of horizontal-lines resolving power per megacycle of bandwidth.
6. The total line interval is 63.5 microseconds. Horizontal blanking is usually 11 microseconds so that the active line interval is  $63.5 - 11$  or 52.5 microseconds.
7.  $52.5 \times 1.5 = 80$  TV lines/mc (approx).

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When the total risetimes (rise plus decay times) equal the spacing between lines, they are not visible as separate picture elements and are not resolved; rather, they appear as a solid area (Fig. 1-5).

Assuming that the scanning beam is properly focused, the limitation on horizontal resolution is the system bandwidth. The pulse risetime, representing an instantaneous transition in the picture, is directly related to the system bandwidth. As a "rule-of-thumb," 80 TV lines requires a 1-mc bandwidth. This is explained in Chart 1-1.

The gain-bandwidth product defines the relationship between a practical amount of gain for a necessary bandwidth:

$$\text{Upper-frequency limit } (f_u) = \text{Gain} \times \text{Bandwidth.}$$

This  $f_u$  is the limit for a gain of unity; for example, for a given circuit with gain reduced to unity at 35 mc:

$$\text{Gain} \times \text{Bandwidth} = 35 \text{ mc}$$

Then for an uncompensated amplifier, the bandwidth for a gain of 10 is:

$$\begin{aligned} \text{Bandwidth} &= \frac{35}{10} \\ &= 3.5 \end{aligned}$$

Video circuits normally employ series- and shunt-peaking coils for frequency compensation to achieve better gain over a given bandwidth.

The bandwidth-versus-risetime relationship is of equal importance. The product of bandwidth and risetime gives a factor,  $k$ , which depends on type and magnitude of high-frequency compensation. If leading-edge overshoot is limited to less than 3%, factor  $k$  can be given a value of 0.35.

Then the product of the bandwidth (BW) and the risetime (RT) is:

$$\begin{aligned} \text{BW} \times \text{RT} &= 0.35 \\ \text{BW} &= \frac{0.35}{\text{RT}} \\ \text{RT} &= \frac{0.35}{\text{BW}} \end{aligned}$$

Thus, the greater the bandwidth, the shorter is the risetime capable of being passed. For a bandwidth of 10 mc:

$$RT = \frac{0.35}{10}$$

$$= 0.035 \text{ microsecond}$$

Table 1-1 relates bandwidth to risetime and horizontal-resolving power in terms of TV lines.

The normal bandwidth of modern studio equipment is at least 8 mc. The picture transmitter, however, is limited to approximately 4 mc by Federal Communications Commission (FCC) channel assignments and engineering regulations. Therefore the horizontal resolution is restricted to about 320 lines in the home receiver. The complexity of the problem encountered in recording pictures on magnetic tape warranted a compromise in this particular studio gear. Modern television-tape recorders specify a bandwidth at least to 4 mc (320 lines horizontal resolution) with a signal-to-noise ratio of at least 35 db. This meets the minimum requirements of network-signal distribution as specified by the AT&T.

The video-signal frequency range for television tape extends from very low frequencies (actually DC) to a practical upper limit of 4 mc. If the range is considered to be 10 cps to 4 mc, a gamut of 18 octaves is required which, as discussed in Section 1-1, is not possible in direct magnetic-recording techniques.

### 1-3. SOLVING THE LOW-FREQUENCY PROBLEM

The DC component in a standard video signal is *inserted* by means of line-to-line clampers. Essentially, the clamper charges or discharges a coupling capacitor to a DC reference which usu-

Table 1-1. Relationship Between Bandwidth, Risetime, and Horizontal-Resolving Power

Bandwidth (mc)	Rise Time ( $\mu$ s)	TV Lines
1	0.35	80
2	0.175	160
3	0.1166	240
4	0.0875	320
5	0.07	400
6	0.058	480
7	0.05	560
8	0.0437	640
9	0.039	720
10	0.035	800

ally represents the signal-blanking level. This reference level assures that each active line scan starts from the same reference immediately following horizontal blanking.

The extreme low-frequency requirements are met by employing an RF carrier which is frequency-modulated by the video signal. (FM was chosen over AM to allow amplitude limiting to be employed for attenuation of extraneous noise.) The carrier frequency represents the DC component, either sync tip or blanking, depending on the system clamp reference. Fig. 1-6 shows the modulation characteristic with a carrier frequency of 5 mc clamped to the signal-blanking level.

With the carrier frequency clamped at the video-blanking level, it is standard monochrome practice to adjust picture-signal gain so that peak white deviates 1.8 mc upward in frequency—the peak-white signal occurs at 6.8 mc in Fig. 1-6. With a standard-video input, 0.3-volt sync to 0.7-volt video, sync tips deviate the carrier 0.7 mc lower in frequency to 4.3 mc. The total deviation of 2.5 mc is used currently as the 100% modulation reference for monochrome signals.

Sidebands occur at the carrier frequency plus and minus the instantaneous video frequency. The maximum video frequency in

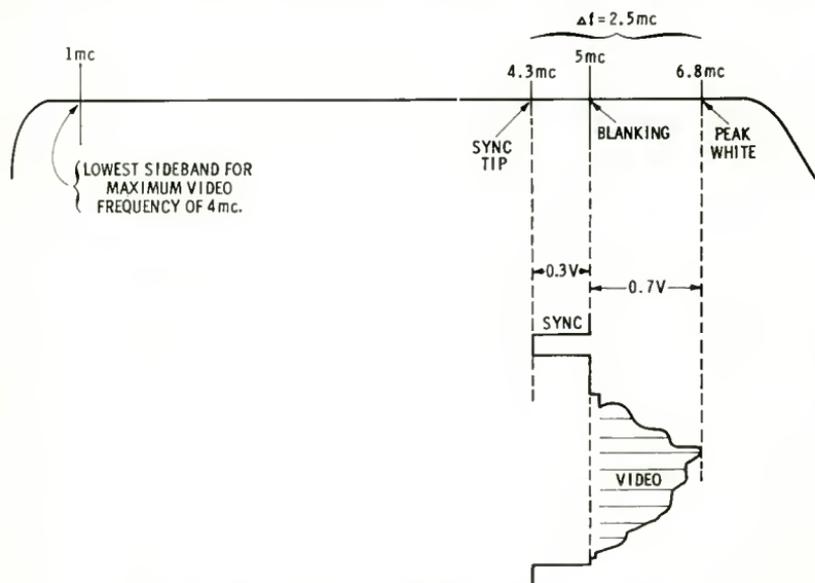


Fig. 1-6. Modulation envelope for television tape.

the system-pass band determines the sideband limits. For a 4-mc bandwidth, the lowest sideband occurs at 5 - 4, or 1 mc.

The upper sideband extends just far enough to provide a *shelf* for the upper frequency deviation. Sidebands beyond this limit are not used. The conventional assumption that the carrier frequency must be at least 10 times the highest modulating frequency is discarded in television-tape applications.

When the modulation index is less than 0.5 (frequency deviation less than one-half the modulation frequency), sideband energies above a single pair are practically nonexistent and approach AM characteristics in this respect.<sup>1</sup>

The only practical result of these compromises is a slight zig-zagging of vertical lines apparent at a resolution of 300 lines and above.

The total frequency range now becomes 1 mc to approximately 7 mc; thus, the modulation process has reduced the original 18-octave video range to less than 4 octaves. A practical solution to magnetically record the video signal has been found if the problem of handling a 7-mc high-frequency signal can be met.

#### 1-4. SOLVING THE HIGH-FREQUENCY PROBLEM

A good audio tape recorder may have a head gap size as small as 0.25 mil (0.00025 inches). Then, for the upper audio range of 15,000 cps and a tape speed of 7.5 ips, the recorded wavelength is equal to:

$$\begin{aligned}\text{Recorded wavelength} &= \frac{7.5}{15,000} \\ &= 0.0005 \text{ inch} \\ &= 0.5 \text{ mil}\end{aligned}$$

The recorded wavelength is twice as long as the gap width. This wavelength/gap-size relationship is the lowest practical limit which can be adequately pre-emphasized for good reproduction and signal-to-noise ratio. (Losses in the magnetic core structure cause the signal to begin to decrease before this point and pre-emphasis is required.)

The smallest practical magnetic gap is approximately 100 micro-inches, or 0.1 mil. Therefore, the minimum wavelength that will

<sup>1</sup> Reference: Charles E. Anderson: "Signal Translation Through the Ampex Videotape Recorder," *Journal of the SMPTE*, Nov. 1958.

represent 7 mc must be twice as long as 100 microinches, or 200 microinches.

The required tape velocity can be calculated, if the gap size and the minimum-required recorded wavelength at the upper-frequency limit are known. Since:

$$\text{Wavelength} = \frac{\text{Velocity}}{\text{Frequency}}$$

then,

$$\begin{aligned}\text{Velocity} &= \text{Wavelength} \times \text{Frequency} \\ &= 0.0002 \times 7,000,000 \\ &= 1,400 \text{ inches per second.}\end{aligned}$$

If the tape was actually pulled across the head at a speed of 1,400 ips, it would require 420,000 feet of tape on a reel over 80 feet in diameter to record one hour of material; try to visualize the required tape transport mechanism—obviously, this is an impractical solution.

The problem is solved by pulling the tape at a practical speed of 15 ips past a rotating video head. Insofar as the video signal is concerned, the resultant velocity is a more accurately termed head-to-tape velocity. The rotating-head principle, illustrated in Fig. 1-7, gives an effective head-to-tape velocity of slightly over 1,500 ips, with a head-gap size just under 0.1 mil. The FM video signal is fed to the individual heads on the rotating drum and brush assembly. Video tracks approximately 10-mils wide are laid down transversely (across) the 2-inch wide magnetic tape. Audio is recorded longitudinally along the top of the tape at the conventional 15-ips rate. A 240-cps control signal, which indicates the precise position of the rotating-head drum relative to the recorded-video information, is recorded longitudinally along the bottom of the tape. (NOTE: Details of connections between the heads and the commutator are given in Section 4-3.)

## 1-5. TRANSISTOR BASICS FOR VIDEO AND PULSE CIRCUITRY

Transistors are assuming a rapidly increasing role in video and pulse applications. This is particularly true of television-tape recorders. The treatment in this section is intended only as an introduction to the principles involved in this highly important field. It is intended as an aid for technicians who have not yet been ex-

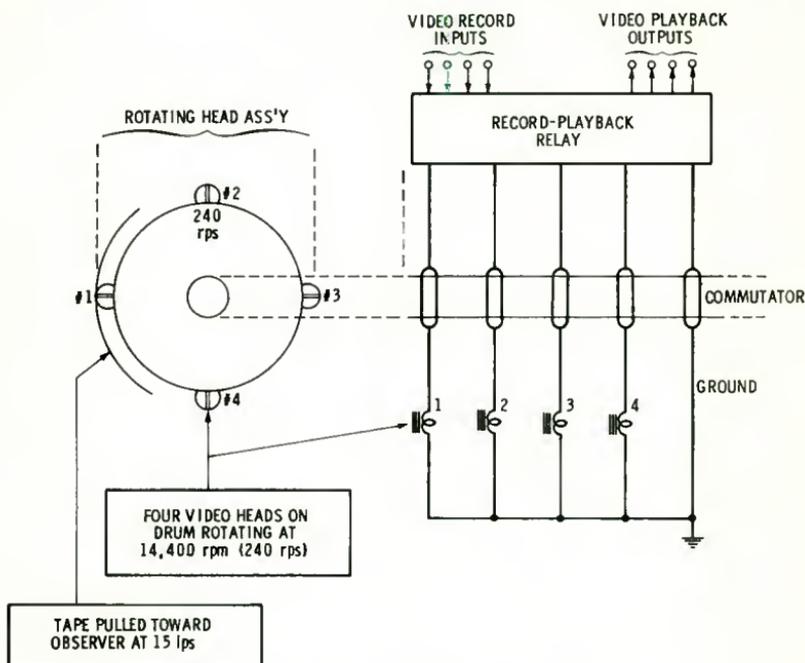


Fig. 1-7. Parallel feed of rotating heads.

posed to transistors through education or experience, and as a review to those who have.

### Transistor Bias—Current Division

1. Current flow in an N-type material is largely by electron flow, and current flow in a P-type material is largely by *hole* flow (migration of holes, or positively charged regions); therefore, the resistance at the transistor terminals can be influenced by external bias conditions.
2. Transistor type is given in terms of following sequence: Emitter, Base, Collector. For example, the PNP-junction transistor has a P-type emitter, N-type base, and P-type collector.
3. The principle of a PNP-type transistor in a grounded-base circuit, showing bias arrangement and resultant current division, is illustrated by Fig. 1-8. In this example, the input (emitter) draws 10 ma, and the resulting current division is 0.5 ma (5%)

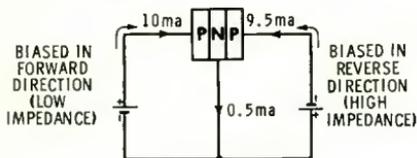


Fig. 1-8. Current division in a typical transistor circuit.

in the base circuit and 9.5 ma (95%) in the collector circuit. This is a typical division.

### Impedance

1. An equivalent circuit to illustrate resistance parameters of the circuit in Fig. 1-8 is given in Fig. 1-9. The various abbreviations are:

$r_e$  is the emitter resistance,

$r_b$  is the base resistance,

$r_c$  is the collector resistance,

$R_L$  is the collector-load resistance,

$R_{in}$  is the input resistance of any cascaded transistor.

$$R_{in} = r_e + r_b (1 - \alpha)$$

where,

$\alpha$  is the Alpha of the transistor (defined later).

2. Due to the biasing arrangement of Fig. 1-8, the input (emitter) resistance is low and the output (collector) resistance is high. Since the transistor is a current device, almost the same current flows in the collector circuit (depending on the Alpha, discussed later) as flows in the emitter. Since the impedance of the collector is relatively high compared to that of the emitter, a voltage gain occurs from the ratio of the impedances.
3. Typical values of effective resistance (considering a single stage) are as follows:
  - A.  $r_e$  50 ohms.
  - B.  $r_b$  300 ohms.
  - C.  $r_c$  Very high (example: 1 megohm). A cascaded stage

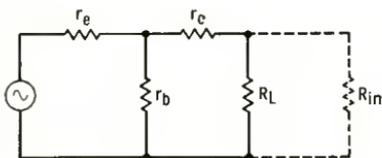


Fig. 1-9. Equivalent circuit of Fig. 1-8.

across  $R_L$  lowers effective load resistance, and effective  $r_e$  can be lowered by relative DC bias levels.

### The Three Basic Transistor Circuits

The circuits illustrated in Fig. 1-10 are for PNP-type transistors. For NPN-type transistors, the arrow direction of the emitter and all bias polarities are reversed.

1. The common-emitter circuit (Fig. 1-10A) is analogous to the grounded-cathode vacuum-tube circuit in that there is a phase reversal of the signal and a moderate output impedance. However, unlike the grounded-cathode vacuum-tube circuit, it has a low-input resistance, which equals:

$$\text{Input resistance} = r_b + (r_e \times \beta)$$

where,

$r_b$  is the base resistance,

$r_e$  is the emitter resistance,

$\beta$  is the Beta of the transistor (explained later in this section).

2. The common-base circuit (Fig. 1-10B) is analogous to the grounded-grid vacuum-tube circuit. There is no phase reversal of the signal; the input resistance is low and the output impedance is moderate to high.
3. The common collector circuit (Fig. 1-10C) is analogous to the cathode-follower vacuum-tube circuit. There is no phase re-

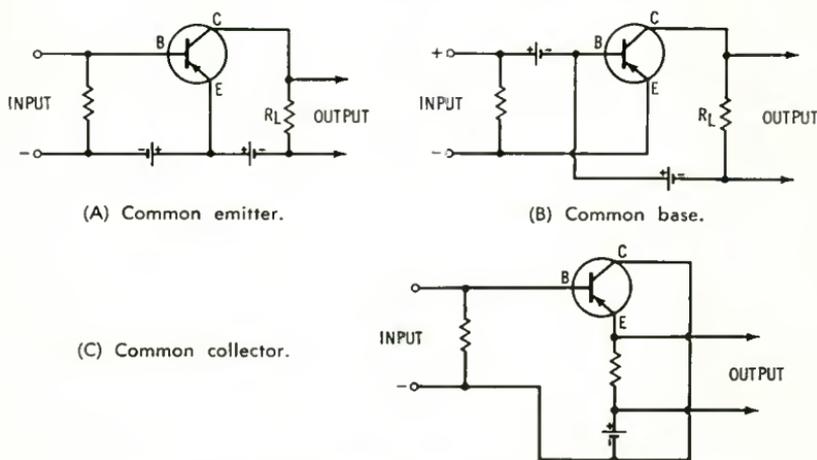


Fig. 1-10. The basic transistor circuits.

versal of the signal. It features a high input impedance, and moderate to low output impedance. However, the actual input impedance is highly dependent upon the load impedance:

$$\text{input resistance} = r_b + r_c \parallel r_e + (R_L + \beta)$$

where,

$r_b$  is the base resistance,

$r_c \parallel r_e$  is the collector resistance in parallel with the emitter resistance,

$R_L$  is the load impedance,

$\beta$  is the Beta of the transistor.

The output resistance is calculated as:

$$\text{Output Resistance} = \frac{r_e + (1 - \alpha)(r_c + r_b)}{1 + \frac{r_e}{r_c + r_b}}$$

where,

$\alpha$  is the Alpha of the transistor.

The current gain is equal to:

$$I_{\text{gain}} = \frac{1}{1 - \alpha} \cong \beta$$

### Alpha ( $\alpha$ )

1. *Definition of Alpha:* The ratio of change in collector current for a specific change in emitter current at constant collector potential.
2. The Alpha of a junction transistor is always less than 1.

### Beta ( $\beta$ )

1. *Definition of Beta:*

$$\beta = \frac{\alpha}{1 - \alpha}$$

2. The above parameter is (approximately) the short-circuit current amplification of the grounded-emitter transistor amplifier.

### Output Current

1. For the grounded-emitter circuit (Fig. 1-10A), the output current (collector current) is Beta times the input (base) current. Stated as follows:

$$i_o = i_b \beta$$

2. For the grounded-base circuit (Fig. 1-10B), the output current (collector current) is Alpha times the input (emitter) current. Stated as follows:

$$i_o = i_e \alpha$$

3. For the grounded-collector circuit (Fig. 1-10C), the output current (emitter current) is Beta times the input (base current). Stated as follows:

$$i_o = i_b \beta$$

### Cutoff Current (Leakage Current)

1. *Definition of Cutoff Current:* The collector current drawn under conditions of zero base current with DC applied between emitter and collector.
2. *Typical Values:*

5 to 25 microamperes.

### Cutoff Frequency

1. *Definition of Cutoff Frequency:* Generally taken as frequency where value of Alpha is 3 db down from a specified low-frequency value (such as 1,000 cps). Influenced by transit time, and capacity from P to N, N to P, and P to P.
2. The cutoff frequency sets the high frequency limitations of the transistor as an amplifier. **CAUTION:** A transistor with a rated Alpha cutoff at 4 mc does not indicate that amplification is good to 4 mc. For example, for an Alpha of 0.95: '

$$\begin{aligned} \beta &= \frac{1}{1 - \alpha} \\ &= \frac{1}{1 - 0.95} \\ &= 20 \text{ at low frequency.} \end{aligned}$$

However, at the 3-db point (0.707):

$$\begin{aligned} \beta &= \frac{1}{1 - 0.707} \\ &= 3.4 \end{aligned}$$

3. The gain-bandwidth product is approximately equal to Alpha cutoff *with double peaking*. The *gain bandwidth* product (GB) is approximately equal to one-half Alpha cutoff with no peaking. Stated as follows:

With Double-Peaking:  $GB \cong f_a$  cutoff.

Without Peaking:  $GB \cong \frac{1}{2} f_a$  cutoff.

### Transistor-Circuit Gain

- Gain may be specified in terms of current, voltage, power, or db equivalents.
- An example of a practical application to a typical circuit: If an increase in  $i_e$  (emitter current) of 1 ma causes an increase in  $i_c$  (collector current) of 0.95 ma, then:

$$\begin{aligned}\alpha &= \frac{i_c}{i_e} \\ &= \frac{0.95}{1} \\ &= 0.95 \text{ current gain.}\end{aligned}$$

Voltage gain (VG) comes from ratio of output to input resistance, or:

$$\begin{aligned}VG &= \frac{e_o}{e_i} \\ &= \frac{i_c r_o}{i_e r_i} \\ &= (\alpha) \frac{r_o}{r_i}\end{aligned}$$

If, in our example,  $r_o$  is 10,000 ohms and  $r_i$  is 200 ohms, then:

$$\begin{aligned}VG &= (\alpha) \frac{r_o}{r_i} \\ &= (0.95) \frac{(10,000)}{200} \\ &= (0.95) (50) \\ &= 47.5\end{aligned}$$

The power gain (PG) is the square of the current gain times the impedance ratio. Thus:

$$\begin{aligned}
 PG &= \alpha^2 \frac{r_o}{r_i} \\
 &= (0.95)^2 (50) \\
 &= 45.6
 \end{aligned}$$

### Leakage Current and Temperature Stabilization

- As contact temperature increases, collector resistance decreases and cutoff current (or leakage current) increases. This produces further heating with accumulative effects.
- If input is open, leakage current is amplified by a factor equal to Beta. With a typical normal leakage current of 10 microamperes and a Beta of 20, the resulting current is  $20 \times 10$  or 200 microamperes.

In some transistors, leakage current doubles for every  $10^\circ \text{C}$  rise above  $50^\circ \text{C}$ .

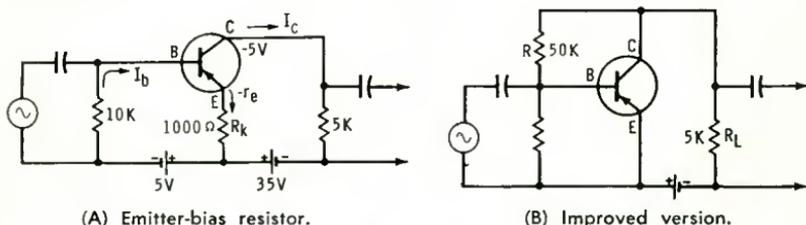


Fig. 1-11. Bias of transistor circuit.

- The effect described under (1) above is common to all junction transistors. The effect of temperature on Alpha and base and emitter impedances varies with the type of junction transistor. (This refers to method of construction, such as diffused junction, rate junction, or rate-grown junction—as opposed to general types such as PNP or NPN). In certain high-Alpha transistors (such as the grown junction), at approximately  $70^\circ \text{C}$  Alpha will exceed unity. This causes instability.
- Temperature stabilization is accomplished by controlling the leakage base, down to zero collector current.
  - Emitter-bias resistor  $R_k$  is added in the circuit of Fig. 1-11A. Now an increase in leakage current is compensated for by an increase in bias.
  - An improved and simpler circuit is given in Fig. 1-11B. Here,  $R$  is added between the collector and the base, eliminating  $R_k$  and the extra base-battery of Fig. 1-11A. The

value of  $R$  is selected for proper base voltage in the circuit under consideration. It provides automatic temperature stabilization by inverse feedback. The usual signal-gain reduction resulting from negative feedback is practically nullified by the low-input impedance of the following transistor stage, while the DC feedback maintains control of leakage current.

5. The *stability factor* ( $S$ ) for a grounded-emitter circuit is as follows:

$$S = \frac{R_e + R_b}{R_b(1 - \alpha) + R_e}$$

or

$$S = \frac{\beta}{1 + \frac{R_L}{R}(1 + \beta)}$$

The incremental load current ( $i_L$ ) due to an incremental cut-off current ( $i_{co}$ ) will then be:

$$i_L = S i_{co}$$

### Square-Wave Generator

1. Because the transistor saturates quite rapidly, the unit can be used as a highly efficient converter of sine waves to square waves.
2. Sine-wave-to-square-wave conversion is illustrated in Fig. 1-12. During the positive alternation of the AC, the base goes positive and no current can flow. As soon as the base goes to  $-0.1$  volt, the collector saturation current of 5 milliamperes is reached and the full battery voltage is dropped across the output resistor.

### Pulse-Narrowing Circuit

The RCA video-processing amplifier uses a generator which narrows the input pulse to produce horizontal sync, drive, and blanking as well as a so-called 9-H pulse.

The circuit is analogous to the familiar tube circuit, termed the *boxcar* (Fig. 1-13A). The grid return is to the plate supply through  $R_1$ ; with no signal at coupling capacitor  $C$ , the grid is reduced to about zero potential by the grid current. Saturated-plate current through  $R_2$  reduces the potential at the plate to a low value (e.g. 30 V).

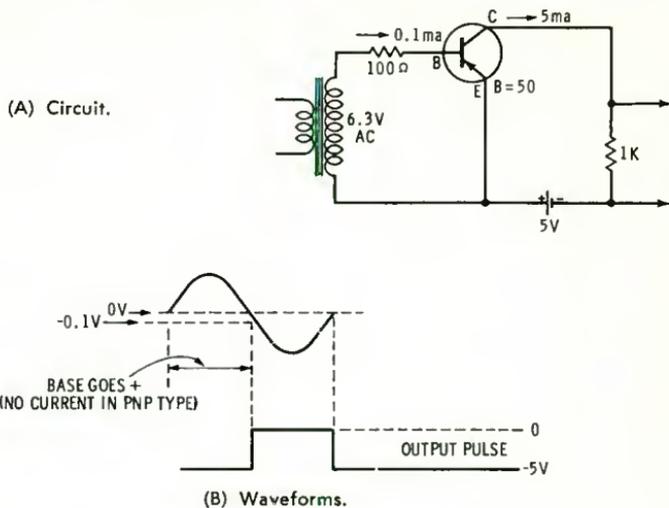


Fig. 1-12. A simple square-wave generator.

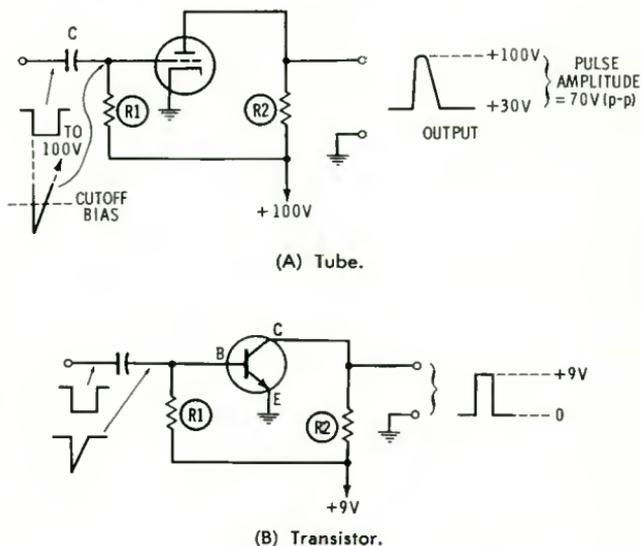


Fig. 1-13. Pulse-narrowing circuits.

The negative pulse applied at capacitor C drives the tube to cutoff. The current through R1 then flows into C, recharging it to the original no-signal potential. The grid waveform is an RC

exponential curve, charging toward +100 V. When the charge exceeds zero volts, the positive grid again draws current, halting the waveform at zero.

The opposite-polarity plate pulse is narrower than the input pulse by an amount dependent on the values of the resistance and capacitance in the input circuit.

Transistor-circuit action (Fig. 1-13B) is similar to that for a tube, but improved. The output-pulse amplitude is equal to the full power-supply voltage because of the sharp-saturating characteristic of the transistor; in addition, the trailing edge of the pulse is sharper. A PNP-type transistor could be used with opposite DC voltage and input- and output-pulse polarities.

### Monostable Multivibrators

Some transistor monostable-multivibrators cannot be duplicated using vacuum tubes. For example, a vacuum-tube monostable multivibrator operates (assuming a relaxed state) tube 1 on and tube 2 off. The trigger then drives tube 1 off and tube 2 on. They remain in this state during the RC timing-cycle; then they return to the relaxed state with tube 1 on and tube 2 off, until the next trigger comes along.

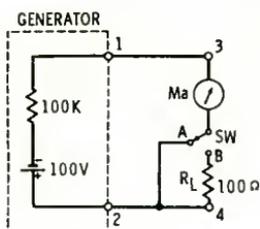
Using NPN and PNP transistors (complementary symmetry), it is possible to have transistor No. 1 and transistor No. 2 both off in the relaxed state, or both on in the relaxed state. The trigger then drives both transistors to the on state, or off state, whichever the case may be.

The second type, that is, with both transistors on in the relaxed state, is the type used for the counting multivibrators in the vertical-advance and horizontal-AFC modules of the RCA processing amplifier.

Operation of the transistor multivibrator is described briefly with reference to the  $\div 7$  stage (X1, X2) shown in Fig. 1-14. Resistors R1 and R2 let enough current flow from the DC supply into the base of X1 to turn it on. This causes the voltage at the junction of R3 and R4 to rise toward (positive) ground. Since the emitter of X2 is at -9 volts, its base, which is at the junction of R3 and R4, becomes more positive than the emitter (but never at ground), forcing X2 to conduct and causing a -9-volt potential to appear at the X2 collector.

A trigger applied through C1 to the base of X1, turns X1 off. Since in this condition there is no current flow through R3 and R4, the base of X2 drops to -22 volts, turning it off. Therefore the





(A) Circuit.

CONDITION	TERMINALS 3-4 VOLTS	TOTAL CURRENT
SWITCH AT A (SHORT CIRCUIT)	0	1 Ma
SWITCH AT B (LOAD CONNECTED)	100	1 Ma (PRACTICALLY)

(B) Conditions.

Fig. 1-16. A constant-current source.

(Transistor circuits can be designed in special applications for high-impedance inputs). In Fig. 1-16, the generator impedance is much higher than the load impedance. With the switch in the short-circuit position (A), the voltage across terminals 3 and 4 is zero, and the current is 1 ma. With the switch at position B, the voltage at terminals 3 and 4 is 100 volts, while the current is still (practically) 1 ma. Thus, the *current* is constant between a short-circuit and a load condition. When the amplifier-input impedance is much lower than the source impedance, it is most convenient to consider the amplifier a current amplifier instead of as a voltage amplifier.

Please observe that these constant sources are (in practice) only approximate, and depend on the ratio of their internal impedance to the load impedance.

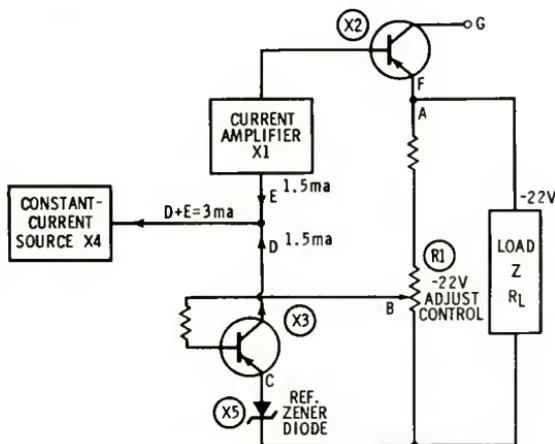


Fig. 1-17. A transistor-regulated power supply.

### Voltage-Regulator Circuit

A transistor-regulated power supply is shown in Fig. 1-17. The current source (X4) provides for a constant (total) current flow of approximately 3 ma from two branches of the circuit (*D* and *E*) in the direction shown by the arrows. Thus, characteristically, an increase in current flow in one branch results in a proportionate decrease in current flow in the other branch, and vice versa. The amount of current flowing in the two branches depends on the relationship between the reference voltage provided by zener diode X5 and the voltage at the arm of the  $-22\text{V}$  adjust potentiometer (R1).

Operation is as follows: Assume that the voltage appearing at point *A* (Fig. 1-17) increases as the result of either a decrease in the load ( $R_L$ ) or an increase in the unregulated voltage at *G*. Since R1 is across the load, a voltage increase will also occur at point *B*. This will produce increases in current flow in both *C* and *D* and a decrease in current flow in *E*. The reduced current flow in *E* will in turn result in a decrease in current flow in *F*, which will reduce the output voltage at *A* as required. Conversely, if the voltage at *A* is reduced by a change in load or by variations in the unregulated supply voltage, the reference voltage at *B* will decrease. This lowers the current in *C* and *D*, which will produce an increase in the currents in *E* and *F* and an increase in voltage output at *A*.



SECTION 2

ROTATING HEAD  
ASSEMBLY

C

C

C



## SECTION 2

# ROTATING-HEAD ASSEMBLY

The circular mounting which contains the four video heads is termed the *headwheel* by RCA, and the *drum* by Ampex. Ampex employs a horizontal tape-transport, and RCA uses a vertical tape-transport.

### 2-1. ORIENTATION OF RECORDED SIGNALS

A rotating head contacts the tape for an arc of approximately  $120^\circ$ . Since the tape is pulled past the head at a velocity of 15 ips and the head rotates at 240 rps, it takes  $\frac{1}{240}$  second for  $360^\circ$  and one third of this time ( $\frac{1}{720}$  second) to traverse the 2-inch tape ( $120^\circ$ ).

Inasmuch as the tape travels 15 inches in 1 second, it will go  $\frac{15}{720}$ , or 0.02, inches (20 mils) while the head describes its arc across the tape. Therefore the bottom of each video track is ended 20 mils later than the start, resulting in an angle of  $0.54^\circ$  (Fig. 2-1).

The orientation of recorded information on the RCA vertical tape-transport is shown in Fig. 2-2A. The video heads contact the entire 2-inch surface of the tape; however, a 70-mil-wide track

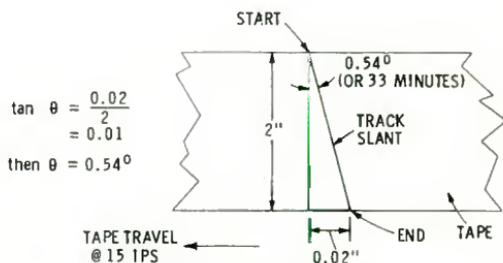


Fig. 2-1. Track slant on tape.

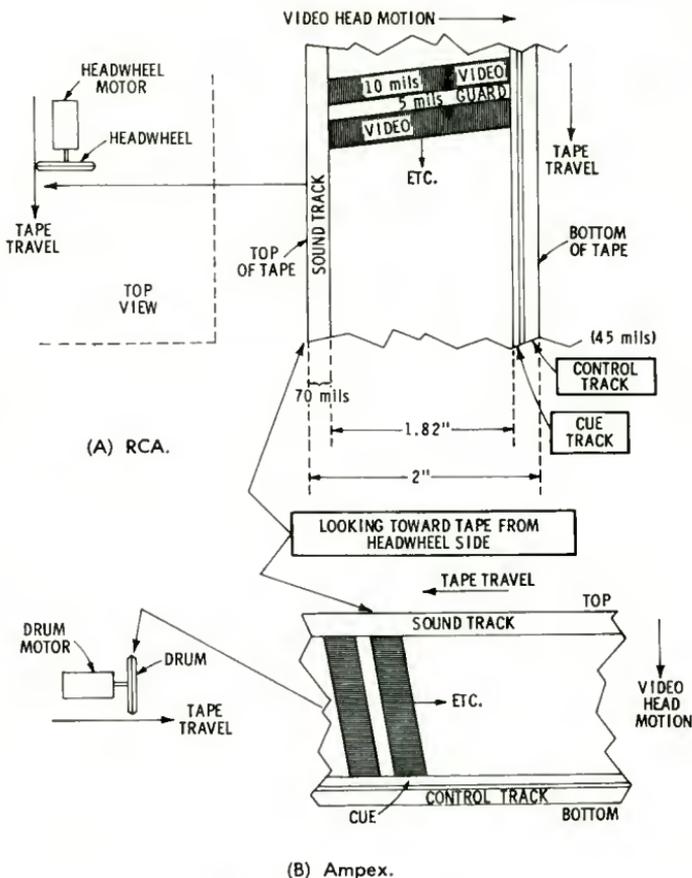


Fig. 2-2. Track orientation.

across the top is erased for audio information, which is recorded by a conventional audio head longitudinally to tape travel. The video tracks along the bottom of the tape, containing the control and cue track, are not actually erased; however, only that portion, which is used as video information, is shown in Fig. 2-2A.

Tapes recorded on either system (RCA or Ampex) are entirely compatible and may be played back on either system. The track orientation on the tape is that which is viewed looking toward the coated side from the rotating heads. The track dimensions on the Ampex version shown in Fig. 2-2B are exactly the same as for the RCA in Fig. 2-2A.

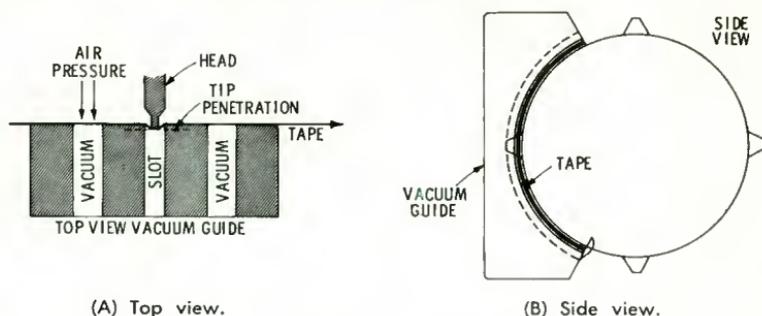


Fig. 2-3. Cross-sectional view of vacuum guide.

The method of holding the tape concentric to the rotating heads is shown in Fig. 2-3A. The vacuum guide holds the tape in place, and the center slot provides clearance for tape *stretch* under head penetration. Fig. 2-3B is the side view of the vacuum guide and the rotating head.

## 2-2. HEAD-TO-TAPE VELOCITY

The wheel which contains the four video heads has a reference diameter of 2.064 inches. The tip projection of a new head is about 3.7 mil and for a worn head it is about 1.0 mil (Fig. 2-4).

The maximum recording diameter (tip projection of 3.7 mils) is:

$$\begin{array}{r}
 A + B + C = 0.0037 \\
 \quad 2.0640 \\
 \quad 0.0037 \\
 \hline
 2.0714 \text{ inches}
 \end{array}$$

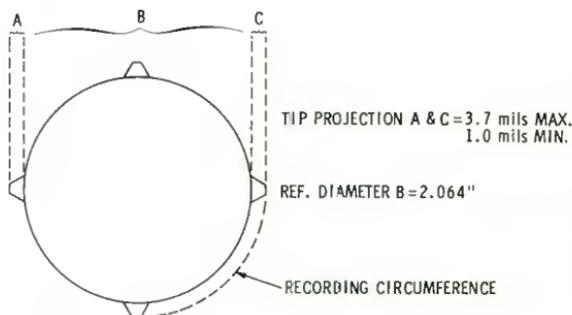


Fig. 2-4. Headwheel reference diameter and tip projection.

The recording circumference is:

$$\begin{aligned}\text{Circumference} &= \pi D \\ &= 3.14 \times 2.0714 \\ &= 6.504 \text{ inches}\end{aligned}$$

Since the head revolves at 240 rps, the head-to-tape velocity at the maximum tip projection is:

$$\begin{aligned}\text{Head-to-tape velocity} &= 6.504 \times 240 \\ &= 1,561 \text{ ips}\end{aligned}$$

The recording diameter at the minimum tip projection of 1.0 mil is:

$$\begin{array}{r} A + B + C = 0.001 \\ \quad \quad \quad 2.064 \\ \quad \quad \quad \underline{0.001} \\ \quad \quad \quad 2.066 \text{ inches} \end{array}$$

The recording circumference is:

$$\begin{aligned}\text{Circumference} &= \pi D \\ &= 3.14 \times 2.066 \\ &= 6.487 \text{ inches}\end{aligned}$$

The head-to-tape velocity is:

$$6.487 \times 240 = 1557 \text{ ips}$$

at minimum tip projection of 1.0 mil.

HEAD-TO-TAPE VELOCITY AT 3.7-mil TIP PROJECTION = 1,561 ips.

HEAD-TO-TAPE VELOCITY AT 1.0-mil TIP PROJECTION = 1,557 ips.

The foregoing relationship of tip velocities has a direct bearing on proper timing to avoid space errors in television-tape playback.

The *angular velocity* remains the same regardless of tip projection. The spacing of the horizontal-sync pulses across the entire video track must also remain the same to avoid time-space errors in the reproduced picture. This is to say that the space occupied by a TV line must be the same at the middle and end of the video track as it is at the beginning of the track.

Fig. 2-5A shows the tape without the head engaged. As the vacuum guide is moved toward the head, the pole pieces contact the tape and a stretch occurs as shown in Fig. 2-5B. The greater

the tip penetration, the greater is the stretch and the wider is the space between sync pulses. The effective spacing in time between pulses is determined by the tip velocity. A recording made with a 3-mil tip penetration can be played back with a worn head having a tip penetration of only 1 mil. This is because the reduced tip velocity of the worn head means it takes a longer time to scan a given length of the video track; therefore *less tape stretch* is required to maintain the correct space-in-time relationship between pulses.

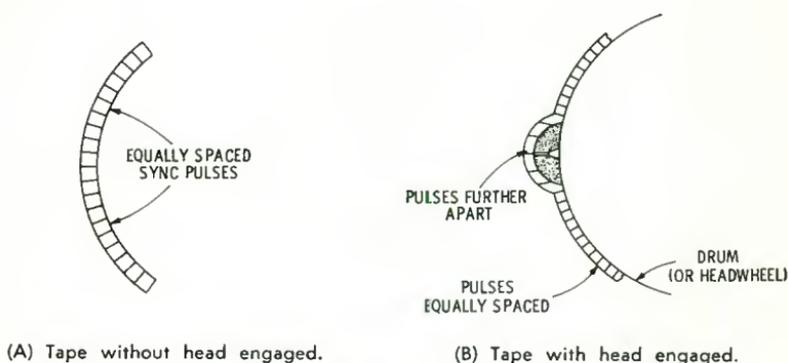


Fig. 2-5. Pole tip stretch of tape.

From this analysis, it is evident that reduced velocity, due to worn tips, is complementary to the resulting reduction in tape stretch. Therefore, assuming that the video-tape stock neither shrinks nor stretches during its life, the vacuum-guide position relative to the headwheel remains the same as tip projection decreases with head wear.

### 2-3. TIP PENETRATION

The position of the vacuum guide which cups the tape around the rotating heads determines the amount of pole-tip penetration into the tape. When the guide is sufficiently far away from the pole tips, a positive clearance between tape and heads occurs and no contact exists. Under this condition, no recording would be laid down on the tape, and no playback of recorded information can occur (Fig. 2-6A).

RF output from recorded information begins to occur as the vacuum guide is brought closer to the head. A negative clearance

now occurs between the pole tips and the tape in the slotted guide. The amount of this negative clearance is the tip penetration. When this penetration is extremely light, concentricity between the tape and head does not exist. Under this condition, tip penetration is less at the center of the tape than at either end, resulting in a dip (Fig. 2-6B) in the RF envelope of the head output. As tip penetration is further increased, intimate contact is gained with full concentricity, and an even RF output (Fig. 2-6C) is obtained from the head.

An adequate magnetic contact must prevail at the low values of tip penetration which exists near the end of head life. Therefore since the guide position relative to the head is a constant value (Section 2-2), new heads with high tip projection will exhibit relatively high values of tip penetration.

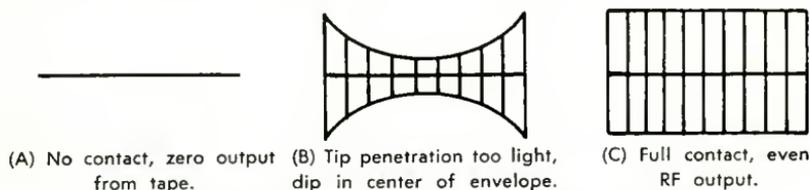


Fig. 2-6. Relationship of RF output and pole-tip contact with tape.

High values of tip penetration increase both head and tape wear as well as the load on the head-motor drive amplifiers. If excessive loading occurs, head servo instability can occur. This is particularly true when marginal tubes are in service.

A tip penetration of less than 1 mil aggravates dropouts and possible head clogging. *Dropouts* are white flashes in the reproduced picture, which are caused by microscopic irregularities in the magnetic coating of the tape. Head clogging results when iron-oxide particles, loosened from the tape coating become lodged in the head gap.

*Standard* tip penetration must be a compromise among all the conflicting elements. It is now prevailing practice to use from 2.5- to 3-mil tip penetration for a new head. Methods of setting tip penetration are outlined in Section 6.

## 2-4. TIMING

The headwheel (or drum) rotates at 240 rps, or 4 times the TV-field frequency of 60 cps. Thus, one revolution ( $360^\circ$ ) of the wheel

lays down four tracks (four heads spaced  $90^\circ$  and fed simultaneously) which are equal to one-fourth of a field:

$$1 \text{ field} = 262.5 \text{ lines}$$

$$\frac{1}{4} \text{ field} = 65.625 \text{ lines in 4 tracks on the tape.}$$

Then each track contains one-fourth of 65.625, or 16.4 lines.

NOTE: A TV line is designated as  $H$ , where  $H$  is the interval from the leading edge of one horizontal-sync pulse to the leading edge of the next horizontal-sync pulse. (Standard equals 63.5 microseconds.) Therefore a recorded track equals 16.4  $H$ .

The preceding is the average value of picture lines used in reproducing the signal; actually, each track contains more than this number of lines:

$$\begin{aligned} 360^\circ &= \frac{1}{240} \text{ second} \\ &= 4,166.6 \text{ microseconds} \\ 90^\circ &= \frac{4,166.6}{4} \\ &= 1,041.6 \text{ microseconds} \\ &= 16.4 H \end{aligned}$$

Then,

$$\begin{aligned} 1H \text{ (in degrees)} &= \frac{90}{16.4} \\ &= 5.48^\circ \\ \text{lines per degree} &= \frac{1}{5.48} \\ &= 0.182 \end{aligned}$$

The guard bands and control, cue, and audio tracks (Fig. 2-2) leave approximately  $102^\circ$  of the tip pass for picture information.

The heads at  $90^\circ$  apart (at 0.182H per degree) lay down 16.4 TV lines ( $90 \times 0.182$ ), which was already derived previously. Since the heads are spaced  $90^\circ$ , the remaining time that both heads are in contact is  $102^\circ - 90^\circ$ , or  $12^\circ$ . This leaves an overlap of 2.2 lines ( $0.182 \times 12$ ). (See Fig. 2-7.) In recording, the same information is duplicated in this 2.2 lines. During playback, electronic switching is used to disconnect the head nearing the end of a track and to connect the head beginning the next track. The

switching is done during horizontal retrace to avoid visible switching transients.

The four heads make 960 sweeps ( $240 \times 4$ ) across the tape per second, during which time the tape has traveled 15 inches. One revolution of the headwheel (four tracks) is equal to one-fourth of a field, since 240 rps is 4 times the TV-field frequency of 60 cps. Therefore there are 60 fields ( $240 \div 4$ ) per 15 inches of tape. Thus, one field equals 0.25 inches ( $15 \div 60$ ), and a frame (2 fields) equals 0.5 inch of tape.

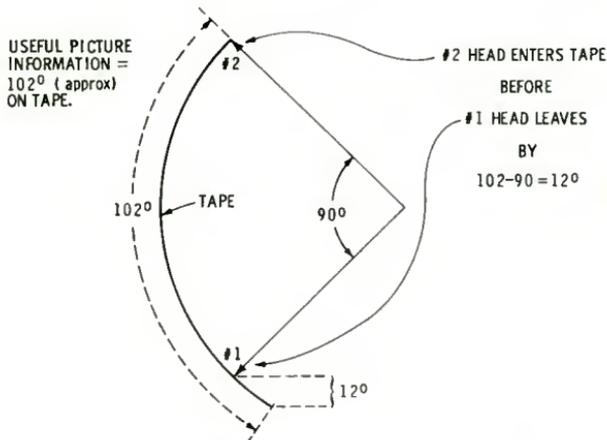


Fig. 2-7. Active picture information on tape is  $102^\circ$ , allowing  $12^\circ$  overlap.

The foregoing timing relationships plus other significant factors are summarized in Table 2-1.

NOTE: The tracks on video tape can be made visible by coating with a suspension of carbonyl iron and diluent (Fig. 2-8). Horizontal-sync pulses show as white dots between the long white lines of vertical blanking. Fig. 2-9 shows how the picture raster is made up of consecutive bands of 16 to 17 lines contained in each head pass across the tape.

## 2-5. TIME-SPACE ERRORS

Errors in spacing, as a function of time, in a video-tape reproduction occur as horizontal displacements of vertical lines in the picture. The following illustrations show the space errors resulting in the reproduced picture from time-base discontinuities.

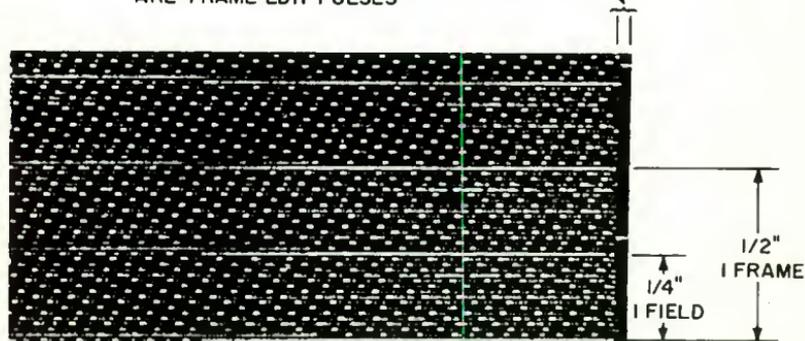
Table 2-1. Significant Head Timing.

Subject	Relative Frequency (cps)	Microseconds ( $\mu$ s)	Vertical (V = 1/60 sec) = 16,667 $\mu$ s	TV Lines (H = 63.5 $\mu$ s)	Headwheel Degrees 360° = 1/240 sec. = 4,166.6 $\mu$ s
TV Field	60	16,667	1	262.5	1,440
TV Line	15,750	63.5	1/262.5	1	5.48
1 Revolution of Headwheel	240	4,166.6	1/4	65.625	360
1/2 Revolution of Headwheel	480	2,083.3	1/8	32.8	180
1/4 Revolution of Headwheel	960	1,041.6	1/16	16.4	90
Playback Switching Rate (and Sweeps Across Tape per Sec)	960	1,041.6	1/16	16.4	90
1° of Rotation		11.58		0.182	

Additional Significant Measurements

Width of video-head magnetic gap	0.09 mil
Video-head tip speed	1,561 ips
Maximum recorded frequency	7 mc
Minimum wavelength on tape (7 mc)	0.223 mil
Length of one TV line on video track	.98 mils (approx.)
Head-to-head spacing around circumference	1.626 inches (approx.)
Length of video track across tape	1.82 inches
Space along tape between fields	0.25 inches
Space along tape between frames	0.50 inches

WHITE MARKS IN THIS CONTROL TRACK AREA ARE FRAME EDIT PULSES



Courtesy Ampex International Operations, Inc.

Fig. 2-8. Visible tracks on developed tape (used only for editing).

### Tape Vacuum Guide Too Far From Head

1. Point Z in Fig. 2-10A represents the center of the drum, or headwheel. Assume that the recording is made with arc X-X representing 16 lines. Arc Y-Y is the playback position, if the guide is too far from the heads, and contains the same 16 lines of information. The pole tip enters this information late, and leaves early compared to the recorded time base.

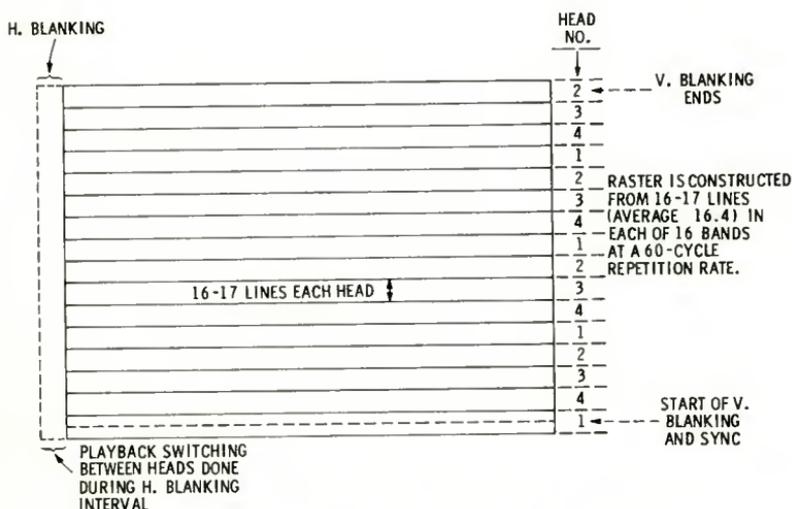


Fig. 2-9. Raster makeup, with vertical sync on head No. 1.

2. Space errors resulting from the condition in Paragraph 1 are depicted in Fig. 2-10B. Each band of lines representing a head pass across the tape starts late and ends early, producing the *skew* effect, also called the *Venetian-blind* effect.
3. Fig. 2-10C shows the effect on a series of vertical lines (viewed on a video monitor) when time-base distortion, resulting from the vacuum guide being too far from the head, is present.

NOTE: The horizontal position of the vacuum guide (which determines distance of tape from heads) is controlled by a servo amplifier. This servo (in the playback mode) may be placed either in the manual or automatic sense position.

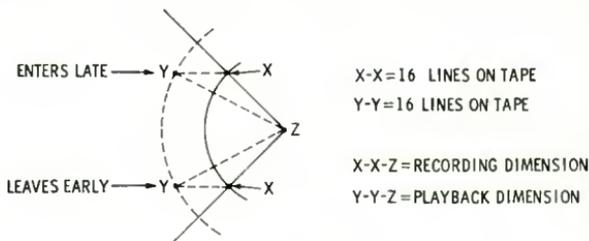
In practice, mechanical adjustments are made on the head assembly with the electrical controls centered. After the initial me-

chanical alignment on a given head assembly, only the electrical control need be used to eliminate skew in the manual mode of operation.

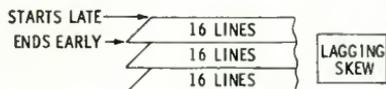
Details of the guide servo in manual and automatic modes are found in Sections 3 and 5.

### Tape Vacuum Guide Too Close to Head

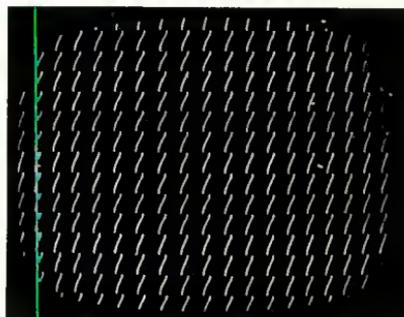
1. In Fig. 2-11A,  $X-X-Z$  represents the recording dimension with a given number of pulses in arc  $X-X$ . The playback dimension



(A) Recording and playback dimensions.



(B) Bands of lines.



(C) Effect on vertical lines.

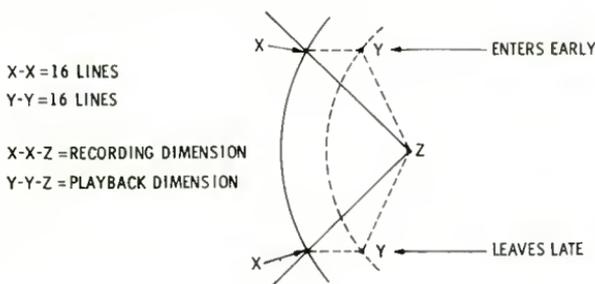
Fig. 2-10. Space distortion—vacuum guide too far from head.

when the guide is too close to the head is represented by  $Y-Y-Z$ . Here, arc  $Y-Y$  contains the same number of pulses as  $X-X$ . The pole tip now enters early and leaves late compared to the recording time base.

2. Each band of lines starts early and ends late, producing leading skew (Fig. 2-11B), which is opposite to that of Fig. 2-10B.
3. The effect of space distortion caused by the vacuum guide being too close to the head on reproduced vertical lines is shown in Fig. 2-11C.

### Tape Vacuum Guide Too High

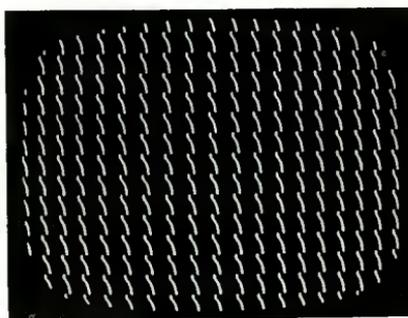
Vertical alignment of the guide constitutes a mechanical adjustment only. The correct alignment is that which allows maximum concentricity of the tape with the pole-tip circumference. A major problem is the same *stretch* of tape at top and bottom of the pole-tip arc in the interchangeability and interspliceability of the tape.



(A) Recording and playback dimensions.



(B) Bands of lines.



(C) Effect on vertical lines.

Fig. 2-11. Space distortion—vacuum guide too close to head.

1. With the guide too high (Fig. 2-12A), less stretch occurs at the top than at the bottom; hence, there is lack of concentricity.
2. Assuming the tape was recorded with correct concentricity, the pole tip enters late and leaves late compared to the recording time base (Fig. 2-12B).
3. The start and end of each band of lines is late, producing a scallop, as shown in Fig. 2-12C.
4. Vertical lines on a video monitor appear as shown in Fig. 2-12D when the guide is too high.

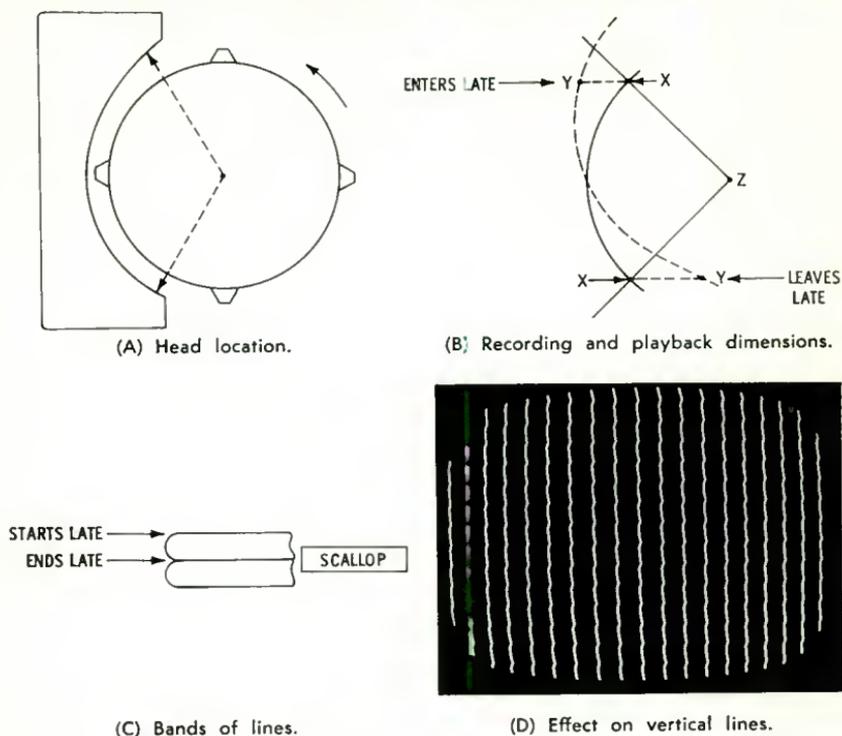


Fig. 2-12. Space distortion—vacuum guide too high.

If a recording is made with the guide positioned as shown in Fig. 2-12A, it can be played back on the same head without distortion. However, if this tape is played back on a correctly adjusted head assembly, the guide must be misadjusted vertically to eliminate scalloping in the picture. A misadjustment, as in Fig. 2-12A, produces excessive wear on the bottom half of the tape.

### Tape Vacuum Guide Too Low

1. When the guide is positioned too low (Fig. 2-13A), more stretch occurs at the top than at the bottom of the tape.
2. Assuming that recording is made at correct vertical alignment, the pole tip enters early and leaves early compared to recording time base (Fig. 2-13B).
3. Each band of lines starts and leaves early (Fig. 2-13C), producing a scallop which is opposite to that of Fig. 2-12C.
4. Vertical lines on a video monitor appear as shown in Fig. 2-13D when the tape guide is adjusted too low.

### Quadrature Error

In the rotary-head TV-tape system, the ideal head spacing is exactly  $90^\circ$  plus or minus zero seconds of arc. Manufacturing problems understandably place considerable strain on this "perfect" situation. For example:

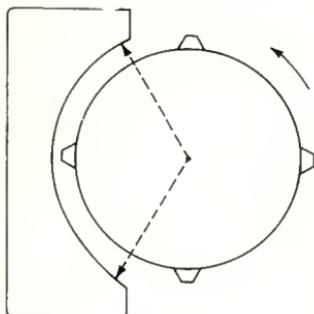
$$\text{Minutes of arc} = \text{degrees} \times 60$$

$$\text{Seconds of arc} = \text{minutes} \times 60$$

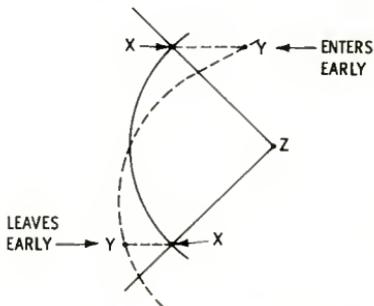
Therefore for  $90^\circ$ ,

$$\begin{aligned} \text{Minutes of arc} &= 90 \times 60 \\ &= 5,400 \end{aligned}$$

$$\begin{aligned} \text{Seconds of arc} &= 5,400 \times 60 \\ &= 324,000 \end{aligned}$$



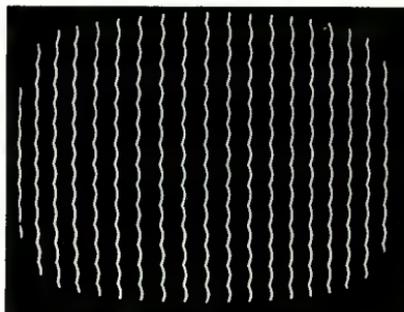
(A) Head location.



(B) Recording and playback dimensions.



(C) Bands of lines.



(D) Effect on vertical lines.

Fig. 2-13. Space distortion—vacuum guide too low.

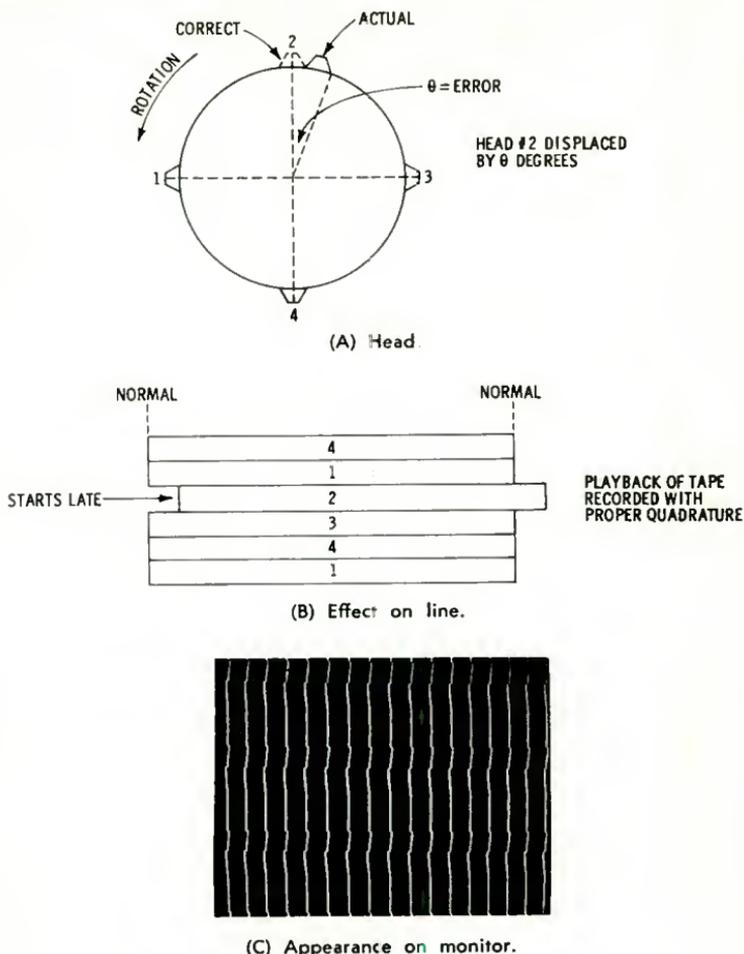


Fig. 2-14. Space distortion—head-quadrature error.

Table 2-1 states that  $90^\circ$  rotation of the head occurs in 1,041.6 microseconds. Therefore the time required for one second of rotation is  $1,041.6/324,000$ , or 0.00321 microseconds. If the head is off quadrature by just 30 seconds of arc, the error is equal to  $30 \times 0.00321$ , or 0.0963 microseconds—close to 0.1 microsecond.

If a recording is made with +30 seconds of quadrature error and played back on a different head with -30 seconds error, the accumulated error is 60 seconds (1 minute). This equals an approximately 0.2-microsecond error in quadrature—a noticeable

displacement of a complete band of lines. In practice, quadrature error must be held under approximately  $\pm 0.02$  microsecond to be invisible on vertical picture lines.

Space distortion caused by head quadrature error is shown in Fig. 2-14. The position of the heads on the rotating drum is shown in Fig. 2-14A. Notice that head No. 2 lags the correct position by  $\theta$  degrees. Assuming that a tape is recorded with correct quadrature, the band of lines from head No. 2 are displaced as shown in Fig. 2-14B on playback. Displacement is to the right, since the head enters the recorded information late. Fig. 2-14C shows the effect on a series of vertical lines viewed on a video monitor.

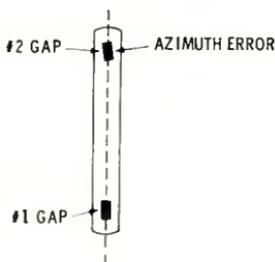


Fig. 2-15. Azimuth error.

If a recording were made with the error shown in Fig. 2-14A and played back on a correct quadrature head, head No. 2 would be advanced in time relative to the recorded information. This deletes a portion of the duplicated overlap interval (Fig. 2-7) and starts the lines of head No. 2 slightly early, displacing the band of lines to the left.

The "reading" of quadrature error is complicated by certain misleading factors, such as possible overmodulation, overcompensation of high-frequency response, gap tilt, and horizontal-flywheel in the monitor, discussed in Section 7. All personnel concerned with the use of video tape are obligated to make continual checks against quadrature standards, if true interchangeability and interspliceability are to be achieved.

### Other Time-Space Error Sources

*Azimuth error*, a manufacturing problem not subject to the control of the user, occurs when the gap is not perpendicular to the transverse magnet track made on a tape by a head with zero azimuth error. In Fig. 2-15, gap No. 2 is in azimuth error. If a properly recorded tape is played back with this error present, banding of No. 2 channel from loss of higher frequencies and re-

duction of signal-to-noise ratio results. A pseudo-quadrature effect can also occur.

Axial-position error is another manufacturing defect. As shown in Fig. 2-16A, head No. 4 is positioned to the right of its correct location. The effect of axial-position error on a recording is shown

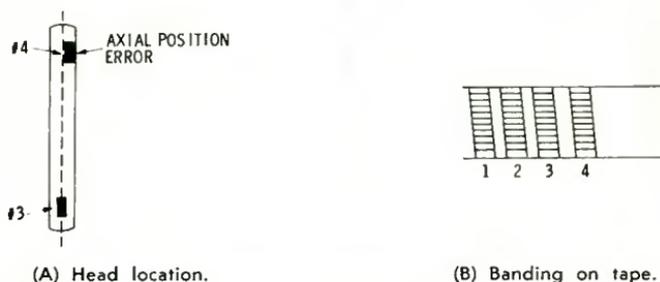


Fig. 2-16. Axial-position error.

in Fig. 2-16B. Banding of one channel occurs because of irregular spacing between head tracks 3 and 4. This effect often occurs as *half-banding* on a single channel.

Techniques for checking possible head errors are outlined in Section 7; however, such techniques are full of pitfalls unless a good background in theory and practice is acquired.



SECTION 3

**SYSTEM  
REQUIREMENTS**

②

②

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## SECTION 3

# SYSTEM REQUIREMENTS

A brief tabulation of what the television tape system must do can be outlined as follows:

1. The composite video signal is presented to the four rotating heads simultaneously in the form of an FM signal.
2. One revolution of the headwheel lays down 4 video tracks. Since the tape is pulled past the headwheel at 15 ips, adjacent video tracks are spaced approximately 5 mils apart.
3. To recover the recorded information, video-head outputs are first amplified, then fed to an electronic switcher which selects the signal from the head that is in contact with the tape. This selection occurs during horizontal-retrace intervals so that switching transients are invisible.
4. The electronic-switcher output is then demodulated to recover the video signal from the RF carrier. It is then processed to *clean up* sync and blanking intervals for distribution to the television system.
5. For proper synchronization, the tape velocity (15 ips) must be locked to the headwheel rotation (240 rps). During recording, stripped-off sync from incoming video is utilized to obtain a 240-cycle signal (4 times a field pulse-frequency of 60 cps), which is amplified to obtain sufficient power to drive the headwheel. This 240-cps signal is also converted to a sine wave, which is recorded on the control track of the tape.
6. Also during the record mode, the speed of the headwheel is obtained (by an exciter lamp and photoelectric cell in the Ampex unit; and by a magnetic tonewheel in the RCA unit) and divided back to 60 cps to supply power to the capstan motor. The speed of the capstan motor has absolute control

over the velocity of the tape which is a nominal 15 inches per second.

7. In the playback mode, the headwheel again rotates at 240 rps with the initial reference being either the 60-cycle power-line frequency or local sync. The 240-cps control-track signal is phase-compared to the playback speed of the headwheel, and any phase error slightly modifies the 60-cps frequency applied to the capstan motor. Thus, tape velocity is continuously maintained so that the rotating heads sweep directly across the video tracks originally laid down.
8. The audio signal is handled by conventional magnetic-recording techniques, but it is briefly outlined in this section.

### 3-1. THE TAPE TRANSPORT

The tape transport conveys the magnetic tape across the recording and pickup heads at the correct velocity and tension.

#### RCA TRT-1B Transport

The basic RCA-type transport, with the principle terms identified, is shown in Fig. 3-1. The following numbers refer to the identification numbers given in Fig. 3-1.

1. The supply reel contains the tape on which a recording is to be made or from which a recording is to be played. The length and recording times for the various reel diameters are given in Table 3-1.
2. The upper stabilizing arm dampens and takes up excess tape in event of erratic motion as in starting. (See Item 13.)
3. The master erase head is energized (in the Record mode only) to erase any previous signals.
4. Air guides preceding and following the master erase head position the tape for its approach to the headwheel. Air under pressure from the headwheel blower escapes through small pinholes in the guides across which the tape passes. This technique is sometimes referred to as *air lubrication*.
5. Video and control signals are either written onto or read from the tape by the headwheel panel assembly.
6. The audio- and cue-erase heads (energized in the Record mode only) clear their respective tracks of any previous information, and remove the video from this portion of the tape.
7. This guide post serves to maintain tight tape contact with heads 6, 8, and 9.

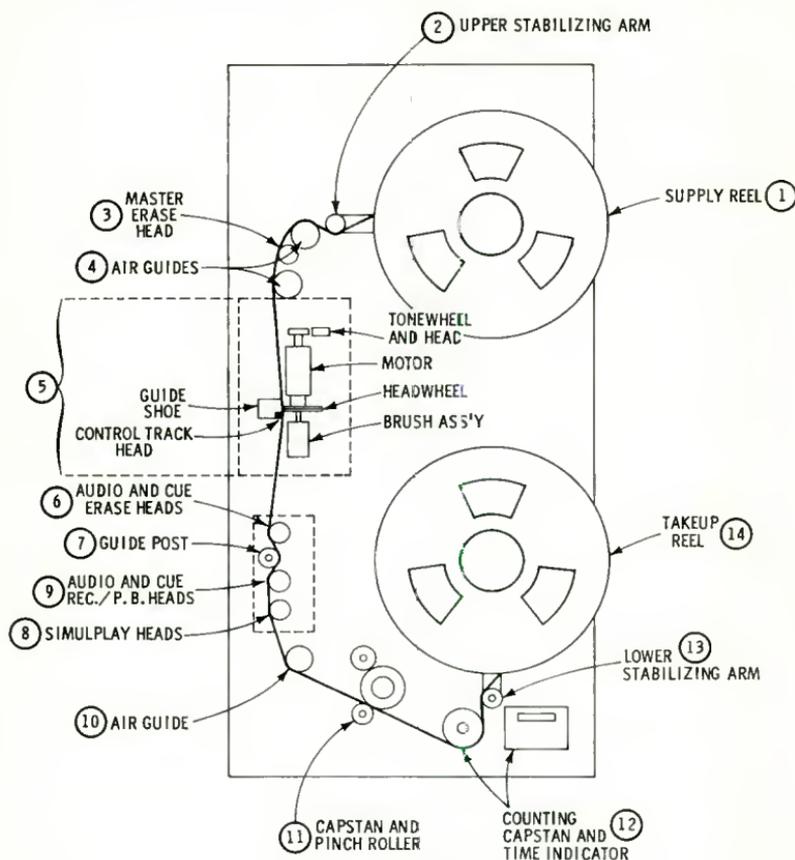


Fig. 3-1. The basic RCA tape transport.

8. Simulplay heads consist of an audio playback head at the top of the tape, which functions to ensure that an audio track is being recorded, and a control-track playback head at the bot-

Table 3-1. Tape Reel Data

Feet	Minutes	Reel Diameter (inches)
1,200	16	6
2,400	32	8
4,800	64	12½
7,200	96	14

tom of the tape to ensure that control-track amplitude is maintained.

9. The audio record/playback head is at the top of the post. The cue record/play head is at the bottom. The relative location of the sound and cue tracks is given in Fig. 2-2.
10. This air guide changes the direction of the tape for approach to the capstan and pinch rollers.
11. In normal Play and Record modes, the pinch rollers, actuated by a rotary solenoid through spring-loaded linkage, clamp the tape against the capstan, which controls the tape speed. The shaft of the capstan motor is sized to a tape velocity of 15 ips at a motor speed of 600 rpm. A hysteresis-synchronous two-phase motor with 11 inch-ounces rated running torque is employed. A flywheel is mounted on the rear end of the capstan motor shaft to smooth out speed fluctuations.
12. The counting-capstan diameter and spur gears are designed to give one count per 15 inches of tape. The counter indicates minutes and seconds of tape, with a maximum time of 99 minutes and 59 seconds.
13. The lower stabilizing arm provides the same control over the tape on starting the transport as does the upper arm (2). Both of these arms employ unidirectional air dampers (mounted on the rear of the support panel) for proper tape damping and stabilization.
14. The takeup reel provides storage of the tape after it passes through the previous items.

The headwheel blower, mentioned under Item 4, cleans and cools the headwheel. A permanently lubricated ball-bearing motor drives a multistage blower which draws the air from the headwheel panel over an oil-wetted wire filter. This filter traps dust, lint, and iron-oxide particles from the tape and headwheel.

In normal Play and Record modes, the reel motors supply power to hold back or take up the tape; the capstan maintains full control over tape speed. During rewind, the upper reel motor is fully energized and the lower motor is energized to rotate counterclockwise (although its direction of rotation is clockwise) to maintain tape tension and avoid spillage. During either rewind or fast forward, the pinch rollers are lifted to disengage the capstan.

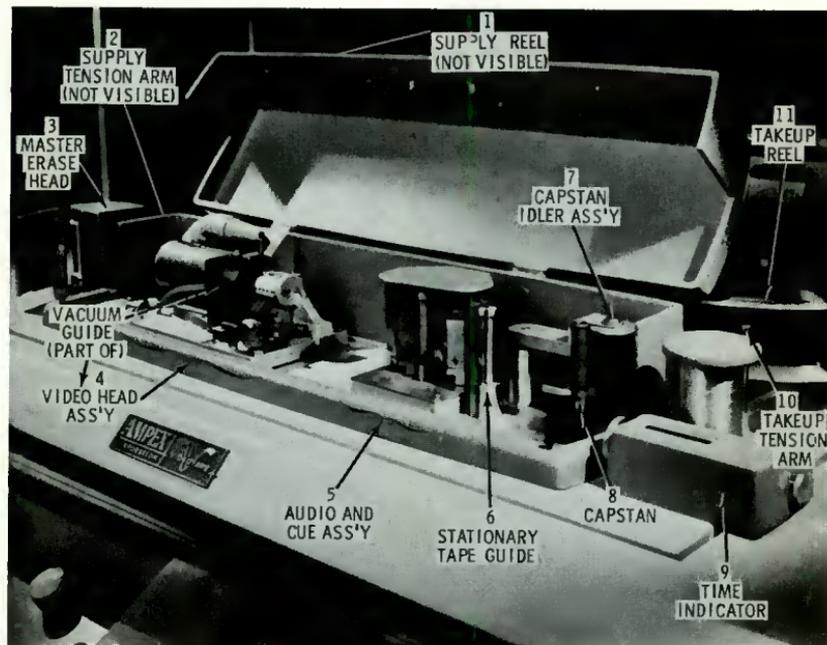
Brakes are spring-actuated and solenoid-released for fail-safe operation. Braking is done by an asbestos-lined band on a brass drum. The linkage is arranged to give differential braking on approximately 240° of the drum. Differential braking is used to keep

the tape tight and prevent spillage during a stop from high-speed wind or rewind.

The adjustment and maintenance of proper tensions are important to over-all system stability. (See Section 7.)

### Basic Ampex Transport

The basic mechanical functions of the Ampex transport shown in Fig. 3-2 are the same as those described for the RCA unit. The erase head (3) has a hinged door on the front to provide shielding.



Courtesy Ampex International Operations, Inc.

Fig. 3-2. The basic Ampex tape transport.

The stationary tape guide (6) is used to position the tape vertically with respect to the heads. As a tape-guiding element, the idler is precisely machined so that the tape will fit almost exactly between flanges on the inner surface.

The capstan idler-arm assembly (7) consists of a neoprene rubber-tired hub mounted on a U-shaped bracket (providing a certain amount of self-alignment), which is, in turn, mounted on an arm directly coupled to the pivoting housing shaft. The housing



volved in time (synchronizing) function rather than in video. The following numbers correspond to the like-numbered points in Fig. 3-3.

1. The video signal is applied to a frequency modulator with a typical carrier frequency of 46 mc. The resulting FM signal is heterodyned with a fixed 51-mc oscillator, producing a carrier frequency of  $51 - 46$  or 5 mc. In monochrome operation, the deviation of the carrier for 100% modulation is about 4.3 to 6.8 mc.
2. The FM output from the modulator is amplified and split into four separate channels, one for each of the rotating video heads. This is necessary in the Record mode because the video amplitude of each head must be adjusted individually to obtain optimum results. (NOTE: Whenever "video" is mentioned relative to the video heads, it must be understood that the signal is in the form of a frequency-modulated carrier.)
3. The individually adjusted FM outputs from the driver amplifier drive all four video heads in parallel through a slipping brush assembly. No head-channel switching occurs during the Record mode of operation.

This completes the basic video function when recording. The remaining functions serve in the timing of the recorded signals.

4. Sync pulses are stripped from the video signal being recorded and the field frequency (60 cps) provides the initiating power source for the rotating-head motor. This is termed the reference pulse.
5. The 60-cps pulses are multiplied to 240 cps in frequency multiplier A and fed into phase-comparison circuit B. The other side of this comparator receives a 240-cps nominal frequency from the head-shaft tachometer, a device for measuring shaft speed. The resultant error signal is used to control the nominal frequency of 240-cps oscillator C, which feeds the head motor-drive amplifier.
6. The head motor-drive amplifier is capable of supplying over 80 watts of 240-cycle, 3-phase power to the head motor. Nominal power consumption is about 50 watts. The multiple-phase output is obtained through the use of Scott-connected transformers.
7. The head motor is a three-phase 240-cycle synchronous-type (Ampex) which requires about 50 watts of power. In the RCA system, the headwheel motor is a hysteresis-synchronous-type designed for operation at about 300 cps. It is supplied with 3-

- phase power at about 360 cps, but the speed is held back to 240 cps by the servo arrangement. (Detailed in Section 5.)
8. The head-tachometer signal is used to generate the master-control signal recorded on the tape, and to develop the initial power reference for the capstan motor. This signal indicates the relative position of the heads, controlled by the head motor, and the longitudinal position of the tape, controlled by the capstan motor. The Ampex method (Fig. 3-4A) em-

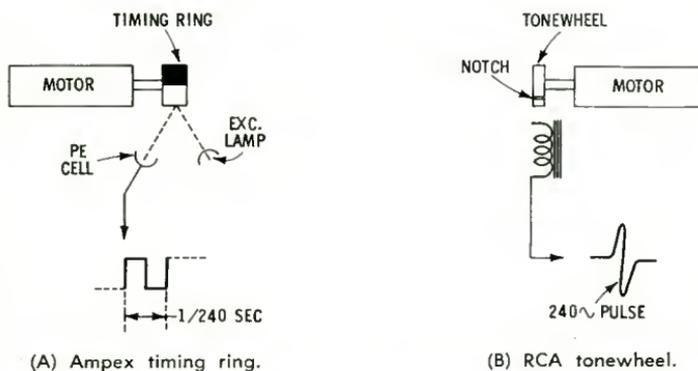


Fig. 3-4. The tachometer or timer.

- employs a timing ring, which is painted black over 180° and white for the other 180° in conjunction with an exciter lamp and photoelectric cell. The output of the photoelectric cell corresponds in frequency to the nominal 240 rps of the motor. In the RCA method (Fig. 3-4B), a tonewheel with a notch that breaks the magnetic path when it passes across the tonewheel head is used.
9. The control-track head records the signal (now a sine wave) which is derived from the head tachometer. Since this same initial reference from the head tachometer is also fed to the phase comparator (B of item 5), any tendency of the motor speed to "hunt" is compared to the original signal timing to indicate the magnitude of error. The corrective action of the servo tightly controls the motor speed.
  10. The capstan motor-drive amplifier receives 60-cycle information derived from the tachometer (through D and F of item 5) and provides amplification to the two-phase power necessary for the capstan motor. Thus, the capstan is electronically coupled to the rotation of the video heads.

11. The capstan motor is a two-phase synchronous-type. It has full control over the tape speed, which is phase-locked to the rotating heads in the manner described previously.

Some important relationships to remember concerning the basic recording mode are as follows:

1. The video to be recorded is converted to an FM carrier, which is split into four individual feeds for feeding to the rotating heads via a slip-ring brush assembly. Carrier amplitudes are adjusted for each individual head to obtain optimum playback of the recorded signal. Pre-emphasis is employed to compensate for various high-frequency losses in the head-to-tape response.
2. The speed of the rotating-head motor is made four times the vertical frequency of the signal being recorded ( $60 \times 4 = 240$  rps). The vertical-scanning frequency in the incoming signal itself supplied the initial power for this motor so that any line-to-line or field-to-field phase drift is followed by the motor.
3. The speed of the head motor determines the absolute values of the deflection frequencies, control-track signal, and capstan speed; therefore it must be tightly controlled. A three-phase winding permits tighter phase control with less power. The leading edge of the photoelectric-cell signal (Ampex), or the pulse from the tonewheel (RCA) bears a direct relationship to the head in contact with the tape. This signal is continually compared to the initial reference pulse so that any tendency of the motor to hunt in speed is corrected by an error signal.
4. The action in 3 assures that each picture field occupies exactly 16 complete transverse tracks on the tape. (Each revolution produces 4 tracks. This is one-fourth field, so four revolutions equal one field or 16 tracks.)
5. Since the speed of the head motor is the determining factor for all frequency components, the signal from the head tachometer is converted to a sine wave (nominal frequency of 240 cps) and recorded as a control track to supply the playback circuits with proper timing information.
6. The head-tachometer signal is also divided down to 60 cps to be amplified for power to drive the capstan motor.
7. The phase-stability requirements for the capstan motor are not as severe as for the head motor. Therefore a two-phase motor is practical.

NOTE: The foregoing discussion has omitted the audio function and the circuitry associated with the vacuum-guide control. Audio

is covered later in this section, and the vacuum-guide circuitry is covered in Section 5.

It should be understood that the method of attack in system functions is, in some instances, quite different between Ampex and RCA practice. Except where noted, the discussions in this section are general in nature rather than specific. The first consideration is to become introduced to fundamental working requirements.

### 3-3. THE PLAYBACK MODE

More circuitry is involved in the playback mode than in the record mode. There are two reasons for this. (1) Electronic switching is required to select only the head that is in contact with the tape. This prevents spurious signal and noise output being fed to the demodulator from the high-speed heads not in direct tape contact. (2) An additional servo control is necessary for the capstan motor. The speed of the tape must be controlled by a continuous comparison of the control track layed down during recording (240 cps) with the 240-cps signal derived from the head-shaft tachometer. This ensures that the video-heads "track," or pass directly over the recorded video tracks on the tape. Failure of such control causes the relative positions of the heads along the length of the tape to drift. Thus, a head could bridge two adjacent recorded tracks rather than remaining over a single track.

A block diagram of the basic playback system is given in Fig. 3-5. In the following explanation of the playback system, the numbers refer to those used to identify the various blocks in Fig. 3-5.

1. The relatively low-level (about 2 millivolts) output from the head slip-ring brush assembly is amplified in individual preamplifiers before being fed to the switcher unit. For simplicity, the preamps are not shown in Fig. 3-5. The switcher combines the individual head inputs into a sequential and continuous single output. A 240-cps signal from the head tachometer presets the gates. A 480-cps signal, derived from the same source but with the leading edge placed under horizontal blanking, is used to trigger the actual switch. This technique is further explained in the discussion for item 14.
2. The FM demodulator extracts the useful video signal from the frequency-modulated carrier.
3. The processing amplifier cleans up the blanking and sync intervals of the demodulated video.

4. Either the local sync generator or the 60-cycle power line is used as the initial reference for the head-motor power.

**CAUTION:** This does not mean that the reproduced signal from the tape system can be treated as a local signal for lap-dissolves or local superimposures. Neither horizontal- nor vertical-sync pulses from the tape are necessarily coincident in time with the external pulses from the local sync generator. Unit 4 is used *only* for an initial yardstick to supply a stable comparison.

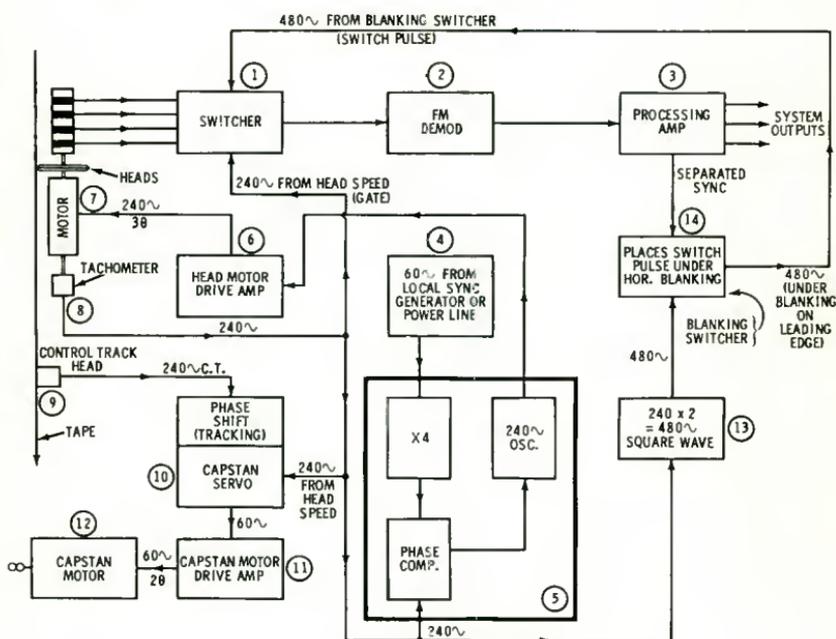


Fig. 3-5. Basic block diagram—playback mode.

**NOTE:** Later developments, such as the Ampex *Intersync*, which permits local lap-dissolves and supers, are covered in Section 5 of this notebook.

5. The head motor is controlled by the same servo system as used in the Record mode, except that the initial reference signal is the local-sync generator (or 60-cycle power line).
6. The head motor-drive amplifier serves the same function as for recording.
7. The head motor functions the same as for recording.

8. The signal from the head tachometer is routed to units 1, 5, 10, and 13, as shown in Fig. 3-5.
9. The control-track head reproduces the recorded control track.
10. The capstan servo compares the control-track signal (which is indicating the relative position of the heads during recording) with the head-motor tachometer signal (which indicates the playback speed and phase). From this comparison, an error signal is developed which slightly modifies the frequency of the 60-cps oscillator used as the initial power source to drive the capstan motor. Note that a control is provided to shift the phase of the control-track signal—termed the Tracking control. If, for example, head No. 1 is reproducing vertical sync, tracking can be shifted so that head 2, 3, or 4 reproduces vertical sync. This allows matching of heads to obtain optimum reproduction from a tape recorded by a different head.
11. The capstan motor-drive amplifier serves the same function as for recording.
12. The capstan motor serves the same function as for recording.
13. A 480-cps square wave is formed from the 240-cps tachometer signal.
14. The leading edge of the 480-cps square-wave switch pulse is made to occur during the horizontal-blanking interval. This prevents switching of channels during an active line interval. Such switching results in transients in the picture.

Fig. 3-6 shows the basic principles of the switching function. Switcher-channel inputs are gated by two 90° related, 240-cps signals. Two 480-cps, 180° related pulses chop the signal at a 960-cps rate to place the head outputs in the proper sequence in a single channel. (Details of this operation are given in Section 4.) NOTE: The techniques used by Ampex and RCA differ, but the principle is the same.

### 3-4. THE AUDIO SYSTEM

In the previous drawings of the tape transport it was noted that the audio heads are spaced in distance (and time) from the video heads. This distance is 9.25 inches; each picture frame occupies one-half inch along the tape; therefore, the corresponding sound for a given picture frame leads the picture by  $9.25 \times 2$ , or 18.5, frames. Perfect *lip sync* is maintained because the same audio head is used for both recording and playback. The only problem which arises is the editing (splicing) of the tape between rapidly

spoken words (or continuous music), so proper picture continuity can be maintained.

Since the tape speed is 15 ips, the spacing in time between the corresponding picture frame is equal to  $(9.25/15)$  0.61 second. It is obvious, therefore, that for most editing, the first-frame pulse following a spoken word may be selected for the splice (described in Section 6).

Conventional audio magnetic-tape methods are used for the sound track. A plot of the amount of remanence against the strength of the signal field is given in Fig. 3-7. This type of trans-

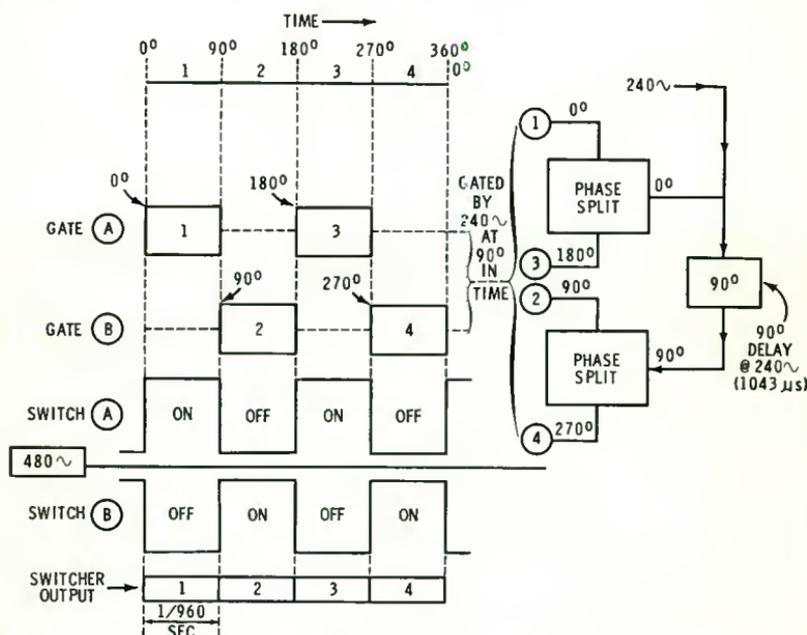


Fig. 3-6. The basic playback-switching functions.

fer curve has no linear portion that would allow an undistorted signal output. Therefore a high-frequency bias (between 50 and 100 kc) is added to the audio current, as shown.

The audio component on the plus side of the zero magnetization axis results in the distorted waveform where loop *a* is larger than loop *b*. The audio component on the minus side results in the distorted wave where loop *c* is smaller than loop *d*. The algebraic sum of *a* + *c* will equal the algebraic sum of *b* + *d* when the loops

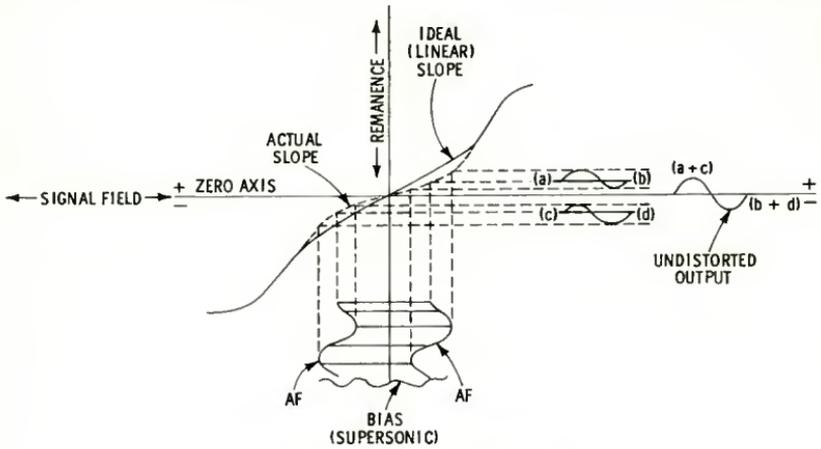
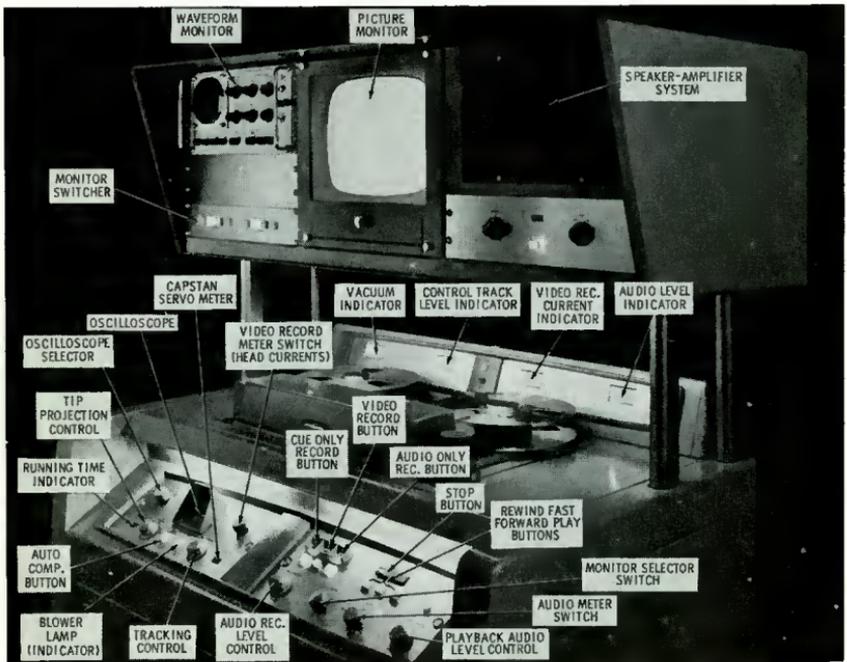
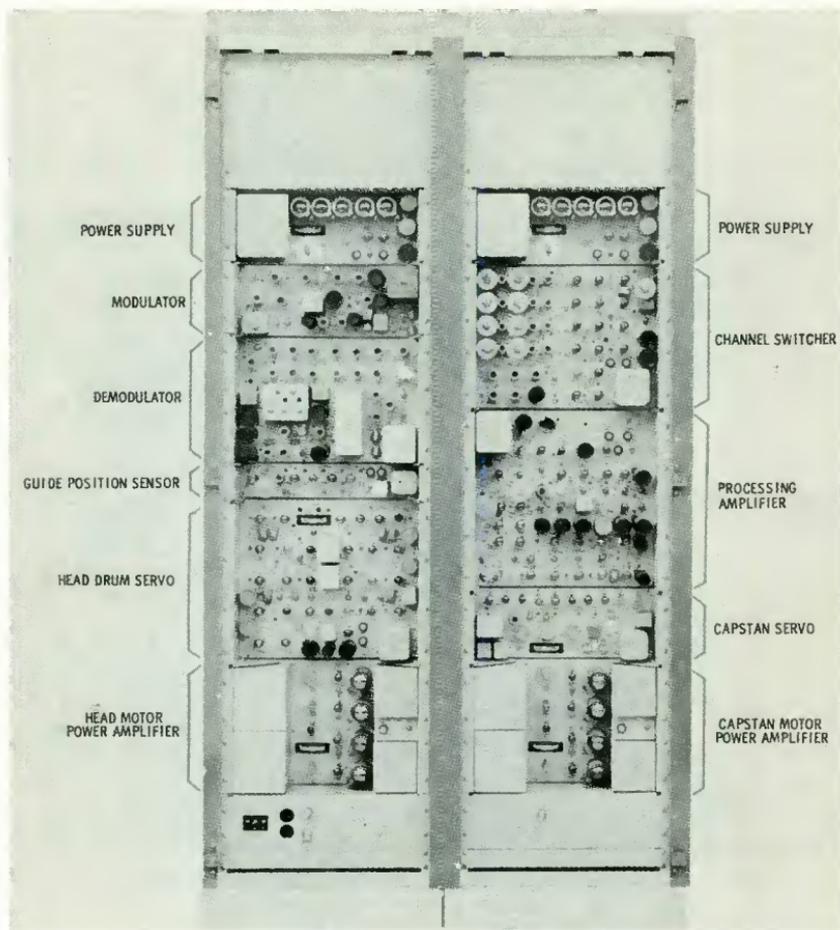


Fig. 3-7. Effect of supersonic bias.



Courtesy Ampex International Operations, Inc.

Fig. 3-8. The Ampex 1000-C console.



Courtesy Ampex International Operations, Inc.

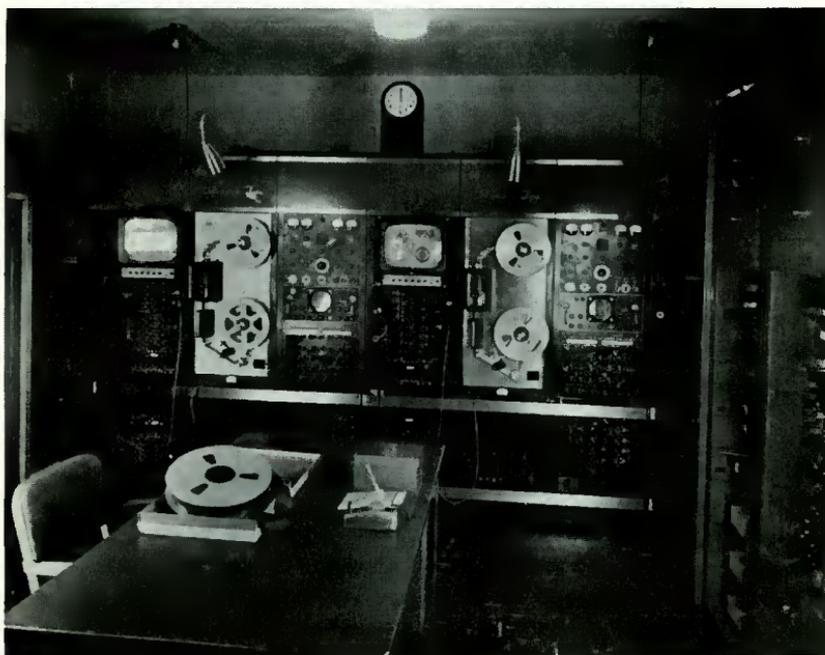
Fig. 3-9. Ampex racks.

are combined on the axis of operation, resulting in an undistorted output.

The axis of easy magnetization of the iron-oxide particles on video tape is aligned transversely across the direction of travel to favor video response. This places a slight limitation on audio bandwidth and signal-to-noise ratios, as compared to conventional 15-ips audio tape recording. It should also be noted that the audio track on the video tape is only about 90-mils (0.09 inches) wide as compared to the conventional one-fourth inch audio tape.

### 3-5. SYSTEM LAYOUTS

Physical layouts and unit identifications for Ampex installations are shown by Figs. 3-8 and 3-9 and for RCA installations in Figs. 3-10 and 3-11. The additional units required for color operation are not considered in this Notebook. In line with the general phi-



Courtesy Radio Corporation of America

Fig. 3-10. RCA installations at WBTV.

losophy of this Notebook Series, color facilities are covered in a separate complete book on the subject. This is of utmost value to the reader since the entire color system is involved. Thus, the Notebook on Color-Television Equipment considers the color processing technique as applied to color-signal generating equipment, camera chains, and color recording.

NOTE: The Ampex operations console (Fig. 3-8) houses the following units (not shown) in the lower section:

Video-Erase and Cue unit,  
Record-Driver Amps,

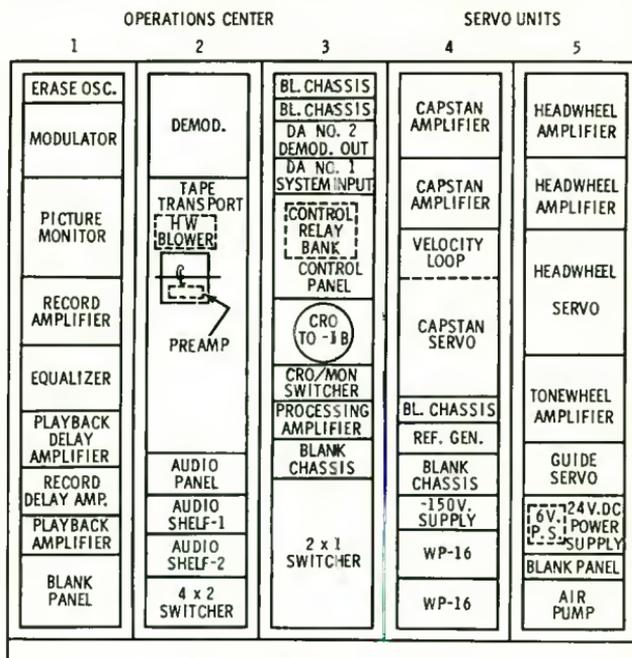


Fig. 3-11. RCA rack identification.

Tape-Guide Servo,  
 Power Supplies (for relays and control panels on console),  
 Head-Blower Assembly,  
 Vacuum-Pump Assembly.



C

SECTION 4

# VIDEO-SIGNAL PROCESSING



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## SECTION 4

# VIDEO-SIGNAL PROCESSING

This section considers the details of video signal processing in recording and playback modes.

### 4-1. THE MODULATION PROCESS

The basic function of the modulator unit is illustrated in Fig. 4-1. The video input (Fig. 4-1A) is pre-emphasized (Fig. 4-1B) to improve the signal-to-noise ratio, and used to frequency-modulate a carrier (Fig. 4-1C) before being applied to the rotating video heads.

The frequency-modulated carrier permits a carrier frequency only slightly higher than the highest video frequency to be used

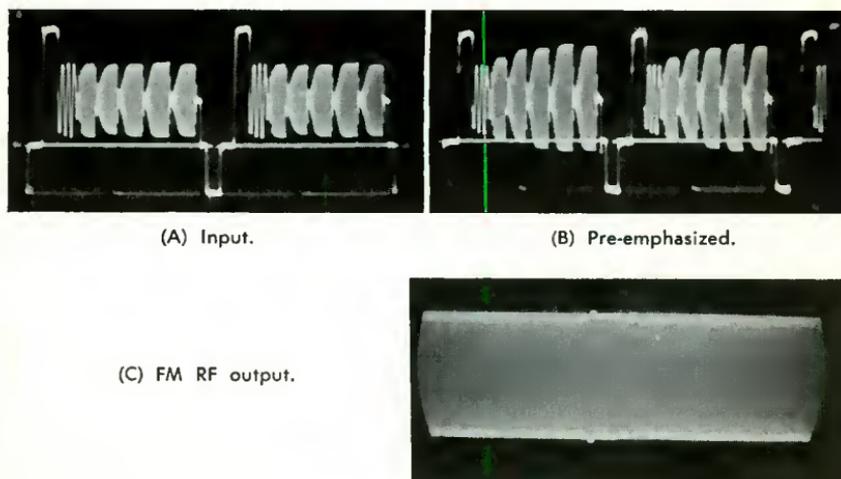


Fig. 4-1. Basic modulator action.

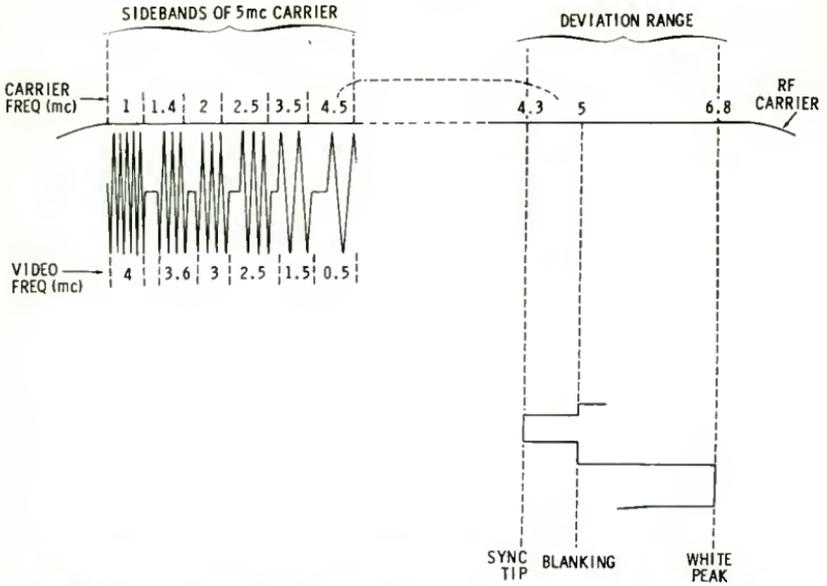
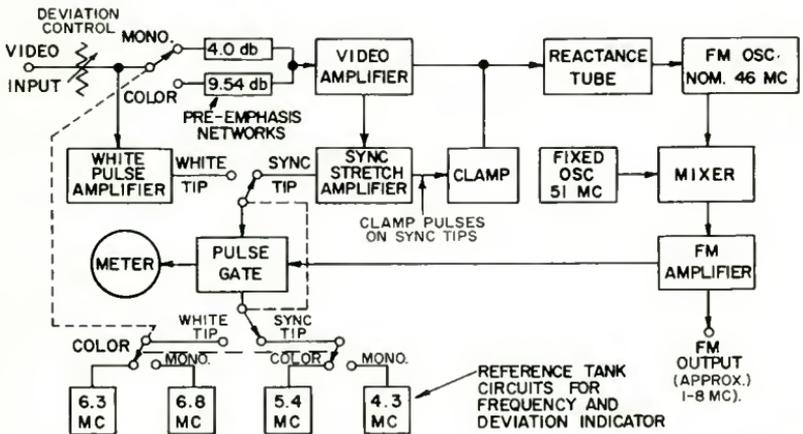


Fig. 4-2. Carrier deviation and sideband energy distribution for a 4-mc signal.

without objectionable nonlinearity caused by the magnetic medium. The reproduction of the low-frequency portion of the video band is excellent, even though the FM carrier is in a region of poor magnetic performance. Reproduction of the higher video fre-



Courtesy Radio Corporation of America

Fig. 4-3. Simplified block diagram of the RCA TRT-1A modulator.

quencies is excellent because the lower sidebands that they produce fall into a frequency band of high magnetic performance (Fig. 4-2)

The block diagram of the RCA modulator (Fig 4-3) will serve to illustrate a typical modulation process. The incoming video signal is applied to a potentiometer labeled Deviation control. From the center arm of the potentiometer, the video signal is applied to a pre-emphasis network to improve the signal-to-noise ratio. The output of the pre-emphasis network is applied simultaneously to the control grid of a video-amplifier tube and sync-

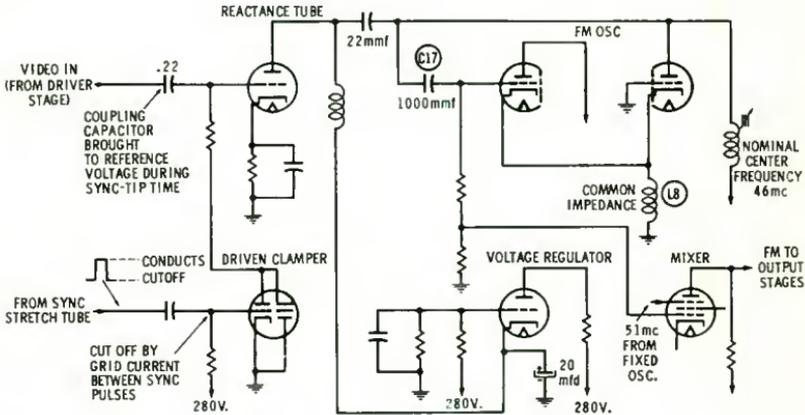


Fig. 4-4. Simplified diagram of the modulator, clamp, and mixer.

stretch amplifier. The sync-stretch stage provides nonlinear amplification which stretches the sync polarity and compresses white polarity.

The video-amplifier stage is a conventional video amplifier with no bypass capacitor connected across the cathode resistors. Thus, it provides considerable degeneration which reduces the stage gain but stabilizes the operation of the amplifier. The video-output signal is taken from a low-impedance cathode circuit and capacitively coupled to the control grid of the reactance tube. The purpose of the reactance-tube modulator is to frequency-modulate a radio-frequency oscillator. The modulator accomplishes this by changing the amplitude variations of the input signal into a varying reactance which is connected across the tank circuit of the oscillator. The plate voltage of the reactance tube is held constant by a voltage regulator to insure that the clamp bias voltage ap-

plied to the grid of this tube holds the carrier frequency limit constant for tip of sync.

The FM output signal of the 46-mc oscillator is applied to the control grid circuit of a mixer stage. Here, it is heterodyned with the master-oscillator signal, which is injected into the suppressor grid circuit (Fig. 4-4). The frequency of the master oscillator is 51 megacycles, but it is not critical. The operation of the master oscillator is the same as the FM oscillator; the coupling between stages is through common cathode impedance L8 and plate-to-grid coupling capacitor C17. There are two heterodyne signals from the mixer: one is the sum of the master oscillator and FM oscillator frequencies, and the other is the difference between the two oscillator frequencies. The output of the mixer is applied to a two-stage amplifier. Inductors in the control-grid circuits of these amplifiers provide high-frequency peaking to keep their frequency response flat. Also, these coils prevent unwanted oscillator-frequency signal and their sum from getting into the FM output. The amplifier output signal is frequency-modulated, with a center frequency of approximately 6 megacycles (midway between 4 and 8 mc for a 50% duty-cycle signal). A portion of the output voltage is applied to the cathode of the pulse-gate tube (Fig. 4-3). This tube is biased at plate current cutoff, except when its control grid receives positive-going pulses.

A portion of the input-video signal is applied to the white-pulse amplifier. Both sections of this stage are biased so as to stretch the white information and compress the sync. When the switch labeled White Tip-Sync Tip is placed in the White Tip position, one of the two RF reference circuits (depending on the position of the Color-Mono switch) will be energized during the whitest part of the picture. The RF voltage generated by the reference circuit is rectified by a germanium diode, and the amount of current is indicated on the meter. Maximum deflection of the meter is obtained when the frequency of the carrier output equals that of the reference circuit selected. When the switch labelled White Tip-Sync Tip is in the Sync Tip position, positive sync-tip pulses force the gate tube into conduction, thereby permitting the FM carrier frequency at the sync tips to be checked with the other two reference circuits.

The Ampex modulator employs slightly different oscillator frequencies, but the principle of operation (heterodyne to obtain carrier frequency) is the same for systems following the original Ampex Model 1000-A. The Ampex 1000-C includes the Ampex

standard monochrome (somewhat higher pre-emphasis than RCA) and color networks, as well as a considerably higher pre-emphasis termed *Ampex Master Video Equalization* (AMVE)—any one is available by means of a push-button switch. In addition, the equalizer components are plug-in units so that any standard that may eventually be established will be conveniently available.

The new Ampex modulator incorporates built-in crystal-controlled test signal generators. Since carrier and deviation are set differently for color than for monochrome, the modulator provides separate presetting adjustments for the two. The recorder can be switched, either locally or remotely, for either color or monochrome operation. The switchover automatically actuates the correct preset carrier and deviation values in the modulator.

The following crystal-controlled test frequencies may be selected by push buttons on the Ampex modulator:

- 5.0 mc—Monochrome blanking level.
- 5.5 mc—Color sync tip.
- 6.5 mc—Color peak white.
- 6.8 mc—Monochrome peak white.

Two additional positions are also available on the Ampex. They allow the user to plug-in any special crystal-controlled frequencies.

At present, the Ampex modulator employs a carrier frequency clamped at the blanking level during the back porch interval (Fig. 4-5). The sync is separated from the composite signal (Fig. 4-5A) and differentiated (Fig. 4-5B) to form leading and trailing edge spikes. The trailing edge is used to form a clamp pulse (Fig. 4-5C) which drives the clamper at the blanking level on the back porch.

## 4-2. ELECTRONIC QUADRATURE CORRECTOR

In the Record mode of operation, the modulator output is routed to the demodulator chassis (for use by servos and monitoring) and to the amplifiers for driving the video heads. An additional panel, the Record Delay Chassis, is employed prior to the video-head drivers in the RCA TRT-1B system. Ampex employs electronic delay controls in the Play mode (only) so that any existing quadrature errors may be corrected in this mode. The RCA unit (Fig.

4-6) accepts the single FM channel from the modulator and splits this input into four individual channels. Delay line switches for each channel provide steps of 0.015 microsecond each, with ten taps each side (+ or -) of zero correction.

If a manufacturing tolerance of  $\pm 10$  seconds of arc ( $\pm 0.03$  microsecond) were employed, the maximum timing error between any sequential head pair can be 20 seconds (0.06 microsecond). If a tape is recorded with +20 seconds of error, and played back

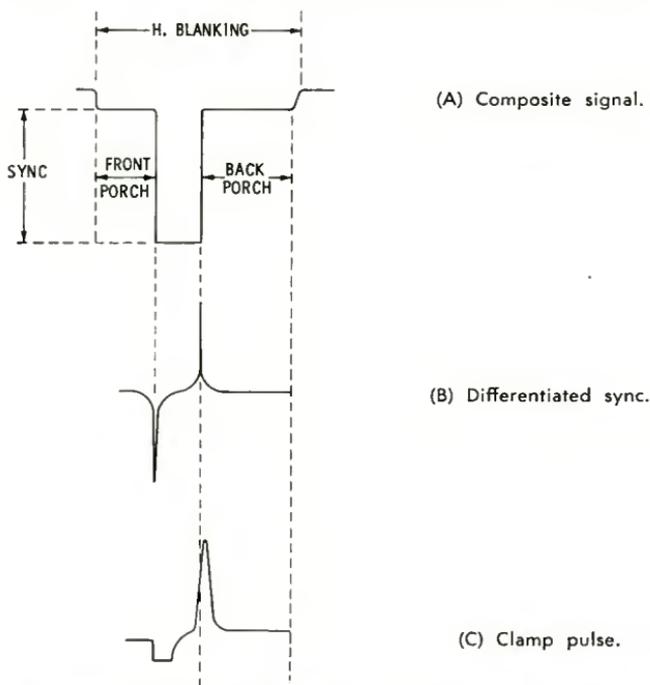


Fig. 4-5. Deviation of clamp pulse from sync for back-porch clamping.

with a head with  $-20$  seconds error, then the effective error is 40 seconds, which is  $\pm 0.06$  or a total of 0.12 microsecond.

By employing 0.015-microsecond taps (5 seconds of arc) on the delay lines, it is possible to set for  $\pm 0.0075$ -microsecond errors in each channel. (A 0.0075-microsecond error is indistinguishable from zero error.)

The adjustment of electronic quadrature circuits as well as the mechanical adjustments for quadrature (when required) on Ampex heads are covered in Section 6.

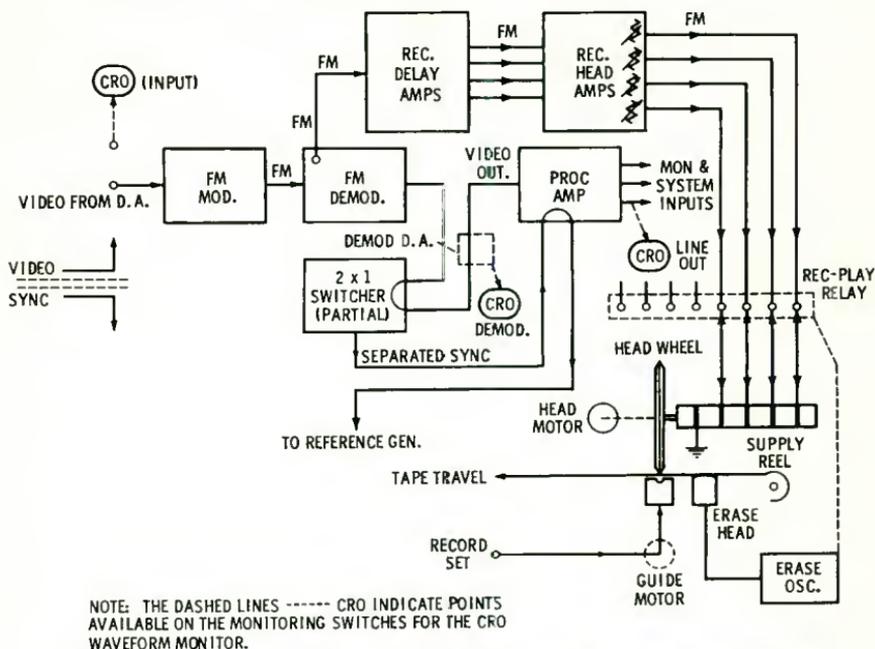


Fig. 4-6. Block diagram of video circuits in the RCA TRT-1B in Record mode.

### 4-3. VIDEO-HEAD DRIVERS

The head-driver amplifiers raise the FM signal to a sufficient level for recording the video tracks on the tape (about 100 milliamperes of FM current to the brushes) and provide individual amplitude controls so that each head may be driven for its optimum characteristics (see Section 6).

A portion of the FM current is rectified and delivered to a tap on the record current meter for monitoring the relative value of current in each head, as shown in Fig. 4-7A. The RCA system uses an additional tap for indication of total head current. Rectified current is taken from across a low value of resistance at the common slip-ring and brush assembly as shown in Fig 4-7B for this measurement.

The slip-ring connections for the Ampex system are shown in Fig. 4-8. The heads are numbered 1-4-2-3, corresponding to the respective connections on the slip-rings-brush assembly. As discussed later in this section, the playback switching sequence is channels 1-4-2-3.

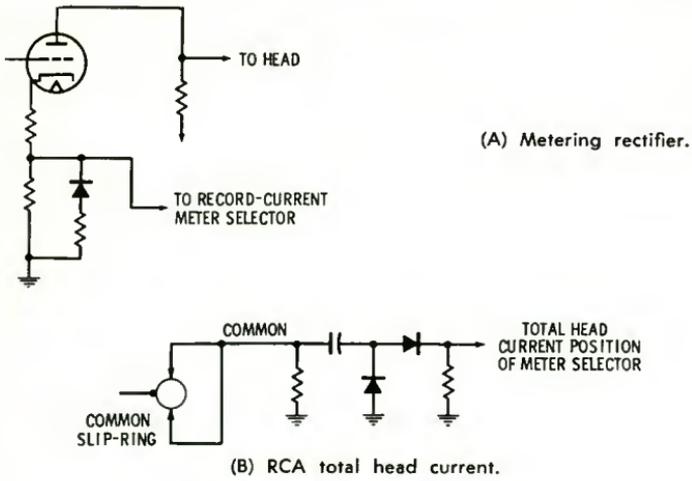


Fig. 4-7. Monitoring head currents.

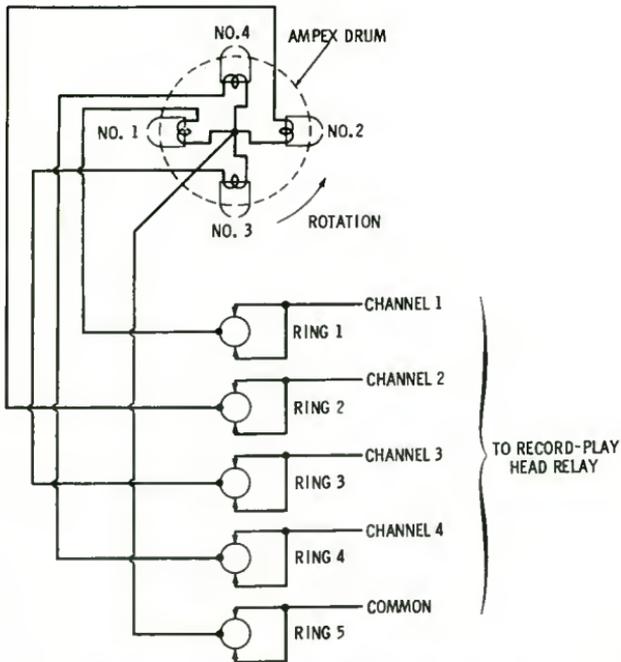


Fig. 4-8. Ampex head and slip-ring numbering.

The RCA configuration is given in Fig. 4-9. The heads are numbered consecutively, 1-2-3-4, but the corresponding channel feeds are taken from alternate slip rings, as shown.

The above arrangements tend to minimize crosstalk in the slip-ring assembly. This is particularly important during the vertical-sync interval. As discussed in Section 5, Head No. 1 in the RCA system and Head No. 4 in the Ampex system are in contact with the tape at the vertical-sync time.

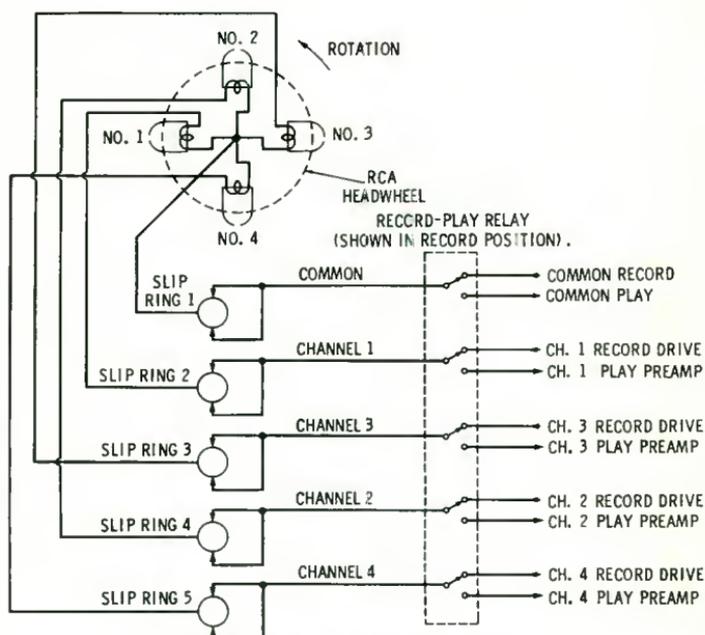


Fig. 4-9. RCA head and slip-ring numbering.

#### 4-4. MASTER ERASE HEAD

In the Record mode, the tape is erased across its entire width by means of a high-frequency (approximately 100 kc) oscillator. Provision is also made to record only the audio signal and not disturb the video recording. In this case, the master erase is disabled and only the audio erase head is energized.

NOTE: Other units shown in Fig. 4-6 are discussed in the Playback description which follows. In the Record mode, monitoring of the signal is complete, insofar as picture monitors are con-

cerned, only up to the FM input channel. Video head currents, which depend on amplitude of video (actually FM) drive, are monitored by a meter indication (shown in Fig. 3-8).

#### 4-5. PROPERTIES OF TELEVISION TAPE

The physical and magnetic properties of the tape itself are highly important because of the high head-to-tape velocity, high tension, and tremendous pressure exerted in video recording and playback. The tape employs a specially prepared synthetic gamma ferric oxide having needle-like particles less than 1 micron in length and oriented transversely rather than longitudinally as in the familiar sound-recording tapes. The extremely high-output oxide material is suspended uniformly in a special heat-resistant binder system, which, in turn, has been treated with a dry lubricant to reduce static and dynamic friction to a minimum. The coating provides a very firm anchorage to the tough, 1-mil Polyester (PE) backing.

A magnetic coating of approximately 460 microinches on the 1-mil Mylar base (see Chart 4-1 for exact specifications) poses a major problem in signal-to-noise ratio for the following reasons:

Chart 4-1. Properties of Scotch Brand No. 179 Video Tape.

PHYSICAL PROPERTIES	
Color .....	Dark Red
Backing Material .....	Polyester (PE)
Thickness in mils	
Backing .....	0.92
Coating .....	.46
	Total 1.38
Ultimate Tensile Strength	
2" Wide—Room Condition .....	.56#
PSI .....	25,000
PSI @ 150°F .....	20,500
Yield Strength	
5% Stretch in 2" Width .....	.30#
Elongation at Break .....	100%
Coefficient of Friction .....	0.28
Residual Elongation .....	0.5%
Standard Width .....	2.000 ins.
Slitting Tolerances .....	+ .000 ins., - .004 ins.

Chart 4-1.—Continued

<b>Toughness</b>	
Tear—grams .....	12
Impact—Kg—cms .....	70
<b>Coefficient of Expansion<sup>1</sup></b>	
Humidity (units per % RH change) .....	$1.1 \times 10^{-5}$
Temperature (units per °F) .....	$2 \times 10^{-5}$
<b>Temperature Limits for Safe Use</b>	
Low .....	-40°F
High .....	+250°F
Wear life, or reusability <sup>2</sup> .....	100 passes
<b>MAGNETIC PROPERTIES</b>	
Oxide Orientation .....	Transverse
Intrinsic Coercivity (Hci) Oersteds .....	240
Retentivity (Brs) Gauss .....	1000
Remanence (Flux Lines/¼ track) .....	Lengthwise.....
	Crosswise .....
Relative Output in db @ 1% distortion <sup>3</sup>	
15 Mil Wave Length .....	Lengthwise..
	Crosswise ...
Relative Sensitivity in db <sup>3</sup>	
15 Mil Wave Length .....	Lengthwise ....
	Crosswise.....
1 Mil Wave Length .....	Lengthwise ....
	Crosswise.....
Erasing Field—Oersteds .....	800
<b>Uniformity at 15 Mil Wave Length<sup>4</sup></b>	
Within a Roll .....	$\pm \frac{1}{4}$ db
Roll to Roll .....	$\pm \frac{1}{2}$ db

<sup>1</sup> These coefficients are unitless and represent the change per % RH (between 20% and 80% RH) or degree F (between -30° to +130°F).

<sup>2</sup> Wear life on rotating head recorders depends upon head pressure, 100 passes is average.

<sup>3</sup> At optimum bias (Output referred to *Scotch Brand* No. 111 Magnetic Tape).

<sup>4</sup> Refers to magnetic uniformity of coating only. Backing and equipment parameters which affect head-to-tape contact may produce greater deviations than those noted above.

1. In conventional audio tape, the noise level is referred to erased, or magnetically neutral, tape. For TV tape, the carrier level is always present, and the zero-signal noise level is comparable to the modulation noise of the tape. It may be 10 to 15 db higher than the erased noise level.
2. The video head pole tips must actually bite into the tape, as compared to the relatively smooth contact in conventional audio tape.
3. The highest carrier frequency (approximately 7 mc) ap-

proaches 0.2 mil recorded wavelength (refer to Table 2-1). At this frequency, at least 50% of the signal intensity is supplied by the first 20 microinches of coating, and all of the effective particles are within the first 100 microinches (one-fourth of the total tape coating). At the lowest carrier frequency of 1 mc (1.5 mil wavelength) about 20% of the signal is contributed by the back of the 460-microinch coating. Since the particles of magnetic oxide are themselves roughly 10 microinches in diameter and 40 microinches long, extreme smoothness of coating is mandatory—especially at the higher FM frequencies. When the coating becomes uneven through wear, irregularities cause the pole tips to “bump away” momentarily from the tape and white flashes or “drop outs” results. This effect, coupled with some loss in picture resolution, is normally the first sign of excessive tape wear.

NOTE: “Drop outs” may also occur on a new tape, but, here, loss of picture resolution does not accompany them. In this instance, the tape can be “polished” by running the entire reel through normal operation on the machine several times before regular programming use.

#### 4-6. PLAYBACK PREAMPLIFIERS

The video circuits concerned with playback of TV-tape signals are shown in block form in Fig. 4-10. Ampex playback systems are essentially the same in principle but the actual method of switching differs.

The RF signal induced into the video heads is routed through the contacts of a record-play relay to the playback preamplifier where cascode amplifier circuits provide high amplification with low noise and stability, and low input impedance. Triodes are used with the plate of one triode directly coupled to the cathode of the other, as shown in Fig. 4-11. The first triode must be a low-noise premium tube, because the greatest percentage of noise is introduced in this stage; amplification is obtained almost entirely by the second triode. The three other channels employ duplicates of the circuit given in Fig. 4-11.

#### 4-7. PLAYBACK DELAY AMPLIFIERS

The playback delay amplifiers (quadrature correctors) are the same in principle as that described for recording (RCA only) in

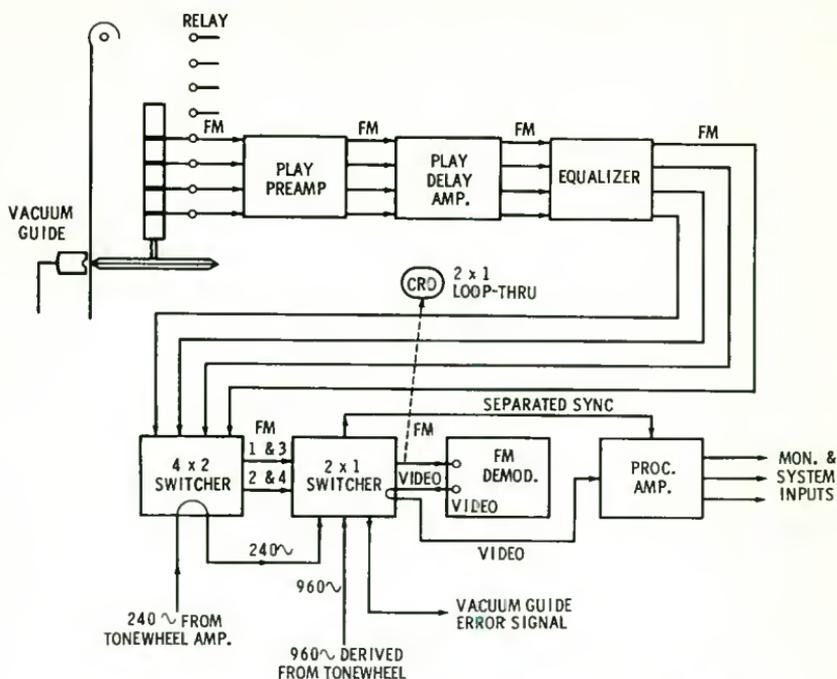


Fig. 4-10. Block diagram of RCA video circuits in Play mode.

Section 4-2. Fig. 4-12 illustrates the low-impedance tapped delay line driven by a cathode-follower stage. Each of the four-channel amplifiers (one for each head) employs unity gain in normal op-

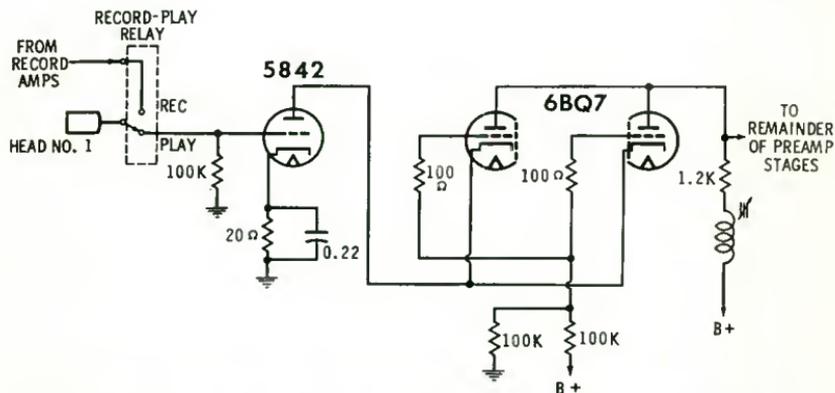


Fig. 4-11. Simplified cascode circuit, video-head preamp for playback.

eration. The sole function is to provide an adjustable electronic correction in the event there is a quadrature difference between the head used for recording and the head used for playback.

#### 4-8. FREQUENCY EQUALIZATION

The video signal is pre-emphasized in the modulator and de-emphasized accordingly in the demodulator to increase the signal-to-noise ratio over that obtainable without such processing. In addition, some means is provided for playback compensation of the video signal (usually acting on the FM signal before demodula-

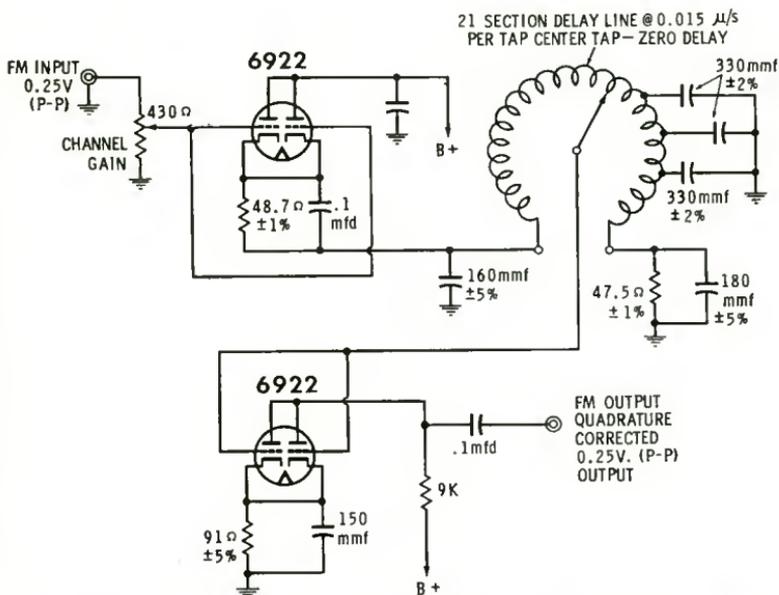
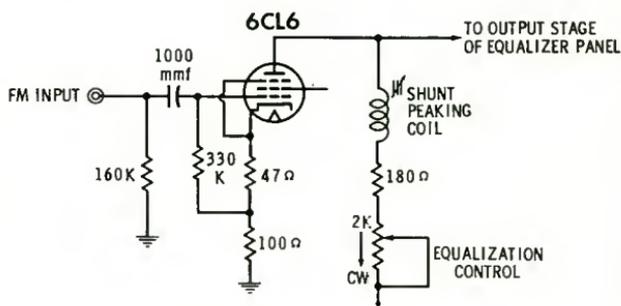


Fig. 4-12. A single channel of the four-channel playback delay amplifiers.

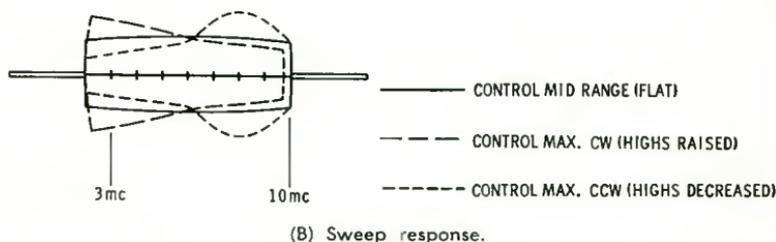
tion) to allow for variations in tape and in characteristics of different systems.

Clockwise rotation of the equalizer control in Fig. 4-13A increases the plate load. At higher plate loads, the normal circuit output capacitances (fixed value) decrease the response at the higher FM frequencies. This action will increase the response to high frequencies in the video signal, as shown by Fig. 4-13B, because the higher video frequencies occur at minimum carrier fre-

quencies. When the control is in mid-range (total plate load of 1,180 ohms), the FM response (hence video response) is flat. (The shunt-peaking coil shown in Fig. 4-13A is aligned to make the response flat at the midrange position of the equalizer control.) As the control is rotated counterclockwise, the plate load is decreased, and the response to the higher FM frequencies is increased. Hence, the response to higher video frequencies is decreased, and that to the lower video frequencies is increased.



(A) Simplified circuit.



(B) Sweep response.

Fig. 4-13. The RCA equalizer panel (used in playback only).

## 4-9. ELECTRONIC CHANNEL SWITCHING

In the playback mode, the four video-head outputs must be sequentially switched to minimize noise and crosstalk, and to prevent two heads from reproducing identical information during the overlap period.

Obviously, switching must be timed with the head revolution. Also, some means is provided to assure that any switching transients fall in the horizontal-retrace period so that they will not be visible in the reproduced picture.

A block diagram of the switcher unit of the Ampex Model 1000-Series systems is given in Fig. 4-14. Switching is accomplished by the four RF gate tubes, which, during the reproduce process act as individual switches for the incoming signals from the video heads. Gating pulses for these tubes are derived from the 240-cycle square-wave output of a photoelectric cell, whose phase is directly related to the angular position of the head drum. Two pulses are required to actuate the switching function—a gating pulse on the control grid and a switching pulse on the suppressor.

The signal to each control grid is a 240-cycle trapezoidal wave, with each trapezoidal wave shifted  $90^\circ$  with respect to the next. These waves provide an initial gate so that each tube, in turn, can conduct when the switching pulse appears. The video signal is added to the gating pulse at the control grid. The actual switching time is determined by a positive excursion of a 480-cycle square wave (with extremely fast rise and decay times) applied to the suppressor grids. This signal is derived by doubling, amplifying, and clipping the 240-cycle input signal. The resultant square waves are then applied to the suppressor grids of the gating tubes through a phase splitter, which delivers in-phase positive pulses to the suppressor grids for channels 1 and 2 and  $180^\circ$  shifted positive pulses for channels 3 and 4.

NOTE: Channel numbering does *not* indicate the order of head switching. Channels are gated 1-4-2-3 (refer to Fig. 4-8).

Only the tube to which the positive 240-cycle gating pulse and the positive 480-cycle switching pulse arrive in coincidence can conduct.

The individual outputs of the four video heads, after amplification in the reproduce preamplifier portion of the record amplifier/reproduce preamplifier unit, are connected to the switcher where they are terminated in 75 ohms impedance. Individual gain controls are provided so that the RF signal can be balanced for each channel. Each signal then passes through two stages of RF amplification (V16002-V16007, V16003-V16008, V16004-V16009, and V16005-V16010 in Fig. 4-14). These are conventional RF amplifier circuits; each employs shunt peaking in the plate circuit and a small interstage time constant to limit the bandwidth to that of the FM signal. The amplified outputs are delivered to the control grids of their respective gating tubes (V16012, V16014, V16013, or V16015), where they are added to the gating signals.

The 240-cycle signal, originated by the photoelectric cell and processed to form a sinusoidal wave in the drum servo control

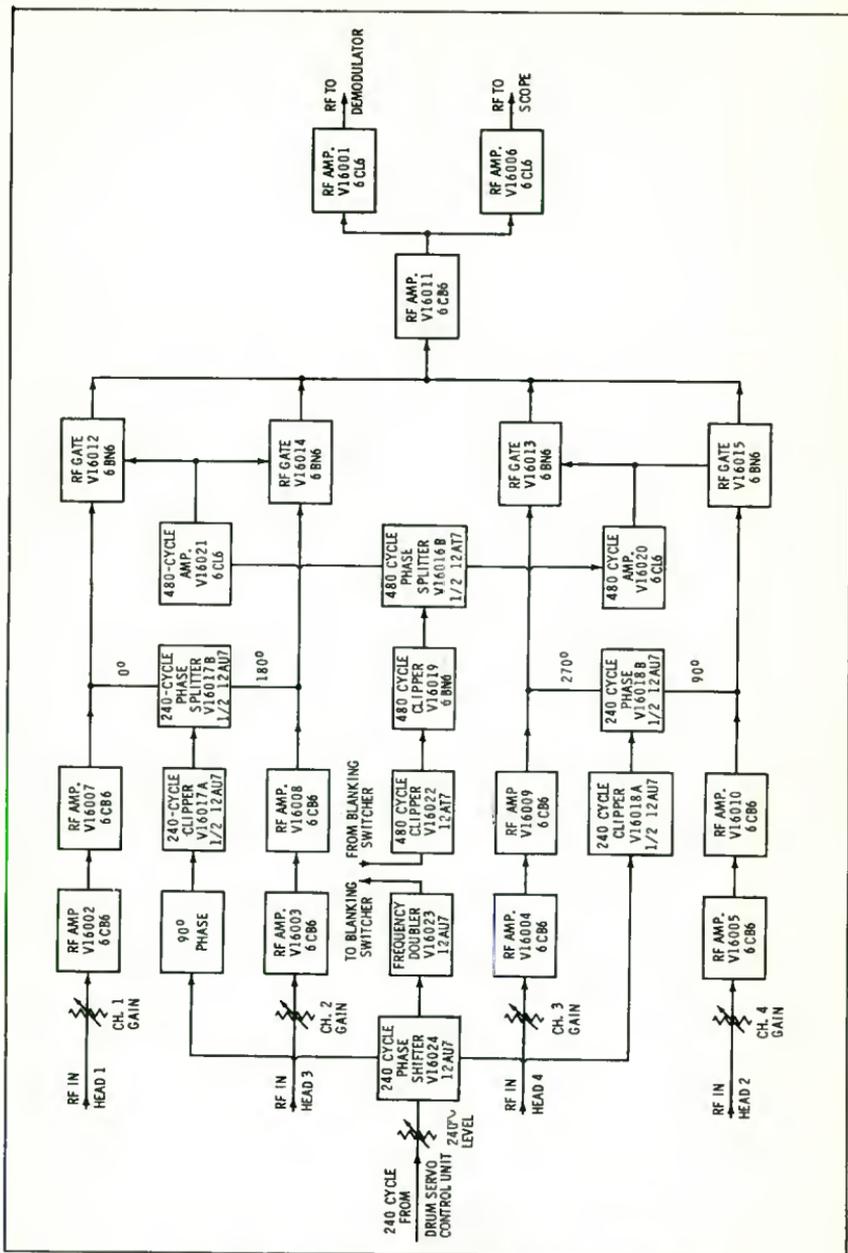


Fig. 4-14. Block diagram of the Ampex switcher.

unit, enters the switcher at the level control (Fig. 4-14). The properly adjusted signal is then fed to the grid of cathode-follower stage V16024A, which provides a low-impedance input to a variable phase-shifting network which follows. This phase shifter controls the switching time relative to the angular position of the head drum. A total phase variation of approximately  $40^\circ$  is possible. The signal is next routed to the grid of amplifier stage V16024B. (V16024 is shown as one block in Fig. 4-14.)

The gating-channel output of V16024B is applied to V16017A and V16018A. A  $90^\circ$  phase-shift network is added between V16024B and V16017A. The circuits of V16017 and V16018 are identical from this point, so only that of V16017 will be described. V16017A amplifies the 240-cps sinusoidal signal, and diodes clip the output. The result is a trapezoidal wave fed to the grid of phase-splitter stage V16017B. This stage provides two  $180^\circ$  out-of-phase signals to the grids of V16012 and V16014, where they are added to the video signals. Resistors compensate for low-frequency tilt on the gating pulse, so that the clipped portion of the waveform remains flat. Controls are provided which set the voltage level at which the top of the gating pulse is clamped by the diodes. Thus, the proper bias on the grids of V16012 and V16014, is determined.

The action of V16018 is identical to that described for V16017; gating pulses are supplied from this stage to V16013 and V16015. Thus, four 240-cps trapezoidal waves, each  $90^\circ$  displaced from the next, are applied to the control grids of the gating tubes.

The 240-cps output of V16024B is also taken through a transformer to a full-wave rectifier (doubler) circuit. An output of approximately 6-volts, at 480-cps, is developed. A Balance control equalizes the amplitude of the waveform and eliminates any 240-cycle component. A coil and capacitor form a resonant bandpass filter tuned to 480 cps. Thus, a pure 480-cps sinusoidal waveform is delivered to the grid of V16023B.

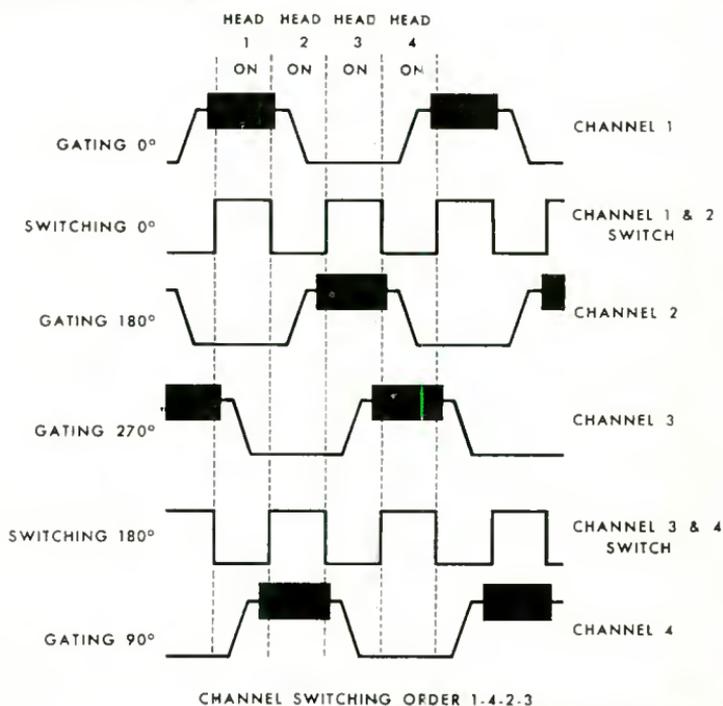
Stages V16023B and V16023A amplify and clip the signal. The symmetry of the resultant 480-cycle square wave is adjustable and is used to control the DC level of the signal fed to a pair of clipping diodes.

The output of V16023A is routed through a blanking switcher unit (described later). A nominal square wave is delivered to the grid of V16022A from the blanking switcher. This circuit provides a third stage of amplification and clipping, with a very good square waveform delivered to the grid of amplifier V16022B, which supplies a 60-volt square wave to V16019.

V16019 performs the final and most important clipping action. The waveform at the plate is derived from a very small segment of the grid signal; therefore, its rise time is extremely short. To preserve this rise time, wideband techniques must be employed. Hence, a 5-microhenry shunt-peaking coil is employed in the plate circuit of this stage.

V16016B is a phase-splitter circuit with each of its outputs feeding a conventional video amplifier (V16020 or V16021). These video amplifiers, in turn, each drive the suppressor grids of two gating tubes. The suppressor grid bias on all four gating tubes is adjusted by a single control.

The foregoing process has generated the two pulses necessary to cause the gating tubes to conduct. The action of these pulses in the gating is illustrated in diagram Fig. 4-15. The sequentially switched outputs of the gating tubes are combined in the plate circuits of these stages (the plates are connected together) to form a continuous RF signal.



Courtesy Ampex International Operations, Inc.

**Fig. 4-15. Ampex gating and switching diagram.**

From the block diagram of the switcher (Fig. 4-14), it was noted that the 480-cycle switch pulse is routed through a unit termed the blanking switcher. This unit delays the time of head switching so that it occurs during the horizontal-blanking interval. Using the block diagram of Fig. 4-16, and the waveform diagram of Fig. 4-17, the principle of operation is as follows:

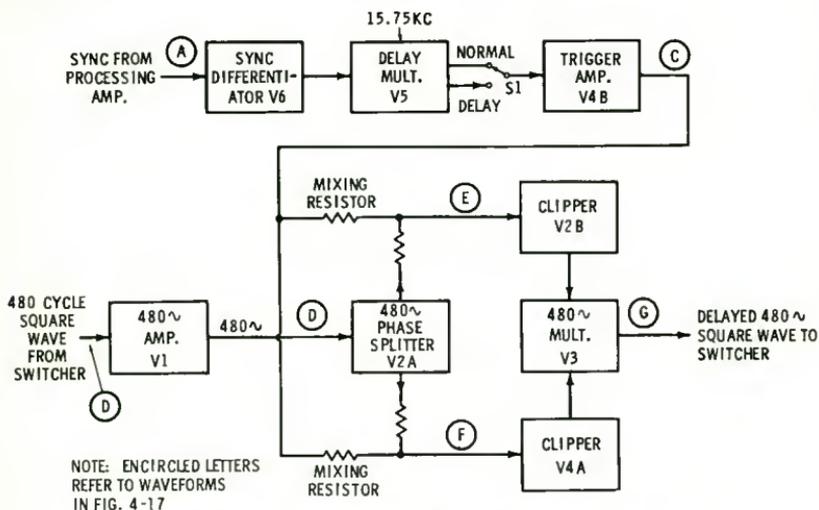
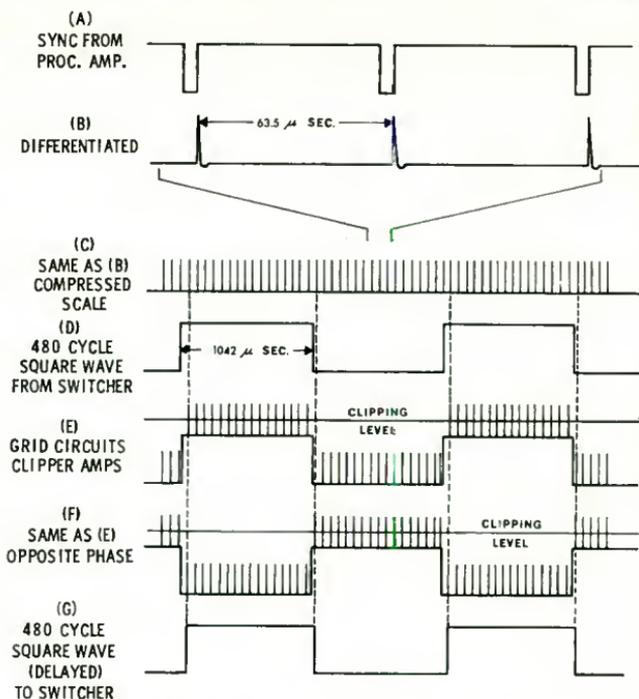


Fig. 4-16. Block diagram of the Ampex blanking switcher.

1. The 480-cycle square wave developed in the switcher unit from the photoelectric-cell signal (waveform D) is amplified by V1A. This signal is clipped by a pair of diodes to provide sharp leading edges; the signal is again amplified by V1B and then fed to phase splitter V2A. Square waves of opposite polarity appear at the cathode and plate of V2A.
2. Negative sync pulses from the video processing amplifier (waveform A) are fed to the grid of V6B. The plate load of this stage is a differentiating transformer whose secondary is connected to supply positive pulses, corresponding to the trailing edge of the sync pulses, to amplifier V6A. The amplified negative output pulse is used to trigger free-running multivibrator V5.
3. Multivibrator V5 serves two purposes: (1) it provides pulses to the circuitry which follows (even if a sync pulse is not present to trigger it); (2) with S1 in its Out (delay) position, it provides delayed pulses which cause switching transients to ap-



Courtesy Ampex International Operations, Inc.

Fig. 4-17. Ampex blanking switcher waveforms.

pear in the picture (this latter function is utilized when adjusting the blanking switcher). The free-running frequency of the multivibrator is adjusted by a Frequency control potentiometer to a frequency slightly lower than the 15,750-cps line rate.

When S1 is in the Normal position (where it should be placed except when adjusting the unit), the output of the multivibrator is taken from V5 and routed through a clipping circuit. Here, the positive spikes are removed from the signal and the remaining negative pulses are fed to the grid of V4B. Thus, sharp, positive pulses (waveforms B and C in Fig. 4-17), corresponding to the trailing edge of the original sync pulses, appear at the plate of V4B.

- There are now 3 signals—two 480-cps square waves of opposite polarity (which were originated by the photoelectric cell scanning the head drum), and a 15,750-pps signal corresponding in time to the trailing edges of the sync pulses. The 15,750-pps

signal is added to both 480-cps square wave signals in the mixing resistors. The resulting 2 composite signals (waveforms E and F of Fig. 4-17) are then applied to a grid of their respective clamped grid clipper (V4A and V2B). Here, the positive tips of the 15,750-pps signal are clamped to zero volts by diode action between the grid and the cathode. The cutoff level of the tubes is such that only the gated tips of the 15,750-pps signal (riding on the positive portion of the 480-cps square waves and indicated by clipping level on waveforms E and F) will cause the tube to conduct. These tips appear at the plates of V4A and V2B as negative pulses.

Since the outputs of these stages are connected to opposing circuits in multivibrator V3, the multivibrator will be alternately triggered by the action of the first negative pulse in the output of either V4A or V2B. Thus, the leading and trailing edges of the waveform from the multivibrator (waveform G in Fig. 4-17) are determined by the first negative spike in each clipped waveform from V4A and V2B. The reformed 480-cps square-wave output, now synchronized with the trailing edge of the first sync pulse that occurs when the heads are to be switched, is returned to the switcher where it determines the precise moment of head switching.

The free-running frequency of multivibrator, V3, is adjusted so that it is slightly less than 480 cps. When the blanking switcher is bypassed (by a switch in the switcher unit), the leading and trailing edges of the 480-cps square wave developed in the switcher unit dictates when the heads will be switched. Under these circumstances, the switching time will be located randomly with respect to the video information being reproduced. The blanking switcher recreates this square wave from the switcher, but the leading and trailing edges of the waveform are delayed approximately 2 microseconds (determined by the delay inherent in the processing amplifier) after the trailing edge of the first sync pulse which occurs following the original switching time.

The basic principles of the RCA video-switching system are shown by Fig. 4-18. The  $4 \times 2$  switcher converts the four channel inputs from the equalizer chassis (Fig. 4-10) into two outputs; Channel A contains outputs from heads 1 and 3, while Channel B contains outputs from 2 and 4. The channels are gated by the 240-cps square wave derived from the head tachometer. The  $2 \times 1$  switcher combines these two inputs into one channel as shown.

Note from the block diagram of Fig. 4-10 that the  $2 \times 1$  switcher feeds the switched FM to the demodulator, and also receives the demodulated video from the demodulator. Timing generators serve to properly phase head switching under horizontal blanking (first half of H sync) and also separates sync pulses for use in the video-processing amplifier.

The sync-pulse circuit of the  $4 \times 2$  switcher consists of a pulse amplifier; a delay multivibrator; two one-shot (square-wave) multivibrators; and two phase-splitter, cathode-coupled amplifiers. (See Fig. 4-19.) Sync pulses are applied to the  $4 \times 2$  switcher from the 240-cycle tonewheel amplifier. These pulses are approxi-

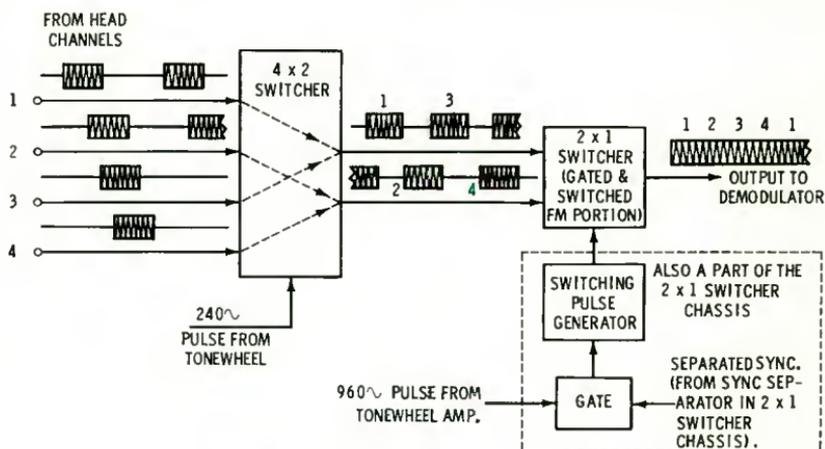


Fig. 4-18. Block diagram of the RCA video switching circuits.

mately 100 microseconds in duration and occur every 4,166 microseconds, or 240 times per second. The pulses are amplified and differentiated by the pulse-shaper stage and are used to synchronize two sync channels. The output of the pulse amplifier is applied to multivibrators V2 and V5. Multivibrator tube V2 is triggered by the sync pulses and produces square waves that have a duration of 2,083 microseconds and occurring at the 240-pps rate. These square waves are applied to phase-splitter, cathode-coupled amplifier V3.

Multivibrator V5 is used as a delay and is so designed that its output is delayed for one-half of the pulse duration of multivibrator V2. Multivibrator V5 has a pulse width of 1,041 microseconds. The trailing edge of the pulse output is differentiated and used to trigger one-shot multivibrator V6 which has a pulse width of 2,083

microseconds. The output of multivibrator V6 is applied to phase-splitter, cathode-coupled amplifier V7.

Since the phase-splitter, cathode-coupled amplifiers for each channel are identical, only one circuit (Fig. 4-20) is discussed in detail. The square-wave output from V6 is applied to one grid of the phase-splitter amplifier V7. When the signal voltage on the grid is positive, the signal voltage output on the associated plate is negative and the cathode voltage is positive. Since the two cath-

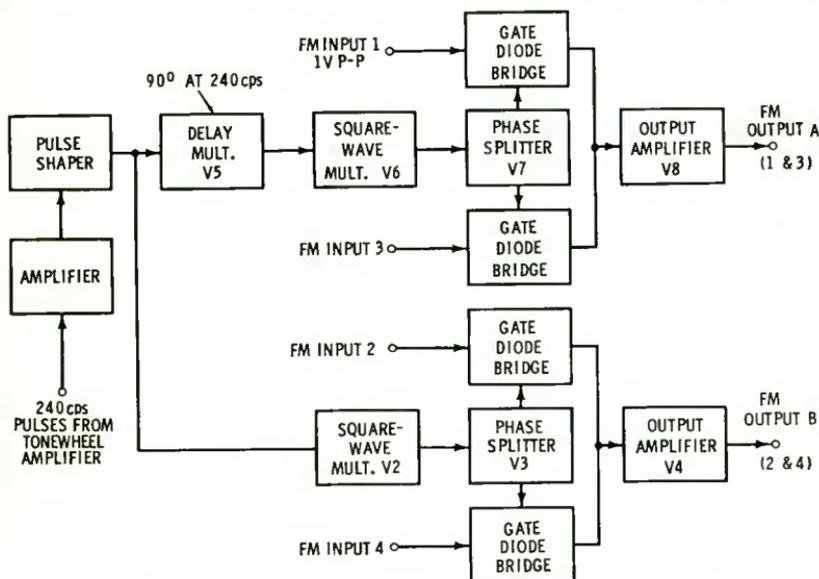
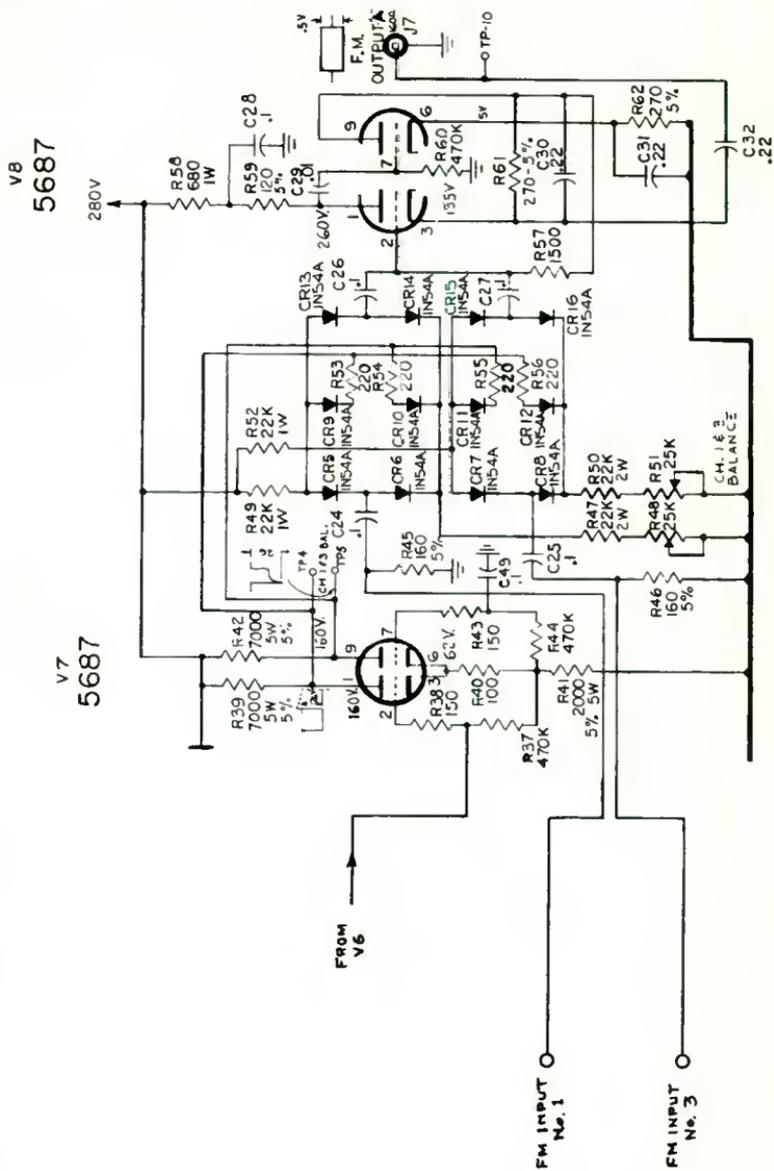


Fig. 4-19. Simplified block diagram of the RCA  $4 \times 2$  switcher.

odes are common, the positive cathode voltage causes the other grid to appear negative. This, in turn, produces a positive output at the second plate (pin 9). Therefore the phase-splitter, cathode-coupled amplifier provides two square-wave outputs with opposite polarities. These two outputs are used to enable and inhibit two six-diode gate circuits.

Channel inputs 1 and 3 are applied to one sync channel and channel inputs 2 and 4 are applied to the other sync channel. Each sync channel is used to control two six-diode gate circuits. The signals for FM channels 1 and 3 are combined in the output of one pair of diode gates to form FM channel A; the signals for FM channels 2 and 4 are combined in the output of the other pair of diode gates to form FM channel B.



Courtesy Radio Corporation of America

Fig. 4-20. Channels 1 and 3 (A output) of the RCA 4x2 switch.

The outputs of the phase-splitter, cathode-coupled amplifiers are applied to the center diodes of the six-diode gates. These outputs inhibit and enable the gate circuits. When the cathode of diode CR9 (Fig. 4-20) is negative and the anode of diode CR10 is positive, the diodes conduct. This clamps the other diodes in the gate with polarities that prevent their conducting, and the FM signal is effectively disconnected from the grid of the output tube. At the same time, the cathode of diode CR11 is positive with respect to the anode and the anode of diode CR12 is negative with respect to the cathode. These diodes are open, thereby permitting the other diodes of the gate to conduct. The FM signal applied to this gate is effectively connected to the grid of the output tube. The timing is such that the on times of the gates effectively straddle their respective head signals.

The output of each pair of six-diode gates is applied to a totem-pole amplifier (V8 of Fig. 4-20) which has a cathode-follower low-impedance output. The totem-pole amplifiers produce an over-all FM signal gain of approximately 0.5

Since the headwheel of the system turns at 240 rps, each head is in contact with the tape one quarter of the time required per revolution, or for 1,041 microseconds. Each diode gate is enabled for 2,083 microseconds—twice the time needed for any one signal. The enabling of one pair of diode gates is delayed 1,041 microseconds, therefore the FM signals of the channel B output will straddle the FM signals of the channel A output. Because of this delay, the four FM signals in the two outputs from  $4 \times 2$  switcher are effectively interlaced.

The following explanatory notes are for the block diagram of the RCA  $2 \times 1$  switcher (Fig. 4-21). The numbers correspond with the encircled numbers on the diagram.

1. FM input A consists of signals from channels No. 1 and No. 3. FM input B consists of signals from channels 2 and 4.
2. The two FM gates are driven in phase opposition, so that when one is on, the other is off. Note that the two gates have a common output connection.
3. The FM stages which follow the gating circuits include a high peaker or equalizer to boost the high-frequency response of all channels equally. This action supplements the frequency compensation action of the four-channel equalizer encountered earlier in the video-playback system.
4. A video signal from the demodulator is introduced in the lower left corner of the diagram to operate a sync separator. Sync



pulses are needed in this chassis to control the timing of the switching operation, but the sync separator provided here also serves all other areas where separated sync pulses are required.

5. A cathode follower and rectifier following the sync separator provide a DC-bias signal for automatic control of the shoe-servo system. If sync pulses are not present, the bias voltage changes and disables the shoe-servo system to prevent it from operating with only a noise input signal.
6. After further clipping, the separated sync pulses are used to control the frequency and phase of a blocking oscillator in a modified *Synchroguide* circuit (a form of automatic-frequency control). The *Synchroguide* circuit has a delay line in its feedback control loop so that its output pulses are *advanced* in phase relative to the separated sync pulses. Thus, the switching action in the FM gates can be made to occur during the first half of the appropriate horizontal-sync periods in the FM signal, taking into account the fact that the separated sync signal has been subjected to appreciable delay in the demodulator and sync separator stages.

The control tube in the *Synchroguide* circuit is actually a specialized form of phase detector. A tuned circuit at the plate of this control tube senses 960-cps timing variations in the separated sync waveform, and provides an appropriate error signal for the shoe-servo system.

Pulses generated by the blocking oscillator are used for two purposes:

- A. Trigger pulses for the gating-function generator which drives the pair of FM gates.
  - B. Pushout pulses to remove switching transients from the separated sync waveform before it is used in other chassis.
7. A bistable multivibrator is used as a gate to select the first horizontal-sync pulse during each overlap period (when two heads are simultaneously in contact with the tape). The 90-microsecond, 960-cps pulses from the tonewheel amplifier are adjusted to occur within the overlap periods. The leading edge of each 960-cps pulse flips the bistable multivibrator to the off condition, and the next line-frequency pulse from the *Synchroguide* restores it to the On state. The subsequent *Synchroguide* pulses then do nothing, until the next 960-cps pulse again flips the multivibrator off. The transition from the Off to the On states generates a trigger impulse for the following stage.

8. The actual gating-function generator is a bistable multivibrator operated as a binary divider—each trigger impulse causes a reversal of the conduction state. To assure operation in the proper phase, 240-cps trigger pulses are applied to one side only. The system is so designed that the 240-cps tonewheel pulses occur near the middle of the interval when head No. 1 is scanning the tape, and the 240-cps trigger connection assures that FM input A (which always carries the signal from head No. 1) is in service when the tonewheel pulse occurs.
9. The sync output channel includes a means for removing the severe switching transients which occur during every sixteenth or seventeenth sync pulse. Two different pushout pulses are added to the sync waveform (one derived from the *Synchroguide*, the other from the trigger pulse for the gating-function generator, with appropriate delay compensation in each case). These pulses are narrower than the desired sync pulses and serve to push the unwanted transient beyond the normal amplitude range. A subsequent clipping stage then “cleans up” the waveform, removing the pushout pulses and the transients. The pushout pulse derived from the trigger for the gating function generator is adequate for normal operation of a single TV tape machine. The *Synchroguide* pushout pulses are provided as a safety factor to assure proper handling of so-called “RF copies” which may have recorded-in switching transients that do not necessarily coincide with those in the final playback machine.

The circuit in Fig. 4-22 is an adaptation of the circuit widely used as the automatic frequency control and horizontal oscillator in RCA television receivers.

The “heart” of the circuit is blocking oscillator V5B. Positive feedback from plate to grid is provided by autotransformer action in T3. When V5B starts to conduct for any reason, the positive feedback quickly drives the stage all the way to saturation. As soon as the output ceases to increase (because of saturation), the positive feedback causes a very rapid decrease in current, and the grid voltage is driven well below the cutoff level. The stage then remains cut off until the grid voltage climbs back to the cutoff level at a rate determined by the RC time constant in the grid circuit.

A tuned circuit between the tap on transformer T3 and the plate supply helps to stabilize the oscillator by modifying the grid waveform.

Automatic frequency control for V5B is provided by returning the grid-bias resistor of the oscillator to the cathode circuit of control tube V5A. V5A, a specialized form of phase detector, compares the oscillator output with the separated sync waveform.

The oscillator output signal used for the phase detector is a rather crude sawtooth, originally developed across a .001 capacitor in series with a 39K charging resistor in the plate circuit of the oscillator. (A linear sawtooth is not required in this case, and the actual waveform is so distorted that some writers actually refer to it as a parabola.)

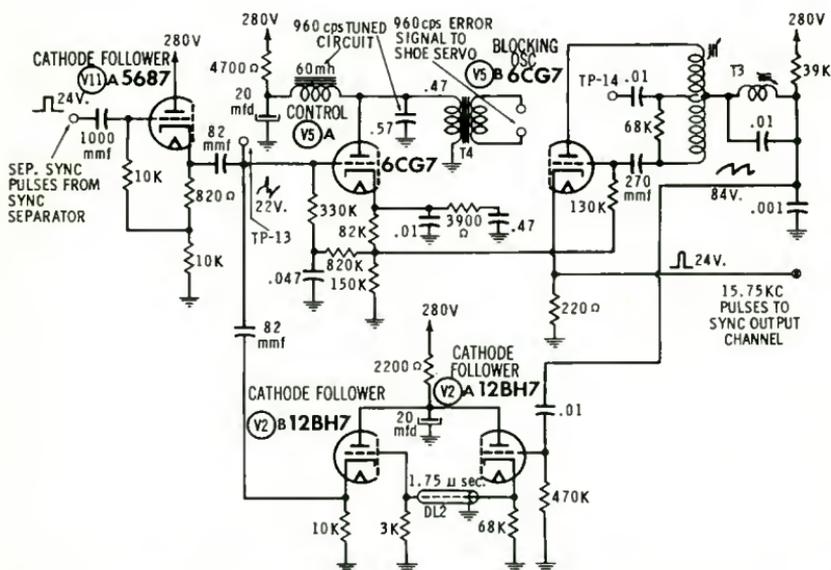


Fig. 4-22. Simplified schematic of the *Synchroguide* section of the RCA 2 × 1 switcher.

In a conventional *Synchroguide* circuit, the sawtooth signal from the oscillator is applied directly to the grid of the control tube; but in this adaptation, the sawtooth signal is delayed by 1.75 microseconds to produce a relative phase *advance* at the output of V5B. Cathode followers V2A and V2B are used for isolation and impedance matching at the two ends of delay line DL2. V1A is a current-stabilized cathode follower which isolates the circuit from the sync-output channel.

The separated sync waveform and the delayed sawtooth signal from the blocking oscillator are mixed at the grid of V5A. Refer

to Fig. 4-23 for an explanation of the basic action of the control tube, including the manner in which a phase advance is achieved.

If the vacuum-guide shoe position is not correct when a TV tape program is being played back, timing variations will occur at a 960-cps rate in the separated sync waveform. The time constant in the *Synchroguide* prevents the output pulses from following these variations, but the current through the control tube would have a 960-cps component if there is an error in shoe position. A 960-cps tuned circuit, consisting of a 60-mh coil and

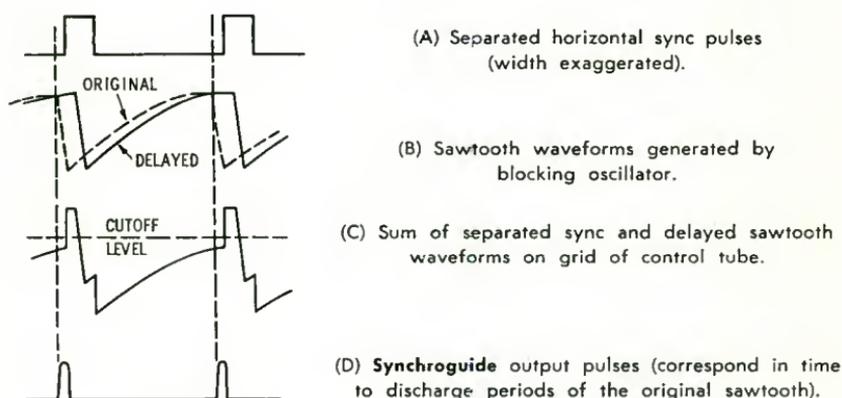


Fig. 4-23 *Synchroguide* waveforms.

a 0.57-mfd capacitor, is provided at the plate circuit of V5A. The voltage across this tuned circuit is coupled via transformer T4 to the shoe-servo chassis where it serves as an error signal.

The pulse advance feature of the *Synchroguide* circuit is achieved by the following action:

The signal applied to the grid of the *Synchroguide* control tube is the sum of the separated sync pulses (waveform A of Fig. 4-23) and the delayed sawtooth waveform (waveform B of Fig. 4-23).

In normal operation, the relative timing of the two waveforms is such that only the first 25 to 30% of each horizontal sync pulse rides near the peak of the sawtooth, as shown by waveform C. The balance of the pulse drops into the "valley" of the sawtooth, below the control-tube cutoff level.

Current flows in control tube V5A only during the relatively brief periods when C exceeds the cutoff level; however, an RC filter in the cathode circuit smooths out the current pulses to

develop an essentially constant bias voltage for blocking oscillator V5B.

If the relative timing of the sawtooth and pulse waveforms shifts for any reason, the duty cycle of the current pulses is altered and the bias voltage developed by filtering the current pulses is automatically shifted up or down to adjust the frequency of the blocking oscillator enough to bring it back into proper synchronism with the separated sync signal.

The time constant of the filtering arrangement in the cathode circuit of V5A is sufficiently long that the bias voltage changes only on the basis of average control information integrated over a period of several milliseconds. This time constant gives the circuit a flywheel effect, providing excellent noise immunity. (An occasional spurious noise pulse or an occasional missing sync pulse has very little effect on the integrated bias voltage.)

The manner in which delay line DL2 produces a pulse advance in the *Synchroguide* circuit is illustrated by waveforms B and D in Fig. 4-23. The *Synchroguide* output pulses occur during the discharge period of the original or undelayed sawtooth that is produced by the blocking oscillator; hence they occur earlier than the separated sync pulses with which the delayed sawtooth signal is compared in the control tube.

The need for the pulse-advance feature results from the delays to which the tape playback signal is subjected in passing through the demodulator and the sync separator. To permit complete removal of the switching transients resulting from the sudden discontinuity in the FM carrier when the gates in the  $2 \times 1$  switcher operate, the switch is timed to occur during the first half of every 16th or 17th horizontal-sync pulse. If separated sync were used directly (without the pulse advance) to control the switch timing, the switch would occur too late.

Referring to the block diagram in Fig. 4-21, it is obvious that the proper phasing of gate multivibrator V9 and binary divider V14 is highly important to the proper switching of FM channels during horizontal blanking time.

These circuits, shown in Fig. 4-24, control the operation of the actual  $2 \times 1$  switcher. The objective is to initiate a switch from FM input A to B (or vice versa) during the first horizontal-sync pulse that occurs during an overlap interval (while two heads are simultaneously in contact with the tape).

960-cps pulses from the tonewheel amplifier provide a means of sensing the overlap periods. While the overlap periods have a

nominal duration of 130 microseconds, the tonewheel pulses are adjusted for a width of about 90 microseconds to provide a realistic tolerance for their location. Since a full-line period is nominally 63.5 microseconds, there is sure to be at least one horizontal sync pulse during the period of each 960-cps tonewheel pulse.

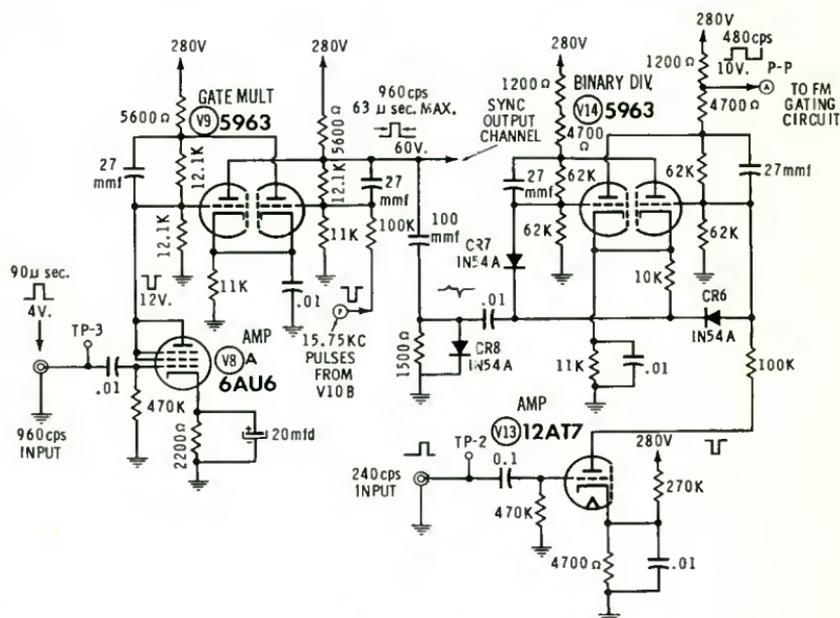


Fig. 4-24. Gate and binary divider circuits.

Triode-connected amplifier V8 delivers the 960-cps trigger pulses by direct coupling to one side of multivibrator V9.

Bistable multivibrator V9 is used as a gating circuit. Separate trigger sources are used for the two sides, and the cross-coupling networks from each plate to the opposite grid are DC connections, so that when either side is conducting it will hold the other side cut off indefinitely until an appropriate external trigger is applied. (The 27-mmf capacitors between each plate and the opposite grid serve only to bypass the high-frequency energy around the DC coupling resistors. This speeds up the operation of the flipping action.)

The tonewheel pulses introduced from V8 serve to cut off the left side of V9 and make the right side conduct. (In the description

of the block diagram in Fig. 4-21, this state was arbitrarily called the Off condition.)

15.75 kc pulses derived from the *Synchroguide* circuit serve to cut off the right side and make the left side conduct. (This state is arbitrarily called the On condition.) The *Synchroguide* pulses are coupled to the multivibrator through triode amplifier V10B.

Since the 15.75 kc trigger pulses occur much more frequently than the 960-cps pulses, the multivibrator operates most of the time in the On condition (left side conducting). Most of the 15.75 kc trigger pulses do nothing, because they find the right side of the multivibrator already cut off; the only time the circuit can flip to the On state is shortly after a 960-cps pulse has put it in the Off state. The off period never lasts longer than one line period, or about 63.5 microseconds, and it is usually much less.

The 960-cps pulse signal at the plate of the left side of V9 is differentiated by a 100-mmf capacitor and 1,500-ohm resistor. The positive pip is effectively shorted out by diode CR8, leaving only the negative pip, corresponding to the transition from the Off to the On states in V9. This pip is used to trigger the next multivibrator, V14.

V14 is also a bistable multivibrator, but it differs from V9 in that triggers from a single source are coupled through diodes CR6 and CR7 to both sides simultaneously. This makes the circuit act as a binary divider, since each trigger pulse causes a reversal of the conduction state by cutting off whichever side was previously on. The trigger pulses occur at a 960-cps rate, but each side of V14 conducts only 480 times per second. The output signal, derived from the plate circuit of the left-hand side, is not a true square wave, because the starting times for successive half cycles are altered slightly by the gating action of V9.

The 240-cps tonewheel pulses introduced through amplifier V13B serve to avoid a possible phase ambiguity in the operation of the  $2 \times 1$  switcher. Because of the alignment of the tonewheel notch relative to the video heads, the 240-cps tonewheel pulse occurs at a time when head No. 1 is near the middle of its tape-scanning operation. When head No. 1 is putting out a signal, multivibrator V14 should be operating with its right side cut off; if not, the FM gates are operating in the wrong phase and delivering mostly noise signals. Therefore, the 240-cps pulse is coupled only to the right side of V14, where it serves to cut off the right side should it ever be in the conductive state at the wrong time. Normally, this 240-cps circuit is operative only during the start-up

period or immediately following a severe discontinuity in the tape signal (such as a bad splice). There is a 50% probability that the  $2 \times 1$  switcher will begin on its own to operate in the proper phase after any form of interruption, thus requiring no action at all from the 240-cps triggering circuit.

#### 4-10. DEMODULATION

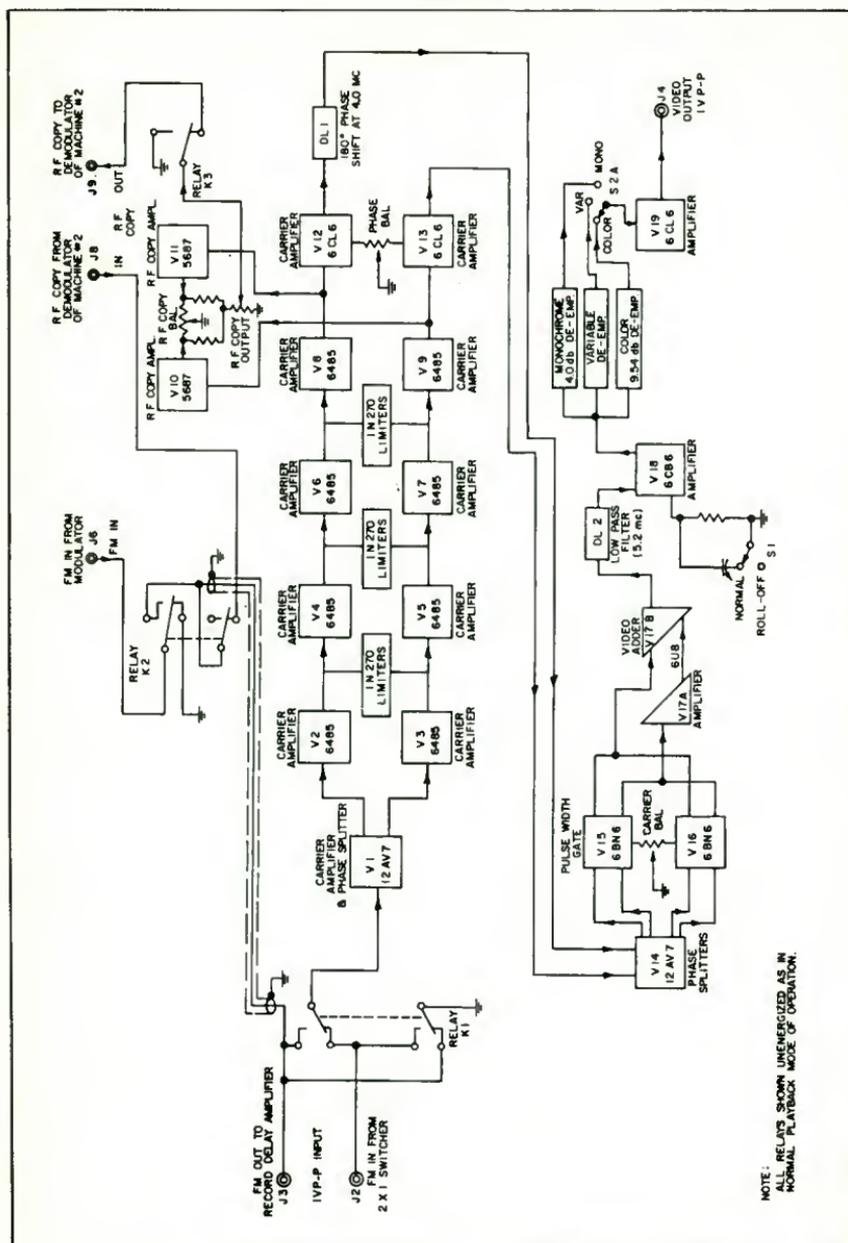
The purpose of the demodulator is to receive the FM carrier from either the switcher (playback mode) or the modulator (record mode) and extract the video information from the carrier signal.

A block diagram of the RCA demodulator unit is given in Fig. 4-25. It serves to illustrate the necessary processes for wideband demodulation. During the playback mode of operation relay K1 is unenergized allowing the input signal from the  $2 \times 1$  switcher to appear at the grid of amplifier stage V1A. Simultaneously, it grounds the input from the modulator chassis. In the record mode of operation, 24 volts DC is applied to relay K1. This energizes the relay and reverses the foregoing situation. The input signal from the modulator is now applied to the grid of amplifier V1A while the input from the  $2 \times 1$  switcher is grounded.

V1A acts as a straightforward FM amplifier. A coil and capacitor are employed in the plate circuit to obtain the proper frequency response. The amplified FM signal is then coupled to the control grid of V1B which operates as a phase splitter. (V1A and V1B are shown as a single block in Fig. 4-25.)

The  $180^\circ$  out-of-phase FM signals are taken off the plate and cathode circuits of V1B and fed to the control grids of push-pull amplifiers V2 and V3. Approximately 50 db of limiting is achieved by diode clippers to minimize dropouts and other effects of amplitude modulation.

The balanced output voltage is fed into four successive stages of push-pull amplification, consisting of matched pairs of tubes. Push-pull amplifiers V12 and V13 raise the clipped FM signal level to 23 volts (peak-to-peak). From the plate circuit of V13 the signal is fed directly to a control grid of phase splitter V14, while the signal appearing in the plate circuit of V12 passes through delay line DL1 before being fed to the opposite control grid of V14. Delay line DL1 shifts the signal phase  $180^\circ$  at 4.0 megacycles, thus enabling the signals which appear at the control grids of V14 to be in phase at that frequency.



Courtesy Radio Corporation of America

Fig. 4-25. Block diagram of the RCA demodulator.

Each section of phase splitter V14 supplies two 180° out-of-phase signals to a pair of matched 6BN6 tubes (V15 and V16) comprising the modulator (discriminator) stage. (See Fig. 4-26.) Looking at the upper section of phase splitter V14, the signal appearing in its plate circuit is applied to the suppressor grid of discriminator tube V15, while the signal appearing in its cathode circuit is fed to the suppressor grid of discriminator tube V16. The signal appearing at the plate of the left hand section of V14 is fed to the control grid of V15, while the signal appearing at the cathode is fed to the control grid of V16.

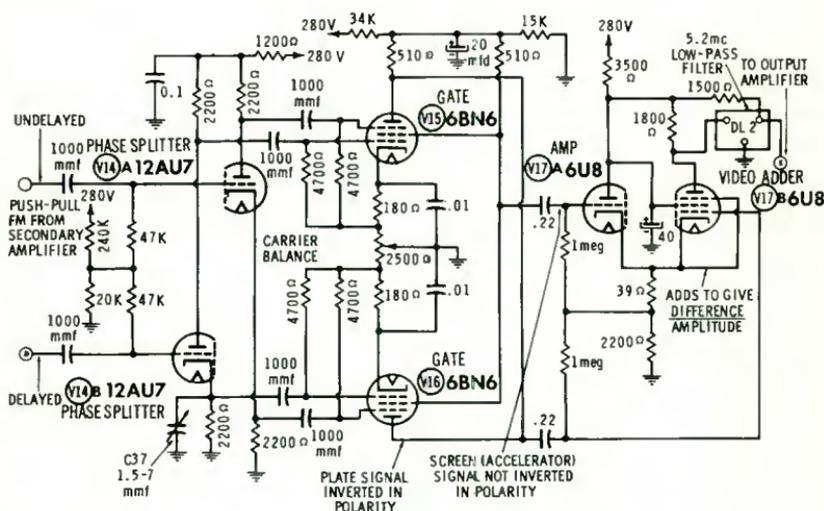


Fig. 4-26. Simplified schematic of duty-cycle (pulse-width gating) section of RCA demodulator.

The 6BN6 modulator (discriminator) tubes V15 and V16 may be considered as pulse-width gating tubes because of their ability to produce pulses of varying width and constant amplitude. The characteristics of these tubes are such that plate current will flow only during the time a positive voltage appears at the control and suppressor grids simultaneously. Therefore, the width of the negative pulses appearing in their plate circuits is equal to the overlap width of the positive pulses applied to their signal grids (Fig. 4-27). The widest negative plate pulse occurs when the signals are in phase and the narrowest when the signals are oppositely phased. If the suppressor grid is negative, current flow is to the

screen; if it is positive, the flow is to the plate. The duration of plate current flow in either tube is directly proportional to the phase difference between signals applied to the control and suppressor grids. The net result is that the 6BN6 discriminator slopes are inherently linear-amplitude versus frequency.

Pulses appearing in the plate circuit of V15 and V16 do not occur simultaneously but are uniformly interspaced in mid-positions because of the phase splitter action of V14. Thus, if

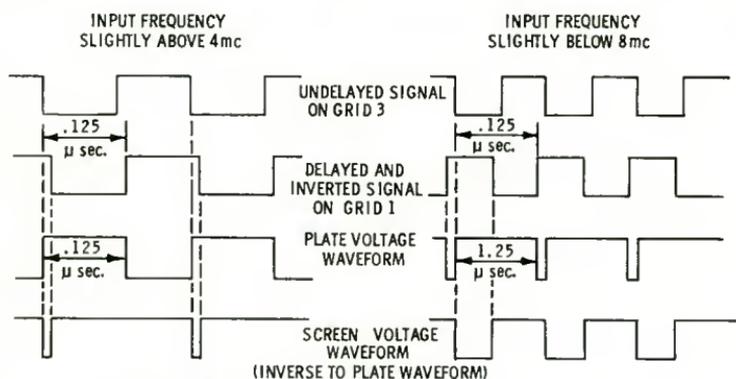


Fig. 4-27. Demodulator waveforms—one of two gate tubes.

the sets of pulses are well balanced, the combined gate output consists only of video information carried by even harmonics of the FM carrier.

The characteristics of the 6BN6 tube are such that the sum of the plate and accelerator currents tends to remain constant and independent of both signal-grid potentials. Thus, a signal current in the plate circuit must be accompanied by a nearly equal signal current of opposite polarity in the accelerator circuit, thereby effectively providing a push-pull output from each gate. The push-pull output signals are fed to the cathode-coupled adder stage V17B. (See Fig. 4-28.) Note that the varying duty cycle from 4 mc to 8 mc results in a DC level which represents the instantaneous frequency—effectively converting frequency change to DC change.

Video adder-stage V17B receives video information from the plate and accelerator circuits of discriminators V15 and V16. This information is added by V17B and appears at the plate. The video output is then fed into a 10-section low-pass filter (DL2) which removes the carrier harmonics and unbalanced fundamental car-

rier frequency above 5.2 megacycles. When the deviation of the FM carrier does not occur lower than 5.2 megacycles, as in color operation, this filter adequately removes small unbalanced carrier components that would degrade the video signal. However, when deviation occurs down to 4.3 megacycles with blanking at 5.0 megacycles as in monochrome operation, discriminator balance requires more careful adjustment to keep blanking free of residual carrier not removed by DL2.

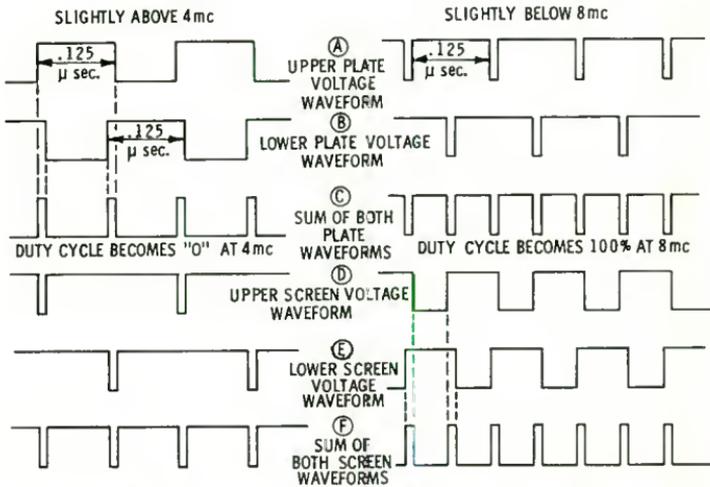


Fig. 4-28. Demodulator waveforms—both gate tubes together.

The video signal from filter DL2 is fed into video amplifier V18 (Fig. 4-25). This tube incorporates a de-emphasis network in its plate circuit which matches the pre-emphasis circuit located on the modulator chassis to improve the signal-to-noise ratio.

Switch S2 also opens or shorts a lead fed to the chroma processor chassis (color equipment). This lead is in series with a circuit which operates a relay on the processor chassis. Its purpose is to make certain that the relay is not triggered by false color bursts when the tape recorder is operated in the monochrome mode.

A series-resonant circuit is located in the cathode circuit of V18. This circuit may be switched out, to compensate for small high-frequency losses inherent in the modulation and demodulation processes, by placing switch S1 (Normal-Roll-Off) in the Roll-Off position. This position may be desirable to reduce excessive noise

for either mode of operation of the tape recorder. However, when switch S1 is placed in the Roll-Off position the signal resolution is lost with the noise.

Output stage V19 operates as a conventional video amplifier; the final video output signal is taken off its cathode and fed to the  $2 \times 1$  switcher chassis through output jack J4.

The discriminator slopes may be seen readily by applying a 1-volt peak-to-peak sweep signal to input jack J2 and observing the waveform at output jack J4. Fig. 4-29 indicates the ideal waveform (solid line) obtained with the demodulator well balanced and switch S2 (Chrome-Monochrome) in the Monochrome

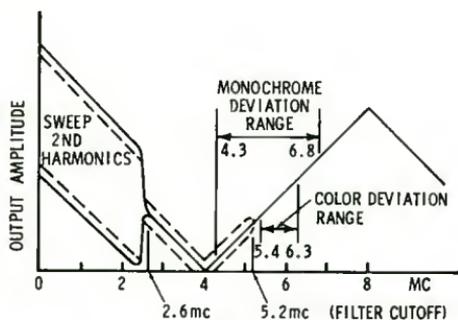


Fig. 4-29. Video sweep response of demodulator.

position. The single-line slope from 4.0 to 8.0 mc is the discriminator slope used for demodulation. The large envelope at the left is the second harmonic which appears to be cut off at 2.6 mc but is actually cut off at 5.2 mc—the cutoff point of DL2.

A simplified block of the Ampex 1000-A demodulator is given by Fig. 4-30. During replay, the signal enters the demodulator from the switcher assembly and is fed to a 60-db limiter strip. The limiter strip, in turn, drives a delay-line type of demodulator. The delay is chosen to represent a  $90^\circ$  phase shift at the carrier frequency of five megacycles (or 0.05 microseconds). The signal is split into two paths at the output of the last limiter stage—one path proceeding directly to the grid of the adder tube while the other goes through the delay line before being fed to the adder stage. The diagrams in Fig. 4-31 illustrate what happens when the carrier frequency, a lower frequency, and a higher frequency is passed through this circuit. The resultant amplitude will vary as a function of frequency; therefore, FM demodulation is accomplished.

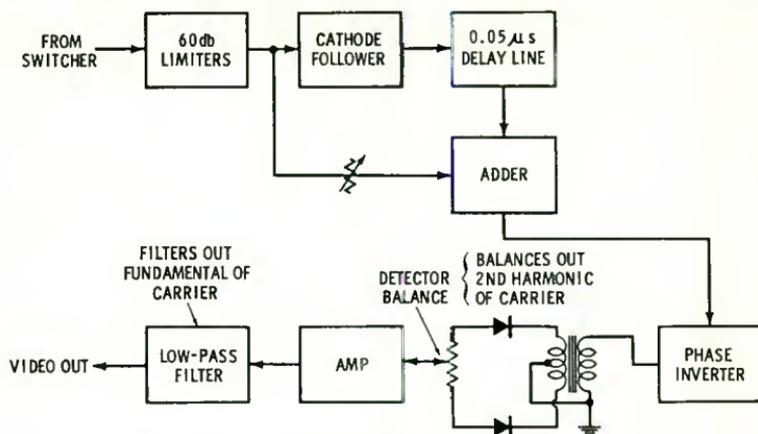


Fig. 4-30. Simplified block diagram of Ampex demodulator.

The AM signal produced, still contains an FM component. It is detected by a pair of diodes from a transformer as shown in Fig. 4-30. The transformer acts as a phase-splitter to provide the signal for full-wave rectification, which is employed to achieve full-time signal recovery and to cancel the unwanted second harmonics of the RF signal.



Fig. 4-31. Vector analysis of delay-line demodulator.

After further amplification, a low-pass filter eliminates all of the double frequencies developed in the full-wave rectifier diodes and most of the carrier frequency (filter cutoff is approximately 4.5 mc).

#### 4-11. SIGNAL PROCESSING

The output of the demodulator unit of a TV-tape system will produce satisfactory pictures on local monitors, but it is not suitable for distribution to transmitting facilities without further processing.

Briefly, the basic purposes of the processing amplifier are to eliminate objectionable noise on the sync pulses, and to reblank the video signal. Another virtue is its ability to restore setup to a video signal with insufficient setup.

The basic difficulty in using the unprocessed output of the television-tape recorder for transmission is that unavoidable transient noise (resulting from tape dropouts as well as head switching) is unacceptable insofar as stabilizing amplifiers and sync-tip clamps are concerned.

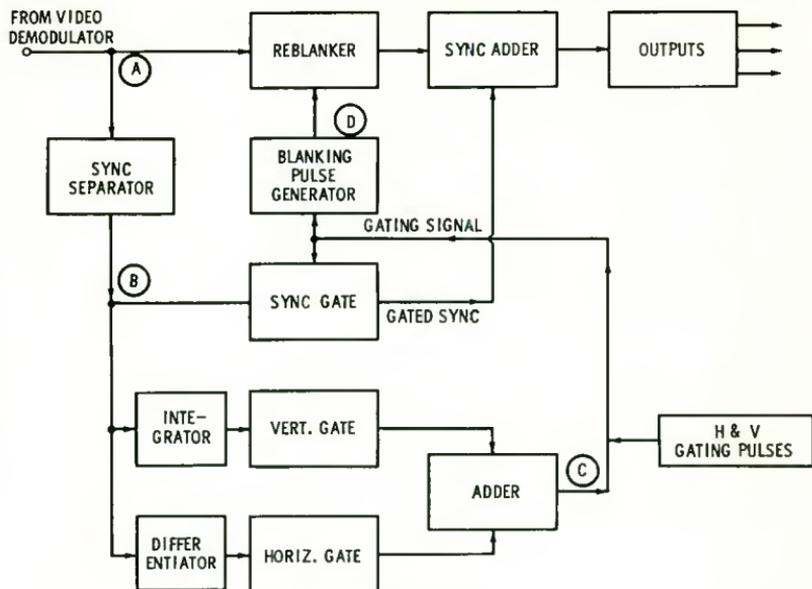
Through relatively conventional video techniques, the processing amplifier strips off synchronizing information, reconstitutes it, then again adds it to the video information. This process allows an improved composite video signal, and the relative levels of the picture and synchronizing signals can be varied.

A simplified block diagram of the Ampex processing amplifier and the pertinent waveforms is shown in Fig. 4-32. In systems not employing *Intersync* (Ampex) or *Pixlock* (RCA), the playback video is not directly locked to the local-sync generators. Thus, timing information needed for gating and blanking must be derived from the video signal itself.

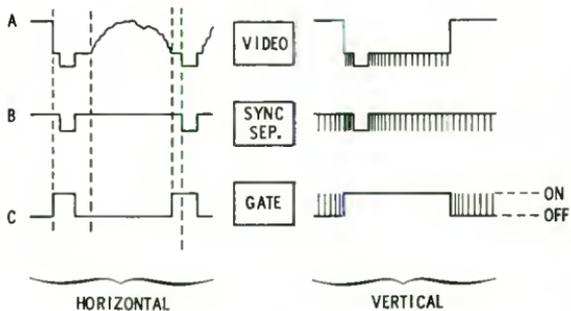
Referring to Fig. 4-32B, the demodulated video (A) is first amplified and clipped to remove black-going spikes projecting below the sync-tip level. Separated sync (B) appears at a sync gate which is enabled (by waveform C of Fig. 4-32B) only at the proper times to pass sync intervals, while blocking transient noise impulses between sync-pulse intervals.

The longer blanking pulses are completely reformed from the gating signals, as shown by waveform D in Fig. 4-32C. The horizontal-gating pulse (just slightly wider than horizontal sync) is widened to equal the horizontal-blanking interval. The leading edge of the vertical-gating pulse is derived in a special sawtooth generator which delays timing information contained in the previous vertical interval for almost one field. This results in a vertical reblanking pulse that begins approximately one-half line before the original blanking-pulse leading edge. Its duration is made to end just after the original blanking pulse trailing edge.

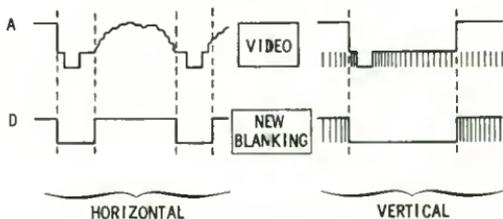
As in any processing amplifier (such as stabilizing amplifiers) which separates sync and later recombines sync with video, the video-signal path employs a delay line to delay video (wideband circuits) an equivalent to the delay of the narrower bandwidth sync circuits. The delay ensures that timing relationships between video and sync will not be disturbed at the output.



(A) Simplified block diagram.



(B) Sync-gating process waveforms.



(C) Reblanking process waveforms.

Fig. 4-32. The Ampex processing amplifier.

The functional interconnections of all modules of the RCA signal processing amplifier are shown in the simplified over-all block diagram of Fig. 4-33.

The input signals to the unit are:

1. Monochrome or color video (to input and blanking module).
2. Separated sync from the  $2 \times 1$  switcher (see the block diagram in Fig. 4-10), to the horizontal AFC and sync logic modules in the processing amplifier.
3. 3.58 mc subcarrier to Color Module.

The output signals from the unit are:

1. Composite monochrome and color signals (Outputs 1, 2, and 3 from the video output module).
2. Regenerated sync (from video output module).
3. Horizontal drive (from sync logic module.)

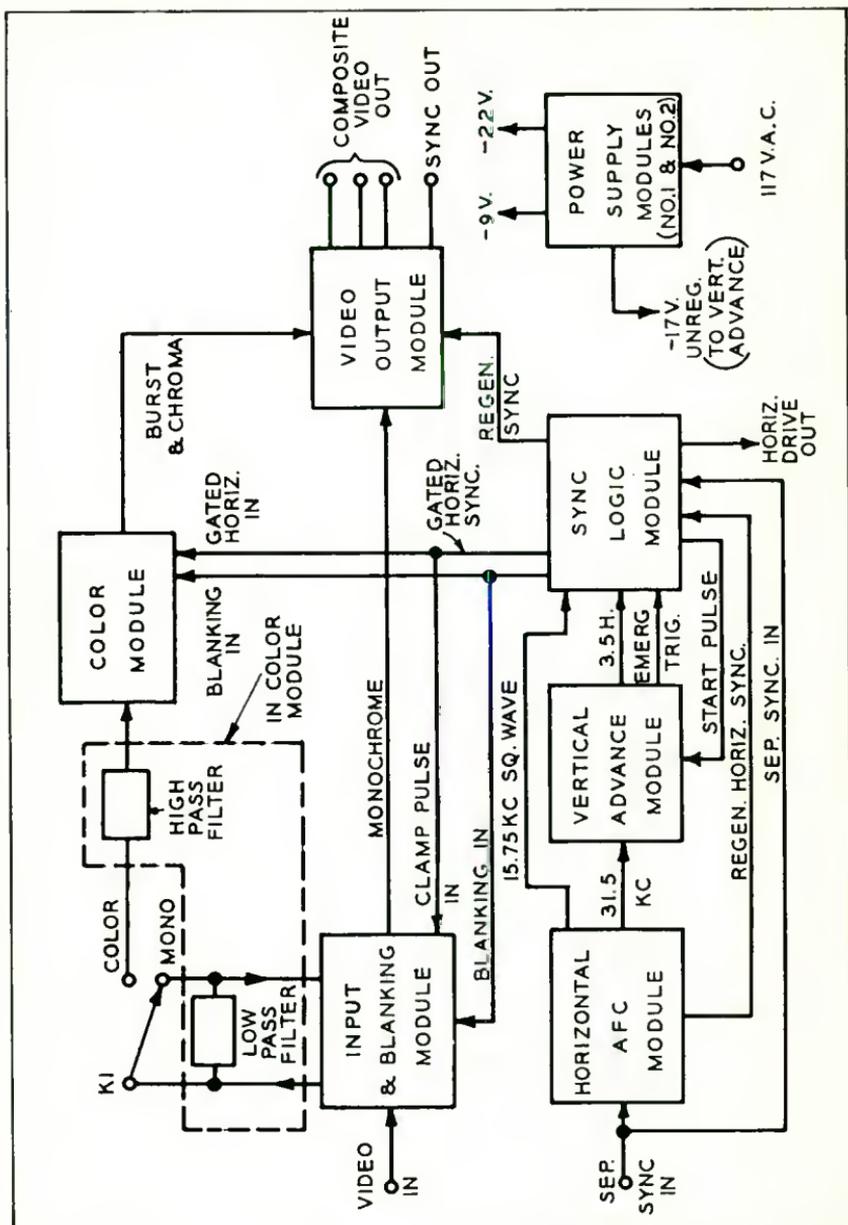
Individual block diagrams and the functions of each module are given in the following explanations. Where required, new and unconventional processes are outlined with the aid of simplified schematics.

### **Input and Blanking Module**

The purpose of the input and blanking module (Fig. 4-34) is to amplify and clamp the video signal, and to insert blanking which may be varied to provide the desired degree of setup (picture black to blanking level).

Monochrome video is amplified and passed through the emitter-follower output stage to the feedback amplifier. The feedback amplifier provides the larger signal ( $3\frac{1}{2}$  volts) necessary for stable clamping and passes it to the emitter follower, which is clamped at the proper operating point by bridge-connected diodes. The clamp pulse, which is timed to produce clamping action during the back-porch interval, is amplified and applied by the clamp driver in phase opposition across the clamp. Thus, the clamp pulse cancels out during the clamping interval.

The blanking adder operates in conjunction with the black clipper in the video output module. The black clipper is biased so that all voltages representing "blacker-than-black" signals are shunted out of the input circuit. Thus, not only is blanking added in this way, but all signals blacker-than-black are effectively clipped by these circuits at the blanking level.



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Fig. 4-33. Simplified block diagram of RCA processing amplifier.

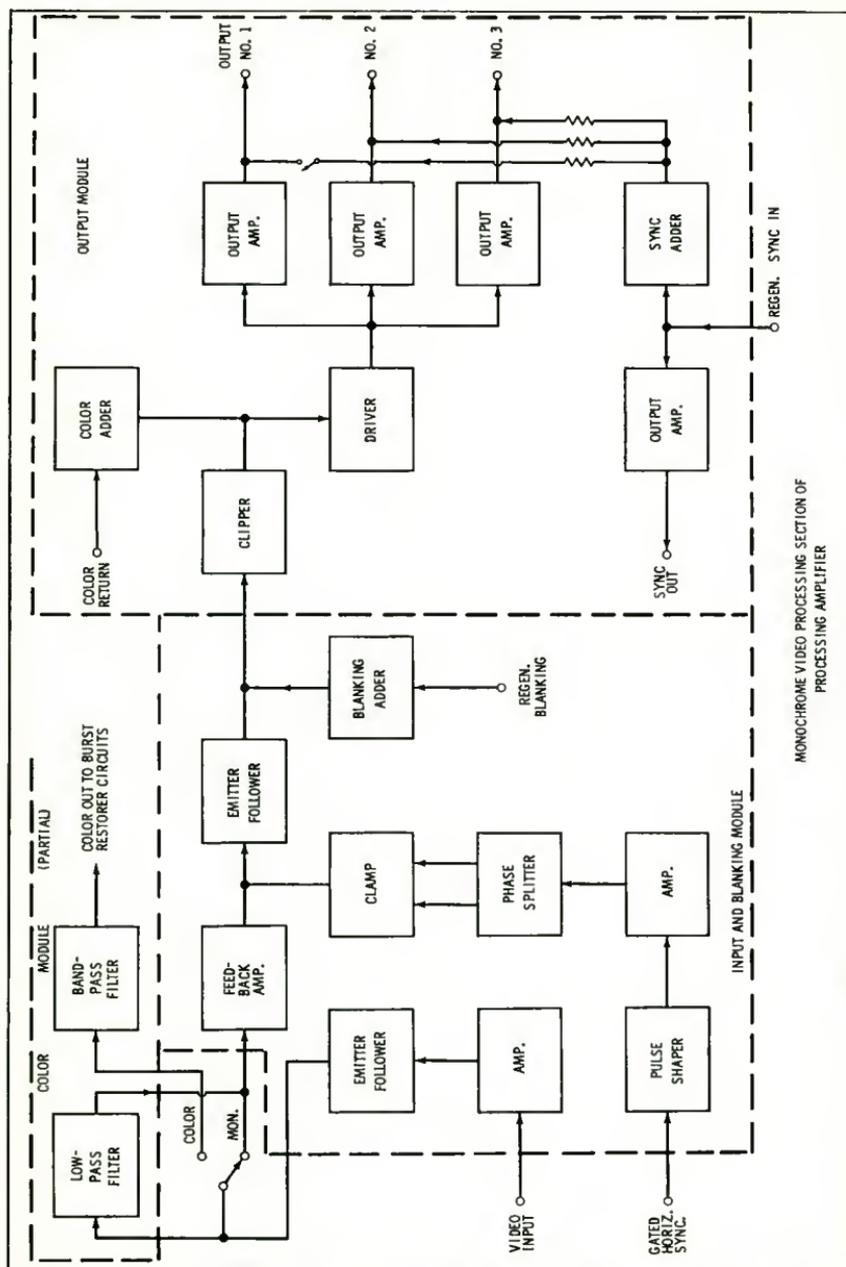


Fig. 4-34. Block diagram of video-processing section of RCA processing amplifier.

### Output Module

The output module (Fig. 4-34) recombines the video and regenerated sync to form the composite video signal which is available at three output jacks on the frame. The unit also provides a separate regenerated sync output for general use.

The monochrome and color signals received from the input and blanking module and the color module, are amplified and combined in the common output of these stages to feed the driver. This driver operates as a series amplifier and provides the driving signals for the three separate output-amplifier stages. Black clipping action is provided in conjunction with the blanking adder in the input and blanking module.

Regenerated sync from the sync logic module is amplified and fed out to the Sync Out jack. Regenerated sync is also added (through a Sync Level control) to the video outputs Out No. 1, Out No. 2, and Out No. 3. An internally-mounted and manually-operated switch removes sync from Out No. 1, permitting this output to contain video only if desired.

### Horizontal-AFC Module

The horizontal-AFC module provides the master timing reference for all circuits of the signal processing amplifier. It also regenerates the horizontal sync signal, and provides a 15.75-kc square wave for the generation of horizontal drive and horizontal blanking.

Regeneration of a color or monochrome signal which has been degraded by poor transmission or other adverse conditions involves regeneration of the sync signal and the blanking signal. Obviously, there can be no regeneration of the picture information. While the sync signal is easily recovered from the incoming composite video, unfortunately, the blanking signal cannot be reliably recovered in this manner. Therefore, it is necessary to regenerate blanking from the sync signal. The special techniques employed to accomplish this are briefly discussed in the next few paragraphs as an aid in describing the circuits of the horizontal-AFC module.

*Pulse Advance Techniques*—Inasmuch as the desired blanking pulse must precede the sync signal from which it is made by 1.6 microseconds (nominal front porch width), the arrival of sync must be accurately anticipated. This is accomplished in the horizontal-AFC module by a method known as pulse advance.

Sync and blanking are both recurrent pulses. Therefore it is possible to predict the position of the next sync pulse from the position of the preceding one.

The RCA signal-processing amplifier employs a multivibrator master oscillator, the frequency and phase of which is controlled by an automatic-phase control circuit referenced to the incoming separated sync, to obtain horizontal pulse advance. This method

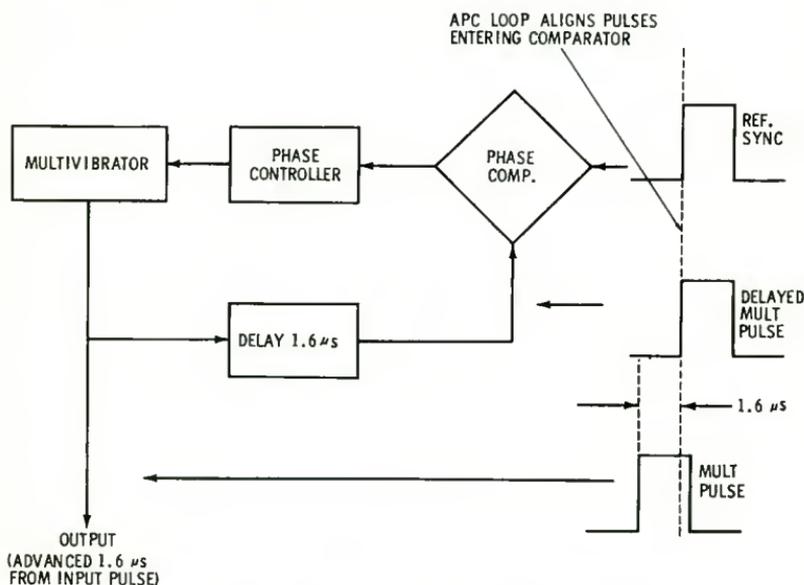


Fig. 4-35. Pulse delay in horizontal-AFC module.

is illustrated in the simplified block diagram of Fig. 4-35. The feedback loop which controls the phase of the multivibrator contains a 1.6 microsecond delay. This delay is converted to an advance by the feedback loop. As shown, the APC loop aligns the two pulses appearing at the comparator. However, the multivibrator pulse is delayed by 1.6 microseconds before reaching the comparator. Therefore the undelayed multivibrator pulse precedes sync by 1.6 micorseconds, and is properly timed to regenerate horizontal blanking.

In this system, the feedback loop tracks any changes in horizontal frequency and eliminates any variation in front-porch width due to frequency changes.

It should be noted that, although the requirements for regenerating the vertical-blanking pulse are similar, other factors necessitate a different solution. They are discussed in the section describing the vertical advance module.

*Circuit Description*—The 31.5-kc timing signals are produced by the multivibrator master oscillator (Fig. 4-36). The output from this oscillator is fed to the vertical advance module where it is used to derive the leading edge of vertical blanking. The master oscillator also feeds the trigger amplifier which in turn drives the  $\div 2$  multivibrator. This multivibrator produces a 15.75-kc square wave for use in generating the horizontal-drive and -blanking signals in the sync logic module, and also feeds 15.75 kc to the front porch delay generator.

Stability of the  $\div 2$  multivibrator can be checked manually by a Stability Test control that is located on the vertical advance module. This control produces a range of voltages above and below the operating point of the multivibrator. The multivibrator, if functioning properly, will be unaffected by the operation.

The 15.75-kc square wave is fed to the base of the front-porch-delay generator. A shunt capacitor slows down the use time of the square wave to produce the front-porch delay. This softened square wave is then clipped to produce a fast-rise-time delayed pulse which is fed to the horizontal-sync generator. Operating as a pulse-narrowing circuit, this stage forms the horizontal-sync pulse which is fed out to the sync logic module, and to the sawtooth generator. The Horiz Sync Width control and the Front Porch Width control are trimming potentiometers mounted on the terminal board.

Sawtooth generator 6Q13 and the complementary-symmetry *bootstrap* stage 6Q14 and 6Q15 produce the required pulse to be applied to one leg of the clamp-type phase comparator bridge. (See Fig. 4-37.) The purpose of the bootstrap is to amplify the sawtooth current output of 6Q13. The output of 6Q13 is applied to the inputs of two transistors of opposite polarity. Operation of these transistors is such as to raise the sloping top portion of the sawtooth wave, thereby linearizing the sawtooth, and increasing its amplitude for application to the comparator bridge. However, the main purpose of 6Q14 and 6Q15 is to provide current gain to drive the comparator.

The reference pulse applied to the other leg of the phase comparator (see Fig. 4-36) is formed from the separated sync signal that is fed into sawtooth generator 6Q7. The sawtooth output



from 6Q7 is clipped to remove the effects of any disturbances following the leading edge of sync and fed to the equalizing pulse gate which gates out the half-line information during the vertical interval, leaving only the 15.75-kc information. In addition, the clipper output is fed to the clamp pulse generator, which, in turn, delivers the reference pulse to the comparator.

**Automatic Phase Control**—The phase comparator consists of four diodes connected in a bridge circuit. The DC output of the

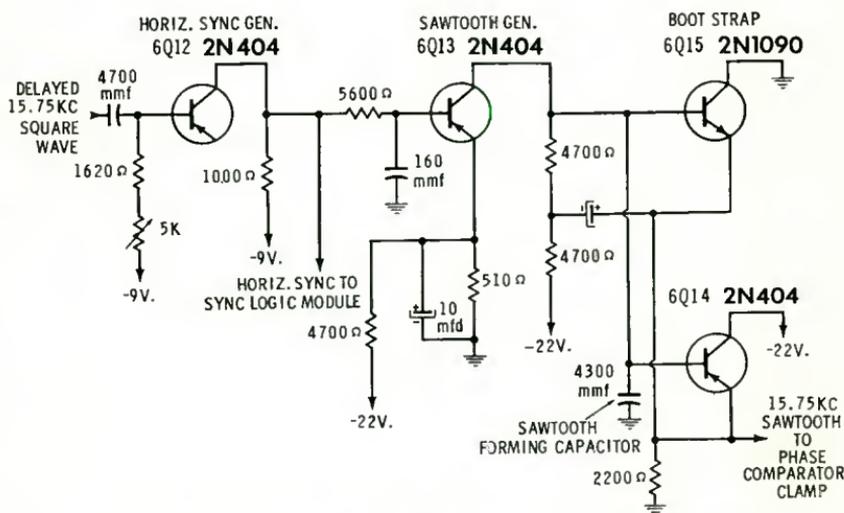


Fig. 4-37. Horizontal-sync and sawtooth-generator sections of horizontal-AFC module.

bridge varies with the frequency and phase differences that occur between the delayed oscillator pulse and the separated sync pulse. This output is amplified by the AFC current amplifier and applied to the master oscillator to vary the current through the base resistors. Hence, it corrects the frequency and phase of the master oscillator to keep it in step with the incoming sync signal.

### Vertical Advance Module

The vertical advance module produces the all-important timing edge which determines the leading edges of vertical-blanking and 9H-gating pulse. Utilizing this timing edge, circuits of the sync logic module regenerate the vertical blanking and reinsert the vertical sync interval.

*Vertical Pulse Advance Techniques*—As in the regeneration of horizontal blanking, a method of pulse advance is employed in the vertical advance module to regenerate the vertical-blanking edge, which must precede the sync signal by  $3H$ .

At first thought, the problem of vertical-pulse advance seems identical, except for time scale, to the problem of horizontal-pulse advance. It might seem practical, therefore, to apply the principle of automatic phase control to obtain vertical pulse advance. However, since the speed of recovery of the APC circuit depends on the rate at which it is operating, it is evident that a vertical APC circuit would produce annoying disturbances to the viewer when recovering from transients or bad splices.

The horizontal pulses between adjacent vertical intervals are counted to obtain vertical advance. The counters follow any changes in the basic sync frequency and automatically readjust the position of vertical blanking. Moreover, they recover from transient disturbances with the same speed as a delay multivibrator pulse advance. This technique provides a method of performing vertical advance in a wholly satisfactory manner.

*Vertical Advance Requirements*—The vertical-blanking interval begins just before the first equalizing pulse, as shown in Fig. 4-38. The vertical-advance circuit produces this timing edge to start vertical blanking. Although the timing difference between vertical blanking and vertical sync is  $3H$ , the difference between the two edges (vertical blanking and vertical-pulse position, waveforms J and A Fig. 4-38) is  $3.5H$ . This is the earliest time for accurately detecting the position of vertical sync. The timing distance of  $3.5H$  must be maintained to produce vertical blanking from vertical sync.

The timing distance of  $3.5H$  is exactly the output of the divide-by-7 multivibrator counting from the 31.5-mc master oscillator. (Since  $H$  equals 15,750 cps, an interval equal to  $3.5H$  is  $15,750/3.5$  or 4,500 cps.) The vertical-advance circuit selects that one period of the divide-by-7 multivibrator out of the 75 periods that occur in each field (262.5H per field, and  $262.5/3.5 = 75$ ) which is so phased that the beginning of the period falls on the leading edge of vertical blanking, and the end of the period falls  $3.5H$  later.

*Circuit Description*—In Fig. 4-39, assume that initially the trigger gate 8Q13 is passing triggers, and the counters are running. The  $\div 7$  multivibrator drives bidirectional trigger 8Q3, which drives the first  $\div 5$  counter both on and off. The off cycle of this  $\div 5$  counter is  $3.5H$  and is the desired pulse.

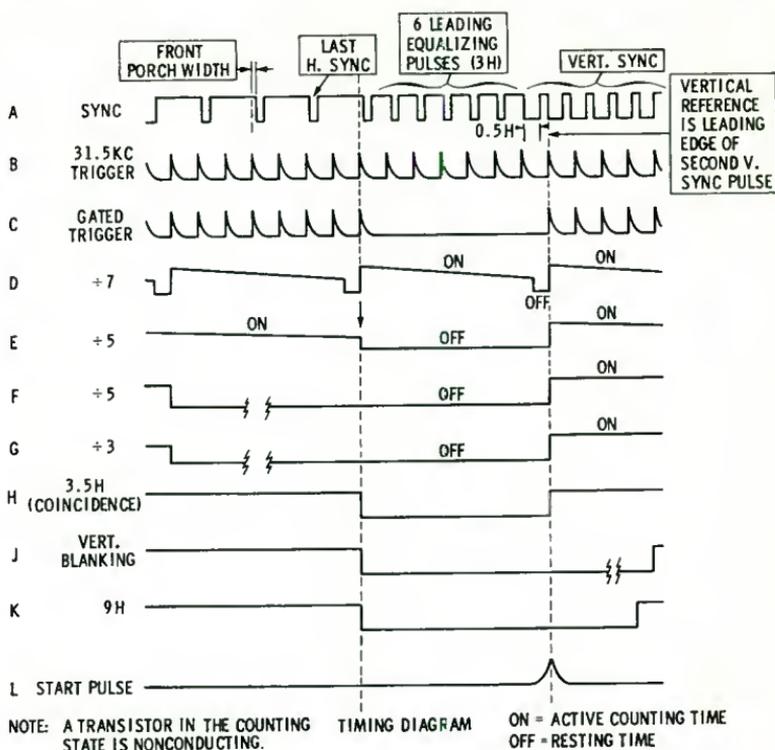


Fig. 4-38. Pulse timing diagram.

At some time, the last three counters will all be off at the same time. This coincidence is detected by the coincidence circuit, which responds by turning off gate 8Q13, thereby holding all the counters in the off position. This condition will persist until a vertical interval appears in the incoming sync. The vertical sync produces a start pulse, which opens gate 8Q13, passing a single trigger which coincides with the edge of the second block of vertical sync. The trigger drives all the counters on, destroying the off coincidence of the last three counters, thereby opening gate 8Q13 and allowing triggers to pass. The counters resume counting, until an off coincidence again occurs in the last three counters. This time, the coincidence occurs just as the first  $\div 5$  multivibrator is driven off by 8Q3. (The other two coincidence multivibrators are already off.) Since the count started at a known point (the edge of the second vertical block) and has proceeded for a known number of counts, the exact position of the coincidence is also known.

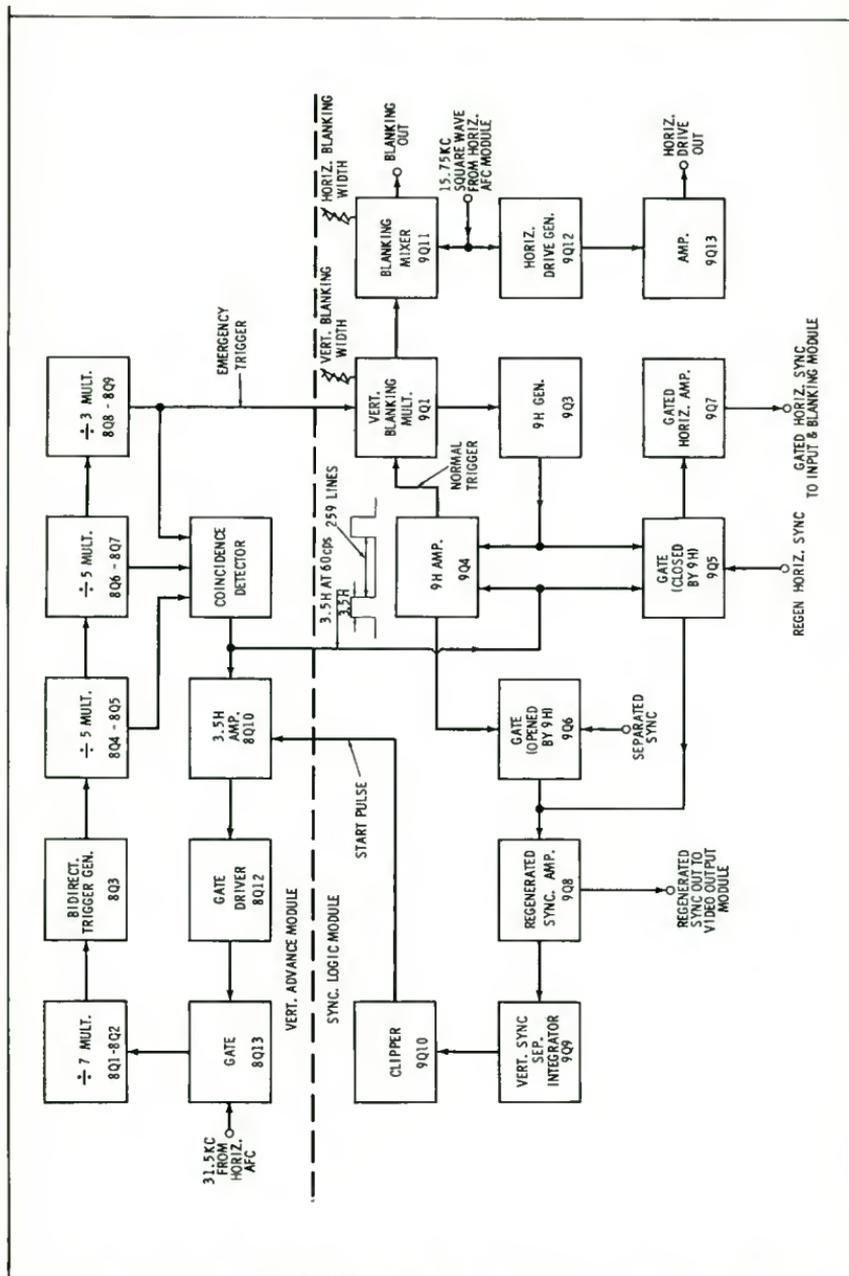


Fig. 4-39. Sync and blanking regeneration section of processing amplifier.

Inspection of the timing waveform shows that the coincidence always occurs at the proper time to generate the leading edge of vertical blanking.

The coincidence turns the gate off, as before, but the start pulse, occurring  $3.5H$  later (see timing waveforms in Fig. 4-38) provides a trigger at the time that the first  $\div 5$  multivibrator would go on if there had been no trigger interruption. Therefore, the count begins again, at the proper place (edge of second block) and without disturbing the period of any of the counters. Thereafter, the counters are properly phased and the coincidence circuit delivers a  $3.5H$  pulse whose leading edge is always correct for timing vertical blanking.

### Sync Logic Module

The principal functions of the sync logic module (Fig. 4-39) are the regeneration of new and clean horizontal-sync and composite blanking signals, and the provision for a source of horizontal drive. In addition to these functions, the unit generates signals essential to the operation of other modules of the signal processing amplifier.

Specifically, the processes which take place in the sync logic module are as follows:

1. Regeneration of vertical blanking.
2. Regeneration of horizontal blanking.
3. Reassembly of sync, using separated sync and regenerated horizontal sync.
4. Combining of regenerated horizontal and vertical blanking to form the composite blanking signal.
5. Provisions for horizontal drive for system use.
6. Provisions for a start pulse for use in the vertical advance module.
7. Provisions for gated horizontal sync, which is horizontal sync with the pulses gated out during the  $9H$  interval. This is used as a back-porch clamp pulse in the input and blanking module, and is used to make burst flag in the color module.

*Sync Gate Switching*—Reassembly of sync is accomplished in part by the sync gate, which employs the vertical-interval gate (9Q5) and the horizontal-sync gate (9Q6) shown in Fig. 4-39. The action of the sync gate can be compared to a switch, except for the duration of  $9H$  during each vertical interval, the sync gate (9Q6) feeds regenerated sync from the horizontal AFC module to

the video output module. A 9H timing signal is used to drive the sync gate (9Q5) to the separated sync position during the vertical interval. However, when a bad splice, bad switch, or other problem causes a signal interruption, the switch is caused to move over to receive separated sync, where it is held until vertical sync appears.

Ordinarily, a 9H pulse is all that would be required for the switch driver (the 9H generator, and 9Q4). However, under certain conditions, such as a bad splice in tape or a nonsynchronous video switch, it is necessary to hold the sync gate in the separated sync position until it finds vertical sync. This holding is done by the 3.5H pulse which becomes very wide under these conditions. (The change in width is accomplished by circuitry in the vertical advance module.)

*Sync Reassembly*—Operation of the sync gate (9Q5, 9Q6) is as follows: As shown in the schematic of Fig. 4-40, 9H pulses from the 9H generator are fed through the isolation diode (9CR4) to the base of the horizontal-sync gate (9Q6), and, through the 9H amplifier (9Q4), to the base of the vertical interval gate (9Q5). Transistor 9Q5 is biased so that in the absence of 9H pulses, it is saturated, and shorts out the separated sync which appears at its collector. 9Q6 is normally open; thus, horizontal sync can flow through the isolation diode (9CR8) to the output. The appearance of the 9H pulse reverses this condition by opening 9Q5 and permitting separated sync to flow through 9CR7 to the output, and by saturating 9Q6 and shorting the horizontal sync at its collector. Thus, reassembled sync passes from the sync gate through amplifier 9Q8 to the output.

*Gated Horizontal-Sync Circuit*—Gated horizontal-sync, which is used to make back-porch clamp pulses for the input and blanking module, and burst flag for the color module, is fed from horizontal-sync gate 9Q6 to gated horizontal-amplifier 9Q7. (See Fig. 4-40.) When 9Q6 is shorted by the 9H pulse as described previously, 9Q7 is also shorted (base to emitter). This prevents horizontal pulses from getting through 9Q7. Therefore there will be no horizontal pulses from 9Q7 during the 9H interval.

*Formation of Start Pulse*—The circuits associated with the formation of the start pulse, used in the vertical advance module are shown in Fig. 4-41. Integrator driver 9Q9 is a current source which charges capacitor 9C10 as a result of vertical pulses received from sync amplifier 9Q8. The pulse so formed is clipped by start pulse clipper 9Q10, and differentiated by capacitor 9C16

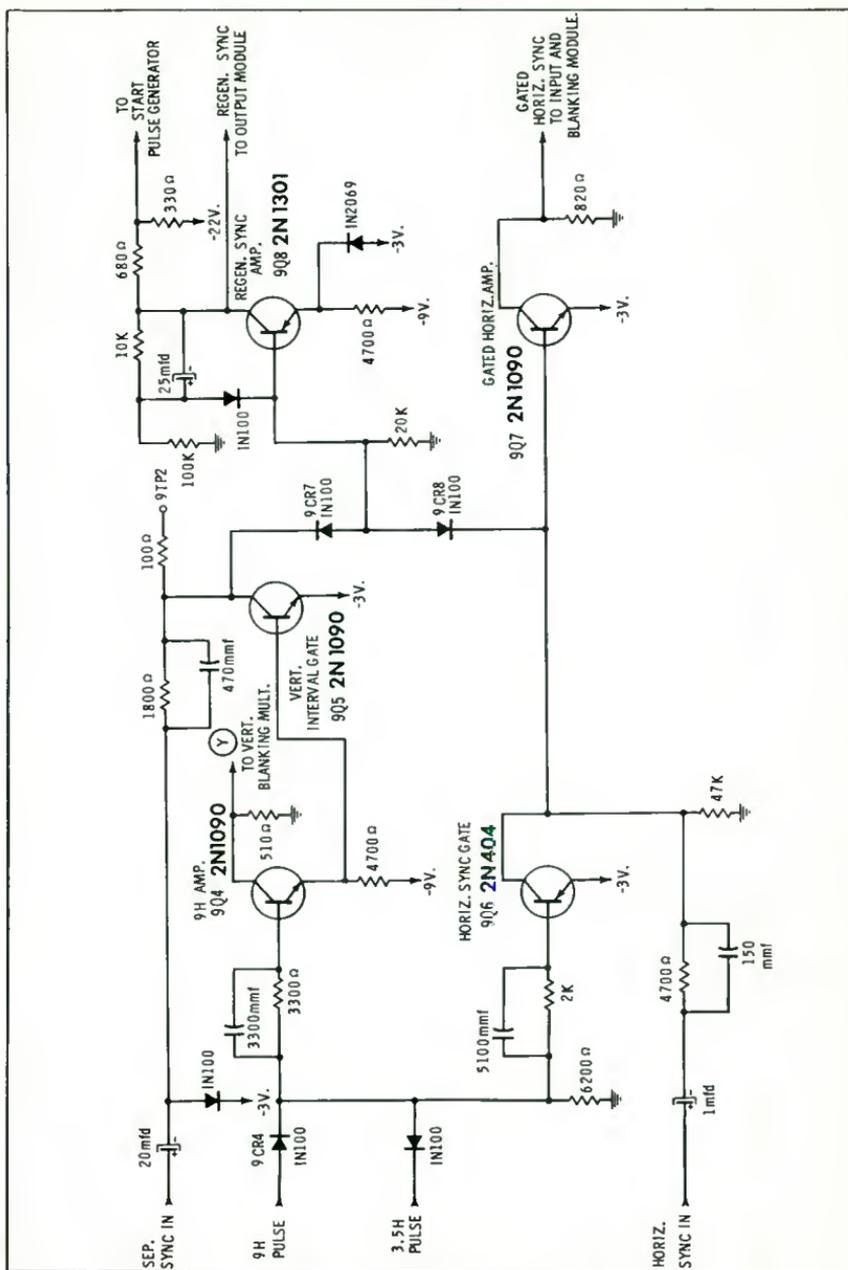


Fig. 4-40. Sync reassembly section.

in the collector output circuit of 9Q10. The differentiated pulse is the start pulse fed to the vertical advance module.

*Derivation of Blanking*—Vertical multivibrator 9Q1 and 9Q2, blanking mixer 9Q11, and the horizontal-drive generator and output stages 9Q12 and 9Q13 in Fig. 4-42 are associated with the generation of the blanking signals.

The precise 3.5H timing pulse, which determines the leading edge of the blanking and 9H pulses, is fed through 9H amplifier 9Q4 in Fig. 4-40 to trigger vertical blanking multivibrator 9Q1 and 9Q2. This produces 21H vertical blanking pulses at the collector of 9Q2. These pulses are then passed through 9CR13 to

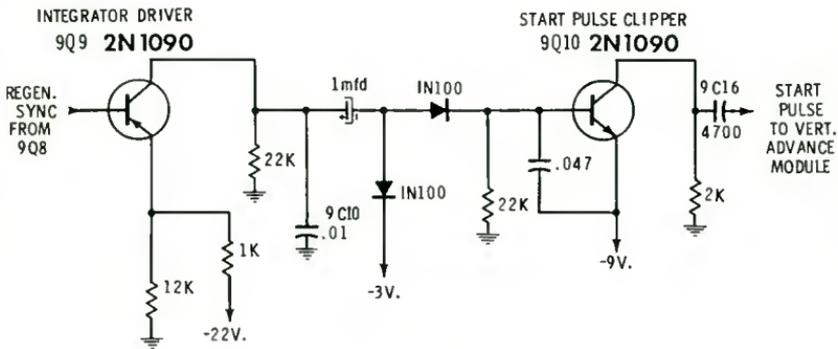


Fig. 4-41. Start pulse former.

blanking mixer 9Q11. Here, horizontal blanking is produced and the composite blanking signal is formed. They appear at the collector output of 9Q11. (The use of 21H pulses in deriving the 9H pulse is described later.)

Blanking mixer 9Q11 and the horizontal-drive generator 9Q12 are both fed by the 15.75-kc square wave from the horizontal-AFC module. Both these stages are pulse narrowing circuits. (See Section 1-5.)

*Derivation of 9H Signals*—The 9H signal which is used to drive the sync gate described in preceding paragraphs is produced in 9H generator 9Q3 in Fig. 4-42. This generator is a pulse narrowing stage fed by the 21H signal from the vertical blanking multivibrator. 21H output from the multivibrator is passed through 9R9 and 9C3 to the base of 9Q3. The resulting 9H pulse appears at the collector and is fed to the 9H amplifier 9Q4 which is directly coupled to vertical interval gate 9Q5 in Fig. 4-39.

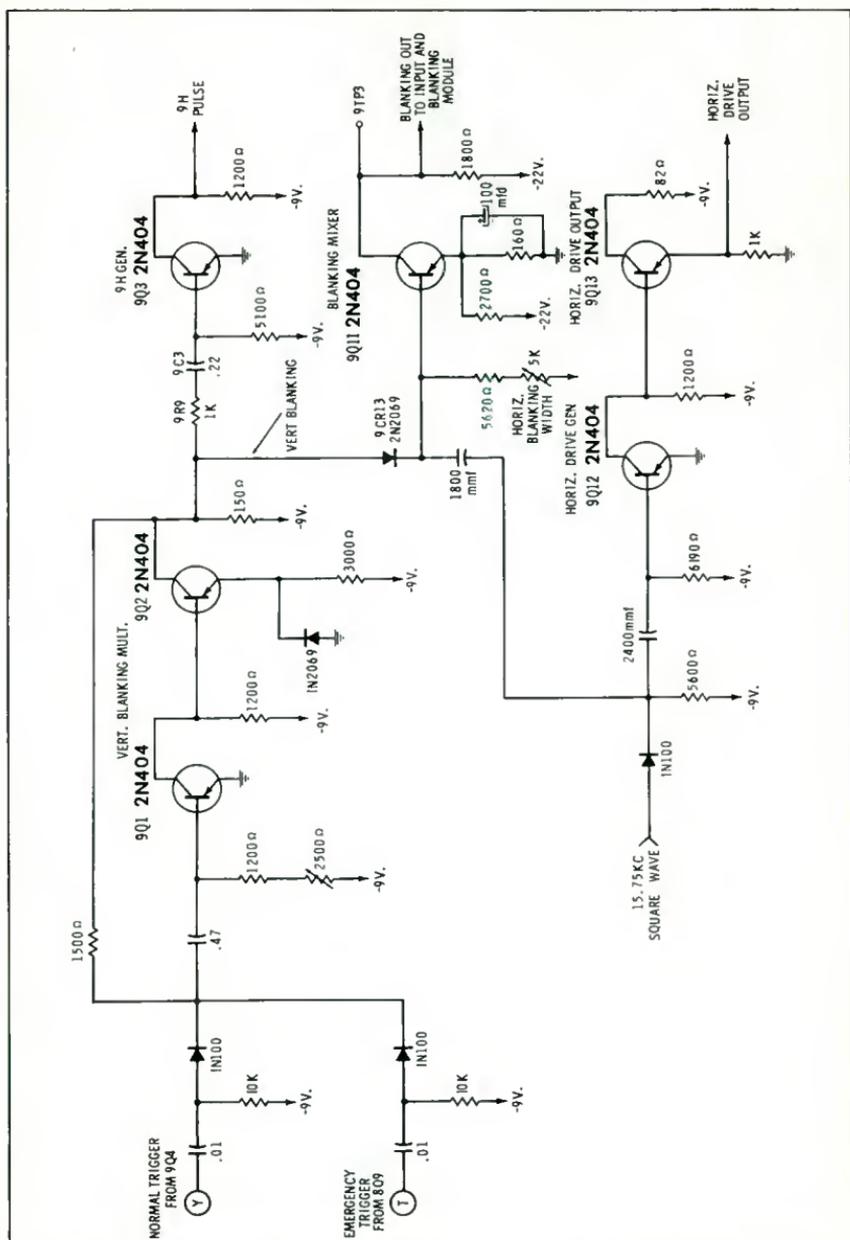


Fig. 4-42. Vertical-blanking generator and horizontal-drive and -blanking generator sections of sync logic module.

*Emergency Trigger*—The emergency trigger input in Fig. 4-42 is a pulse produced by the  $\div 3$  multivibrator in the vertical advance module (Fig. 4-39). Its purpose is to hasten recovery from a bad switch or bad splice. It does this by triggering, just once, the 9H multivibrator at the end of 3.5H instead of at the beginning. This holds the sync gate in the separated sync position long enough to let the entire vertical interval through. Without the emergency trigger, the first vertical interval after a nonsynchronous switch or bad splice would consist of six equalizing pulses and only one vertical sync block because of the missing 9H pulse. This pulse normally holds the sync gate in the separated sync position after the 3.5H pulse is gone.

SECTION 5

**THE SERVO  
SYSTEM**

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## SECTION 5

# THE SERVO SYSTEM

The servo constitutes the *synchronizing section* of the television-tape system, as contrasted to the video section covered in the previous section of this notebook.

The television-tape servo system is electromechanical in nature; the input is an electronic signal, and the output device is an electric motor with a mechanical load.

Three basic servo systems are involved: The rotating-head motor servo, the capstan motor servo, and the tape vacuum-guide motor servo.

### 5-1. RELATIONSHIPS

The basic synchronizing function of the TV-tape system will be clear if the following basic relationships are clearly visualized:

1. Relationship of the head timing pulse (tachometer) to the video head recording vertical sync.
2. Phasing of control-track signal being recorded with the video tracks being recorded, as timed from the 60-cps reference pulse from which the 30-cps frame (edit) pulse is derived.
3. Relationship of the tracking control to the video head playing back vertical sync.

Fig. 5-1 shows the factor determining which of the four video heads records the vertical sync. Since the 240 cycles derived from the rotating-head shaft (review Fig. 3-4) is the servo-phase comparison with the 240 cps derived from vertical sync (reference pulse), the particular head in contact with the tape at the leading edge of this pulse is that which will be recording vertical sync. Thus, the physical orientation of the timing ring (Ampex) or the tonewheel notch (RCA) relative to the head determines which of the four heads will record vertical sync.

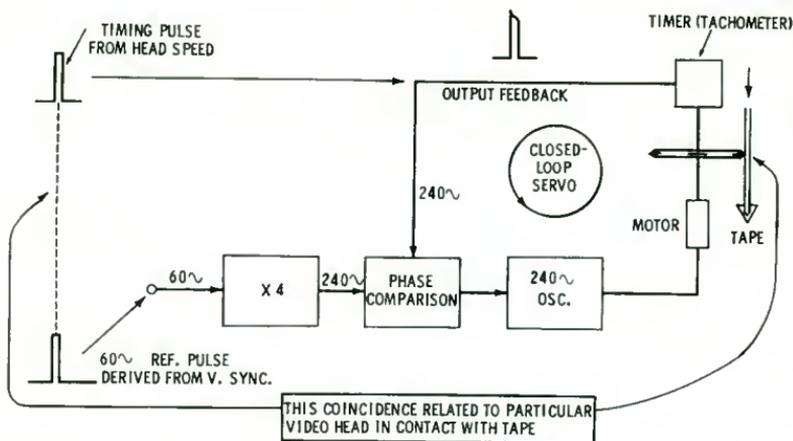


Fig. 5-1. Relationship of tachometer signal to head in contact with tape.

The notch in the RCA tonewheel is directly over the tonewheel head when video head No. 1 is in the approximate center of the tape. Thus video head No. 1 records vertical sync on the RCA.

The orientation of the Ampex timing ring is such that the leading-edge reference occurs when head No. 4 (review Fig. 4-8 for Ampex head-numbering sequence) is in the approximate center of the tape. Thus, head No. 4 records vertical sync on the Ampex.

The oscilloscope (which monitors playback channels) on the Ampex control panel is a driven type, with the horizontal sweep being triggered from a derivative of the photoelectric-cell signal in the timing tachometer. The output of the four video heads on one revolution of the head drum is displayed on one horizontal sweep of the oscilloscope. With the tracking control centered (same head playing back vertical sync as recorded), the presentation is as shown by Fig. 5-2. Since vertical sync occurs at the approximate center of the channel 4 track, the retrace is triggered at this time and channel 4 continues a short distance on the left section of the trace.

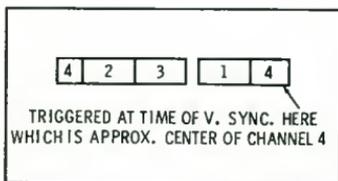


Fig. 5-2. CRO presentation of head switching (Ampex).

NOTE: It should be understood that any existing differences in which video head records vertical sync does not affect compatibility or interchangeability of tapes between any two systems. When a recorded tape is played back on a different head than that used for recording, the tracking control is adjusted to obtain the best match of head-to-tape response.

The phasing of the control-track signal, recording of the video tracks, and the frame (edit) pulse is illustrated in Fig. 5-3. (Since

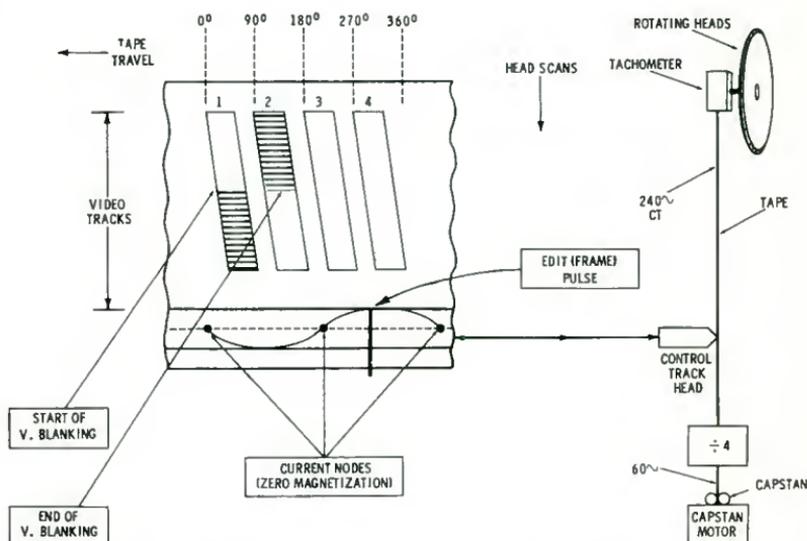


Fig. 5-3. Phasing of control track with control track and edit pulse.

the control-track signal is used to provide a timing reference during playback for the capstan servo, it is sometimes called *tracking-control recording*.)

The 240-cycle sine wave on the control track represents the current in the control-track head during recording, and hence the degree of magnetization (and polarity) on the tape. The point of current nodes (zero magnetization) occur in phase with alternate video-track guard bands. Thus, current nodes and current maximums occur in phase with alternate video-track guard bands. The control-track sine-wave current is so phased that the edit pulse (30-cps frame pulse derived from the 60-cps reference pulse and occurring every 33 video tracks) occurs at the point of maximum current in the guard band between the second and third tracks

following that which contains vertical sync. This is between tracks 3 and 4, if track 1 contains the vertical sync, as shown on Fig. 5-3.

It is very important to note that proper phasing of the control-track signal with the edit pulse (hence reference pulse), automatically establishes a standard phasing relative to the video tracks being recorded; this is most important for interspliceability. If a tape is spliced onto another segment which does not have identically the same phasing between video tracks and control tracks, the tracking control must be manually readjusted immediately after passage of the splice.

Fig. 5-4 shows the relationship of the tracking control to the video head playing back vertical sync. As shown, either the control-track signal or the head-tachometer signal may be shifted in phase so that any one of the four video heads will track on vertical

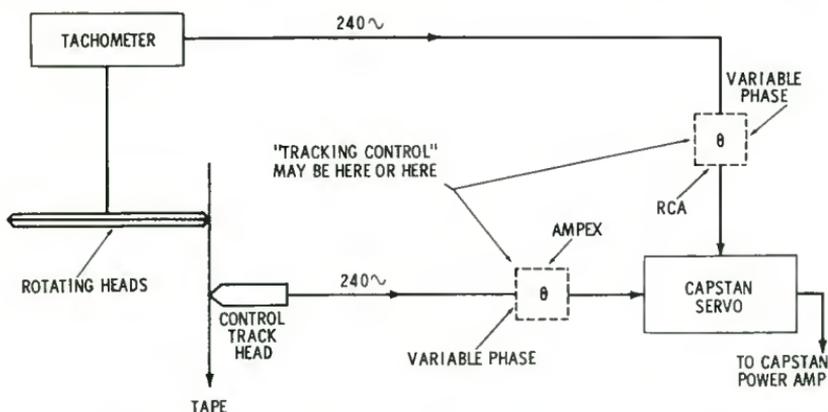


Fig. 5-4. Tracking control of video head playing vertical sync.

sync. Ampex tracks by means of the control-track signal, and RCA tracks in the tonewheel signal, except when the system has been modified for *Pixlock*. (The Ampex equivalent is *Intersync*, which is described later.) In the latter case, RCA tracks by means of the control-track signal.

## 5-2. THE HEAD-MOTOR SERVO

The basic function of the head-servo unit is to control the speed and the position of the head motor in accordance to incoming-video vertical pulses, the local sync generator, or the power-line frequency. During the Record mode, the head motor provides the

drive signal (by means of the tachometer) to the capstan motor. During the Playback mode, the tachometer signal is the reference-timing signal for the capstan motor.

The system can be referred to any of three initial timing signals; in the Record mode, it is customary to use video vertical sync, but the local sync generator may also be used; in the Playback mode, the normal procedure is to use the local sync generator, but the 60-cycle power line timing may also be employed.

Although a number of refinements have been made, the original Ampex drum-motor servo (Fig. 5-5) serves as an excellent study of basic head-servo function. The following description is correlated with the numerical circles on the diagram.

Two servo loops are employed in the head drum motor circuit: The sync servo (position control) acts to eliminate rapid phase-correction requirements for the motor. It has a relatively narrow lock-in range for precise position control. The hunting servo (velocity detector) minimizes any tendency of the motor to "hunt." It employs a wider lock-in range than the position detector to reduce the time required for the servo system to assume control of the starting operating or after momentary interruption, such as could occur from splices in the tape.

1. The vertical-sync stripper strips the 60-cycle vertical sync from the video signal (Record mode). This section also incorporates a means to use 60-cycle power-line reference or local sync pulses (usually in Playback mode).
2. A 240-cycle resonant circuit in the plate of a tube in the 240-cycle frequency-multiplier section is energized every fourth cycle by the vertical sync. From the resulting train of decaying sine waves, symmetrical square waves are obtained by clipping and amplifying.
3. The phase splitter receives the 240-cycle square waves from the frequency multiplier and provides a push-pull signal to the position-detector phase-comparator bridge circuit. This provides the reference signal for the sync (position) loop.
4. The 240-cycle multivibrator derives a large-amplitude 240-cycle square wave from the photoelectric (PE)-cell (head tachometer) signal.
5. The phase splitter delivers the 240-cycle square-wave signal in push-pull to the other two legs of the position-detector phase-comparator bridge circuit.
6. The position-detector comparator now has two push-pull inputs—one set (from 3) representing the reference timing and



another (from 5) which is directly dependent on the position and speed of the rotating heads. At the center connection of the bridge (Fig. 5-6), a square wave with a fundamental 480-cycle frequency is developed; one edge corresponds to the rise (or fall) of the reference signal, while the other edge coincides with the rise (or fall) of the signal from the PE cell. As long as these signals are  $90^\circ$  apart, the output signal from the bridge is symmetrical, and there is no DC component (equal energy above and below AC axis). If the  $90^\circ$  relationship is departed from (phase difference between reference-pulse and head-tachometer signal), the output will become asymmetrical, and a DC component appears.

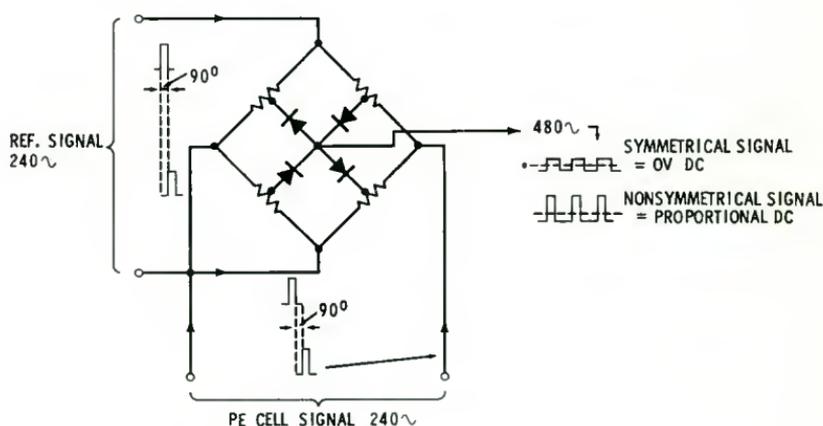


Fig. 5-6. The Ampex bridge phase comparator.

- Any DC component in the output of the bridge is filtered and delivered to the grid of an oscillator control tube. Without an error signal, the frequency of oscillation is 240 cps. The maximum frequency shift from this center frequency is about  $\pm 12$  cycles, corresponding to error signals of about  $\pm 1$  volt. While this sensitivity is necessary for accurately positioning the drum motor with respect to the sync for normal operations, a sudden shift in drum-motor speed (which could result from an abrupt change in the sync phase, such as switching from a local to a remote signal) might exceed the ability of the capstan motor to follow, and result in a large error in sync frequency during the reproduce function. This is avoided by a clamping circuit which has the effect of limiting the mini-

imum and maximum frequencies while at the same time retaining the 12-cycles-per-volt sensitivity in the operating range between the clamp voltages. These voltages are set by controls labeled Min Freq and Max Freq on the drum-servo unit. Thus, sudden, sharp changes in the system are avoided; but if the change persists, the system will gradually change to the potentials dictated by the forces which originated the condition.

8. The output of the oscillator control tube triggers a 240-cps monostable multivibrator. The square wave of this stage is differentiated, and the resultant positive pulses fire a discharge tube which discharges a capacitor from its plate to ground. This results in a sawtooth voltage, which is AC coupled to the third grid of the clipping tube (9).
9. The 240-cycle (nominal) sawtooth, whose frequency deviates in accordance with the error signal generated in the position-detector bridge, is applied to the third grid of a pentode tube. The first grid of this tube receives a DC voltage generated by the velocity detector that is proportional to any instantaneous difference between the actual frequency from the PE cell and 240 cps. The DC reference level at the plate is also proportional to this grid voltage. A diode clipper slices 1 volt out of the plate signal at approximately the 130-volt level. Only that portion of the wave between +129 and +130 volts will pass through the clipper "window." The slicing action of the clipper circuit occurs at different levels on the signal, and the sloping edge of the sawtooth slice moves with respect to the steep edge in accordance with the error signal. The eventual signal has a linear phase-shifting characteristic that is proportional to both the phase- and velocity-error signals.
10. The velocity loop utilizes the PE-cell output from the 240-cps multivibrator as the excitation signal to the low  $Q$  240-cps ringing oscillator. This signal is an approximate 240-cps square wave; but the phase is displaced from (4) by  $90^\circ$ , plus or minus an amount which is proportional to the difference between the actual PE-cell output and 240 cps. (This additional phase shift occurs as the result of feeding any signal, not of resonant frequency, through a resonant circuit.)
11. The phase splitter receives the signal from the 240-cps ringing oscillator, and delivers two  $180^\circ$  out-of-phase signals to the velocity detector.
12. The push-pull signal from the phase splitter is connected to

two terminals of the velocity-detector bridge. With the system operating in a steady-state condition with a resistive load, the output of the bridge would be a symmetrical 480-cps square wave approximately 10 volts peak-to-peak. If the output of the photoelectric cell is other than 240 cycles, the bridge output changes to an asymmetrical rectangular waveform having a DC component that is proportional to the difference between the actual photoelectric-cell frequency and 240 cps. Actually, the bridge is connected to a 180-cps-cutoff low-pass filter. The input impedance of the filter is reactive at 480 cps, so the output waveform of the bridge circuit is partially integrated. The filter sharply attenuates any 240 cps, 480 cps, or higher signals; therefore, its output has components from DC to 180 cycles. The instantaneous output voltage is proportional to any instantaneous difference between the actual frequency from the photoelectric cell and 240 cps. (This is, in effect, a frequency-discriminator circuit.)

13. The phase splitter supplies the other two inputs to the velocity-detector bridge directly from the 240-cps multivibrator.
14. A negative-pulse coincident with the sloping edge of the sawtooth slice from 9 triggers this 240-cps monostable multivibrator. The phase shift of the square-wave output of this stage is proportional to any error signal developed in the combined error detectors. The output is passed through a low-pass filter to remove harmonics of the 240-cps signal and fed to the drum-motor amplifier. Since harmonics are removed, sine-wave power results.
15. The drum motor requires three-phase power. The 240-cps sine-wave input is shifted in phase (effectively  $90^\circ$ ) to obtain two-phase power which is applied to a pair of transformers in a Scott transformer connection. Three-phase power is obtained at the output for driving the drum motor.

A simplified block diagram of the RCA headwheel servo system is shown in Fig. 5-7. The headwheel motor itself is a synchronous, hysteresis-type designed for operation in the vicinity of 300 cps. However, it is not operated in a synchronous mode. It is supplied with three-phase power at 360 cps, but its speed is held back to 240 rps, by the servo system. This nonsynchronous operating condition gives the servo system a good acceleration characteristic. The motor is continuously seeking to increase its speed toward synchronism at 360 rps, but it is held back by the fact that the servo system continuously delivers only enough power to exactly

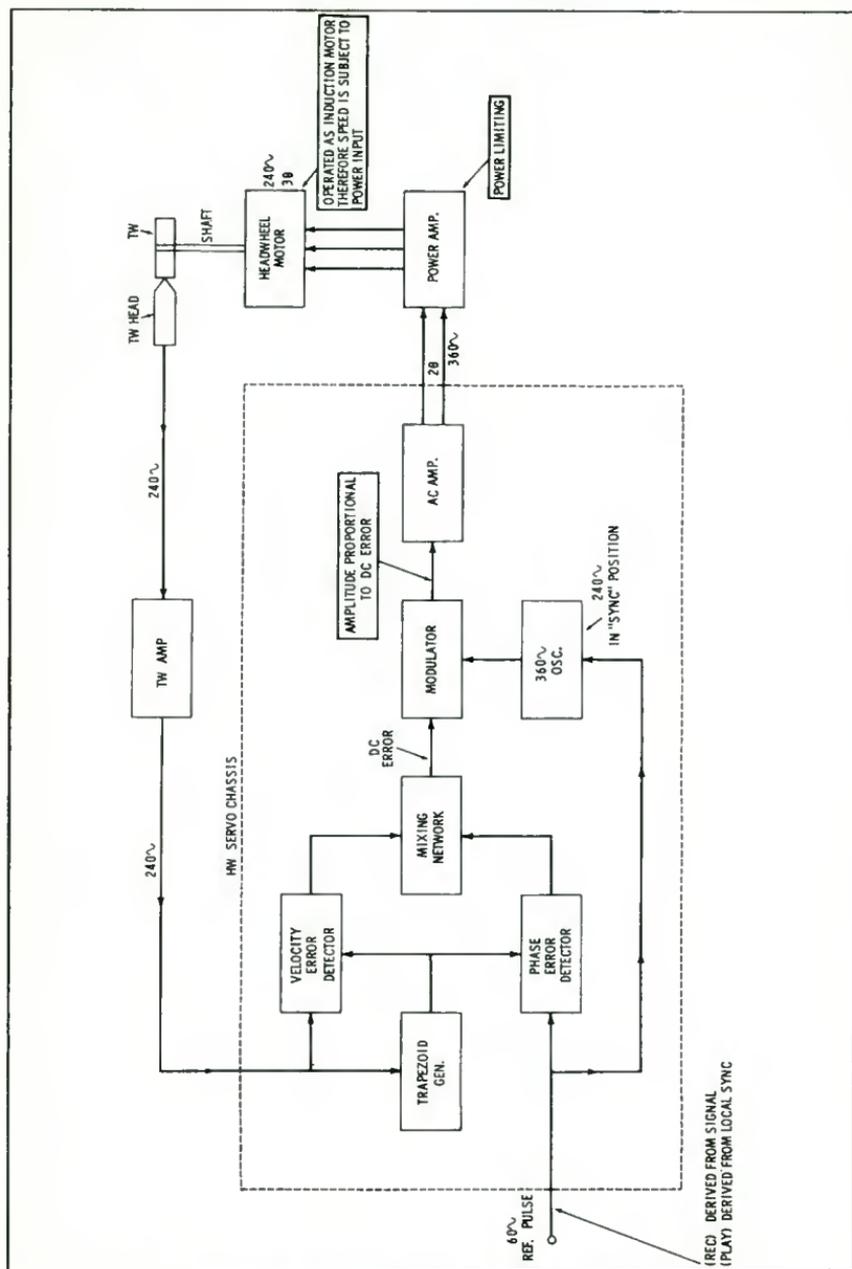


Fig. 5-7. Simplified block diagram of the RCA headwheel servo.

balance the load at a speed of 240 rps. In theory, the headwheel motor could be driven synchronously by power at 240 cps (in fact, provision is made for such synchronous operation for test purposes); however, the gain of a servo system which depends on synchronous operation is lower, other factors being equal.

The power supplied to the motor is controlled by a modulator which adjusts the level of a 360-cps signal in accordance with the output of the error detectors. The modulator operates at a relatively low-power level; therefore, it is followed by two stages of feedback-stabilized voltage amplification and a pair of 70-watt power amplifiers. A pair of phase-shifting networks at the output of the servo chassis provide two signals 90° out of phase. The two phases are amplified separately, and then converted to three-phase power through the use of Scott-connected transformers.

As shown in Fig. 5-7, there are two error detectors in the headwheel servo system. Close control is achieved through the phase-error detector shown at the bottom, wherein a trapezoidal waveform derived from the tonewheel signal is sampled by pulses derived from the stable reference source. (A trapezoid is used instead of the more common sawtooth waveform in order to obtain a steep slope in a narrow-range signal with a reasonable peak-to-peak amplitude—the trapezoid may be regarded as a slice from a much larger sawtooth.) The precise control needed for normal operation results in a narrow lock-in range for the phase detector. A wider-range velocity-error detector is also used to reduce the time required for the servo system to assume control when operation is first started or momentarily interrupted. As will be shown, the velocity detector operates by measuring the period of the tonewheel pulses. The outputs of both error detectors are combined in a mixing network that controls a single modulator, but the detectors are cross-coupled in such a way as to minimize any tendency for the two detectors to supply conflicting information.

The principle of the phase-error detector is shown in simplified form in Fig. 5-8. As noted, the function of this circuit is to develop an error signal through the comparison of the tonewheel trapezoid signal with a series of 60-cycle pulses from a stable reference generator. Sharp sampling pulses are generated from the input reference pulses.

The phase-detector stage is a close relative of the familiar double-diode clamping circuit. The two diodes are normally non-conductive, except during the very brief sampling intervals

which correspond to the peaks of the pulses delivered by the transformer. During the sampling, or clamping, intervals, the charge on the 1,000-mmf capacitor is adjusted to make the output voltage nominally equivalent to the voltage occurring at that instant at the center tap of the network. The voltage across the 1,000-mmf capacitor remains reasonably constant between clamping intervals, because, when the diodes are open, the charge on the capacitor can be altered only through high-impedance leakage paths. The signal applied to the center tap of the clamper network is the 240-cps trapezoid waveform derived from the tonewheel

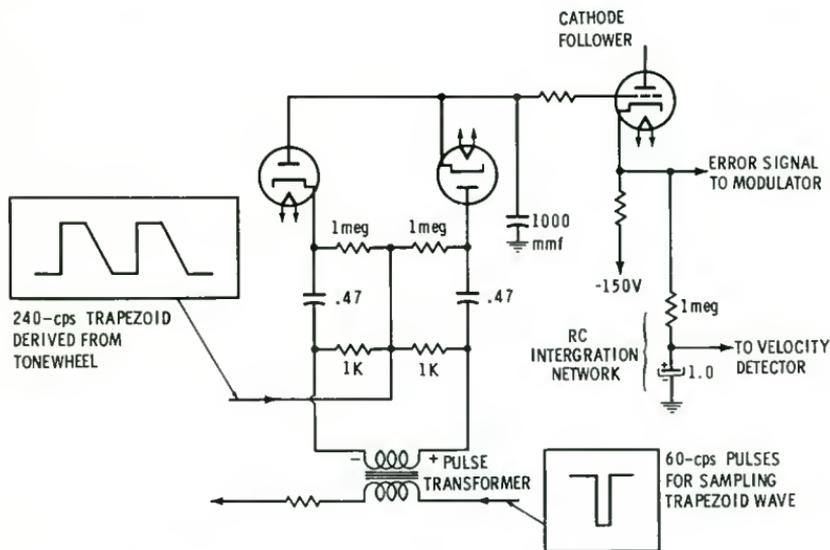


Fig. 5-8. Simplified schematic of the RCA phase error detector.

signal. Provision is made for adding a DC component to the waveform in order to adjust the absolute voltage at the midpoint of the slope on the trapezoid to a reasonable level for the following modulator.

Operation of the phase-detector circuit is illustrated by the waveforms in Fig. 5-9. Only every fourth cycle of the trapezoidal waveform is actually used, because the reference pulses occur at a 60-cps rate. When the headwheel is rotating at the proper speed, the sampling (or clamping) instant should occur exactly at the midpoint of the slope on the trapezoid waveform, as shown at C. If the motor tends to run slightly too fast, the apparent phase of

the trapezoid will be advanced relative to the reference pulses, so that the sampling will occur at a lower point on the waveform (shown at D), and the error-signal output will be reduced. This reduced-level error signal will (through the modulator circuit) reduce the power supplied to the motor and restore it to the proper speed. In similar fashion, a tendency for the motor to run too slowly will cause the error signal to increase in voltage because of the retarded phase of the trapezoid signal (shown at E), and the increased error signal will increase the power supplied to the motor so as to bring it back up to speed.

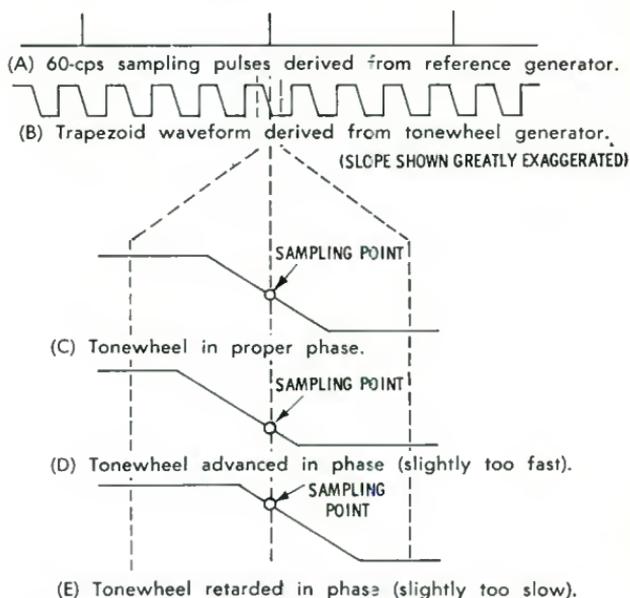


Fig. 5-9. RCA phase-error detector waveforms.

The final stage shown in Fig. 5-8 is a cathode follower which supplies a reasonably low-impedance drive for the modulator. A second output is directed to the velocity-error detector through an RC-integration network. The purpose of this output is to modify the operation of the velocity-error detector so that it does not conflict with the phase-error detector.

The velocity-error detector is quite similar to the phase-error detector, but the sampling pulses which operate the clamp-type detector are derived from a 240-cps square wave instead of from the 60-cps reference pulses. The input square wave is differen-

tiated and the negative-going pips are coupled through a diode to trigger a stabilized multivibrator. Sharp sampling pulses are derived from the falling edges of the pulses by a ringing coil. The phase detector is also identical, except that a 4,700-mmf output capacitor is used instead of a 1,000-mmf capacitor (four times as many pulses are available to replenish the charge on the capacitor). As in the case of the phase-error detector, a cathode follower is used at the output to provide a low impedance driving point for the modulator.

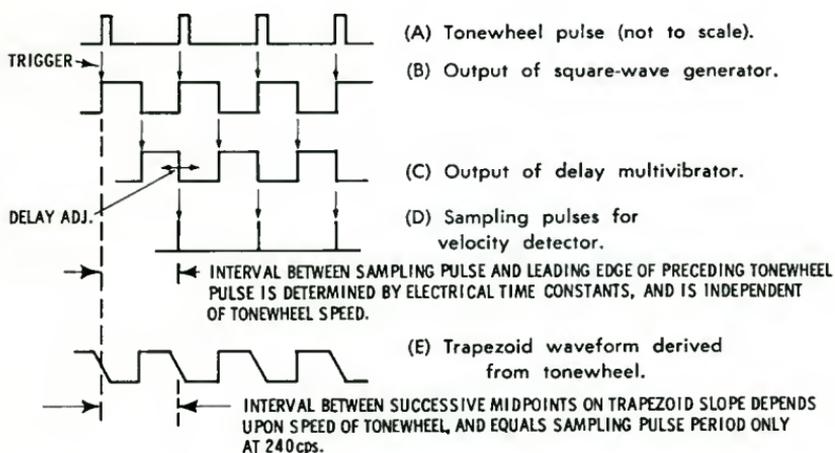


Fig. 5-10. RCA velocity-error detector waveforms.

The operation of the velocity-error detector is explained with the waveforms in Fig. 5-10. The 240-cps sampling pulses used in the velocity-error detector are actually delayed nominally one full period by virtue of the fact that two multivibrators are triggered in series to produce them. The net result is that the time interval between each sampling pulse and the leading edge of the preceding tonewheel pulse is determined only by electrical time constants. Therefore, it is independent of the tonewheel speed. The width of the pulse produced by the first multivibrator is adjusted to make the square wave as symmetrical as possible, and the width of the pulses produced by the second are adjusted to make their trailing edges coincide with the midpoints of the slopes in the trapezoid waveform when the headwheel is operating at exactly 240 rps. Once these adjustments are made, the relative phase of the sampling pulses and the trapezoid signal

will vary slightly, if the headwheel is not running at the proper speed. If the headwheel runs slightly too fast, for example, the period of the trapezoid waveform is shortened slightly, causing the sampling point in the detector to slide down the waveform thus generating an appropriate error signal. In effect, the detector is actually measuring the period between successive tonewheel pulses. The pull-in range of this detector is considerably greater than that of the phase-error detector, and it develops a useful error signal as soon as tonewheel pulses appear when the machine is started up (pulses appear at about 60 rps).

A cathode follower, coupled to a pulse-width-determining time constant in a multivibrator, is the means by which the output of the phase-error detector modifies the operation of the velocity-error detector to prevent the two circuits from delivering contradictory information to the modulator.

Consider what happens if the servo system is subject to a sudden transient disturbance. Suppose, for example, that the headwheel motor is operating in the Record mode at exactly the right speed, but that it suddenly is in improper phase because of a sudden switch to a different composite picture signal at the input. The reference pulses may still be produced at exactly the same 60-cps rate, but a time discontinuity in the input signal could cause the sampling pulses derived from the reference pulses to jump completely off the slope of the trapezoidal waveform and sample either the positive or negative flat portion of the trapezoidal waveform.

Let's suppose that the sampling occurs during the positive flat portion. In this case, the phase-error detector generates its maximum error voltage in the direction implying that the motor should speed up slightly to correct the phase discontinuity. Although the motor is actually running at the proper speed and therefore producing no error signal from the velocity-error detector, it must accelerate momentarily to correct for the phase discrepancy. When this acceleration occurs, however, the velocity-error detector, if left unmodified, produces an error signal in such a direction as to counteract the desired acceleration. To prevent this conflict, the positive error signal from the phase detector is applied through a cathode follower to slightly shorten the multivibrator pulse period. This effectively shortens the "yardstick" against which the velocity-error detector measures the pulse periods and thus prevents the generation of the unwanted velocity-error signal.

In normal operation, when the phase error is seldom great enough to cause the sampling pulses to leave the trapezoid slope, the cross-coupling of the detectors results in increased gain for the servo system. That is, a slight increase in the error voltage as a result of a minor phase error causes the velocity-error detector to develop a slight positive voltage. An integrating network prevents the velocity-error detector from following the slight high-frequency variations in the phase-error detector.

Two separate controls to set the null frequency of a bridged-T-type oscillator are provided on a switchable basis. One of these is adjusted to 240 cps (Sync position) for setup and test purposes. This position also provides emergency operation in case of failure of portions of the headwheel servo circuitry. The other is adjusted to 360 cps (Servo position) for normal servo operation. As shown in Fig. 5-7, the modulator receives the combined outputs of the two error detectors, and the output of the constant-amplitude oscillator (normally 360 cps). The amplitude of the oscillator signal is varied in accordance with the combined error signals. As previously noted, the RCA servo system continuously delivers just enough power to exactly balance the load at 240 rps.

The principle of the modulator-oscillator action is illustrated in Fig. 5-11. The oscillator (V1 and V2) is a cathode-coupled type locked to the sixth harmonic of the 60-cps trigger from the reference generator. The cutoff time of V2 is controlled by the discharge of C3 through R3. The cutoff time of V1 is controlled by the discharge of C1 through R1. When the switch is in the Sync position, extra capacity (longer time constant) locks the oscillator to the fourth harmonic (240 cps) of the 60 cps trigger. In this operation, the error signals are not used.

In the normal or Servo position, the oscillator output from the plate of V1 acts as a control signal to turn a DC voltage appearing across R2 off and on. This DC is dependent on that existing from the phase and velocity-error detectors across modulator diodes CR1 and CR2. The DC voltage across R2 alternates between the error signal and ground at a 360-cps rate. The result is a 360-cps square wave whose amplitude is proportional to the DC error signal fed into the modulator.

### 5-3. THE CAPSTAN SERVO

Fig. 5-12 illustrates a simplified version of the Ampex Series 1000 capstan servo. During the Record mode, the 60-cycle system

reference frequency is the primary motive force for the drum motor. The cell scans a rotating disc on the motor shaft and generates a 240-cycle signal whose phase and frequency are dependent on the head drum. This signal synchronizes a 240-cycle multi-vibrator the output of which is progressively divided by two, with a resulting 60-cycle signal supplied to the capstan-motor circuit. Thus, the rotation of the capstan motor during recording is electronically coupled to the rotation of the head drum. The 240-cycle

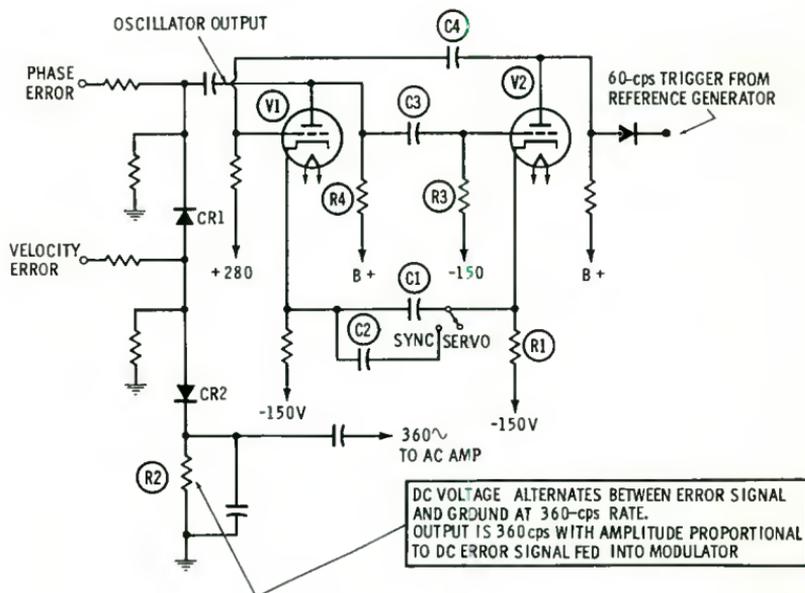


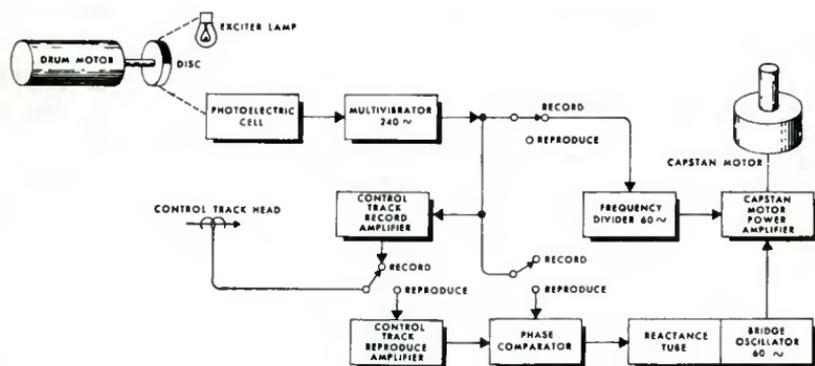
Fig. 5-11. Modulator oscillator for RCA headwheel servo.

signal is also recorded on the bottom edge of the tape as a control track.

In the Reproduce mode, the recorded 240-cycle control track is reproduced from the tape and compared in phase with the output of the photoelectric cell. Both signals are converted to square waves and connected to a phase-sensing circuit. As long as they are exactly  $90^\circ$  out of phase there will be no error voltage generated. However, when the phase angle from the control track and the photoelectric cell differ from  $90^\circ$ , which will occur if the capstan rotation is not synchronized with head-drum rotation, a resultant positive or negative DC voltage will be created.

This voltage controls the operation of a reactance tube, which is one of the frequency-determining elements of a bridge-oscillator circuit. The bridge-oscillator output is routed through the capstan-motor power amplifier to the capstan motor. Thus, any phase error is translated into a control voltage, which varies the frequency of oscillation and corrects the capstan-motor speed.

A simplified block of the RCA capstan servo is presented in Fig. 5-13. In the Record mode, the 60-cps oscillator is controlled



Courtesy Ampex International Operations, Inc.

Fig. 5-12. Block diagram of the Ampex capstan servo.

by a phase comparison of its frequency with that of the 240-cps tonewheel (TW) signal. A delayed 240-cps TW signal is mixed with the frame (edit) pulse and recorded on the control track (CT). The delay is adjusted in the tonewheel amplifier so that the 240-cycle sine wave is phased with the edit pulse (coincident with the reference pulse), as shown by the photo.

In the Play mode, the 60-cps oscillator is controlled by a phase comparison of the 240-cps control track signal and the 240-cps tonewheel signal. The basic operation is illustrated by Fig. 5-14. The diodes are nonconducting, except for brief intervals at the tips of the sampling pulses from T1. Capacitor C1 sufficiently retains its charge between pulses to hold the diodes nonconducting. The arrival of the sampling pulse causes the diodes to conduct, and capacitor C2 charges to whatever voltage is provided by the sawtooth derived from the tonewheel. The resultant DC error signal is used to control the frequency of the 60-cps voltage-controlled oscillator which, in turn, controls the speed of the capstan motor.



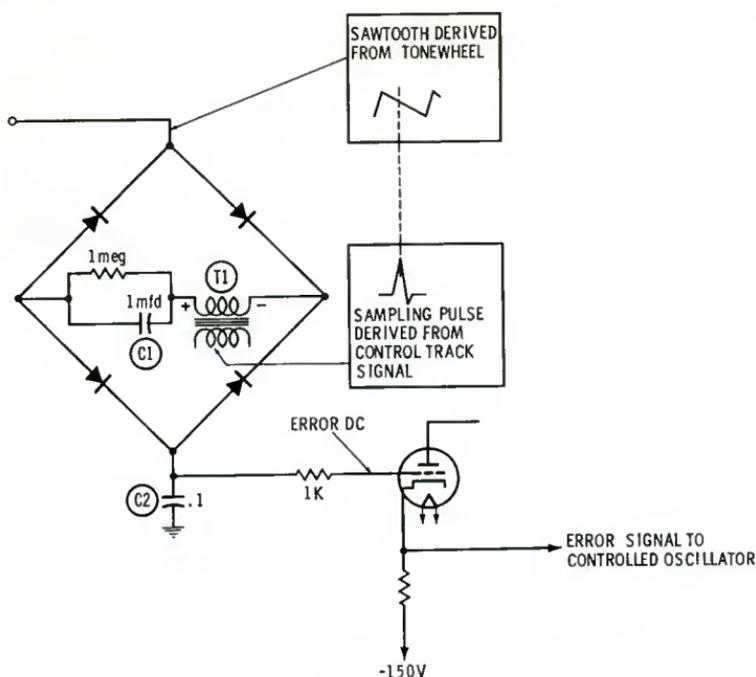


Fig. 5-14. The RCA capstan phase-error detector.

resulting from wear, slight differences between machines, and expansion or contraction in the tape itself. During recording, the shoe is maintained in a fixed position, resulting in a fixed degree of stretch in the tape; the stretch must be great enough to permit

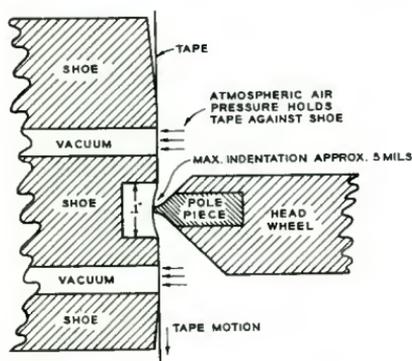


Fig. 5-15. Cross-sectional drawing of the tape guide and headwheel.

Courtesy Radio Corporation of America.

playback in a state of tension under the least favorable conditions likely to be encountered. (Unfortunately, it is not practical to compress the tape during playback, but it is relatively easy to stretch it.) During playback, the tape should be stretched only enough to match the conditions under which it was recorded, and the guide servo system is provided to make the required adjustments automatically.

If the guide position is not correct (resulting in either too much or too little stretch of the tape) the relative head-to-tape speed is not quite correct and there are slight timing errors in the output signal—just as in the case of an audio tape recorder running at an

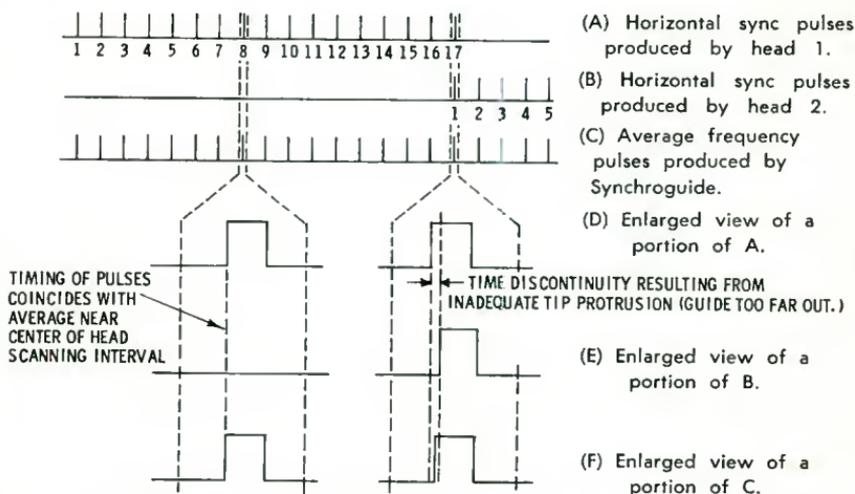


Fig. 5-16. Timing error resulting from vacuum guide position error.

improper speed. The average timing remains correct, however, because the angular velocity of the headwheel is maintained at a proper value by the headwheel servo system. The timing errors appear in the form of discontinuities at the instant of switching from head to head, as indicated in Fig. 5-16. While only horizontal sync pulses are shown, the same timing errors also occur for all picture-signal components.

If a train of pulses containing slight timing discontinuities is applied to the *Synchroguide*-type horizontal oscillator with a flywheel time constant somewhat greater than the 16-line head-scanning interval, it is possible to develop a steady train of average-frequency pulses in which the timing variations are

eliminated, as shown at C and F in Fig. 5-16. Since most horizontal-deflection circuits in television receivers behave in this general fashion, the appearance of shoe-position errors in television pictures is about the same as that indicated in Fig. 5-17. The flywheel effect in the deflection oscillator causes the line scanning to occur at essentially constant frequency, but the timing errors in blanking and all other signal components causes an effect that various people have called jogging, skew, or the venetian-blind effect. The jogs occur in bands of 16 lines per field, or 32 lines in properly interlaced frames, since approximately 16 lines are recorded during each head-scanning interval. Fig. 5-17 illustrates

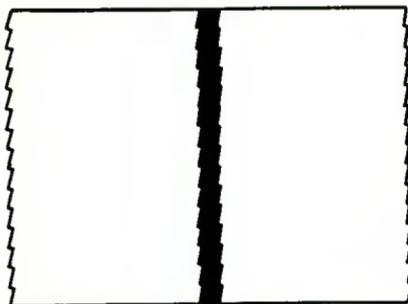


Fig. 5-17 Effect of a 1-mil guide error on a television raster.

Courtesy Radio Corporation of America.

inadequate head-to-tape pressure resulting from the guide being too far out. If the guide is too far in (excessive pressure), the result is very similar, but the jogs slope in the opposite direction. As a rough "rule of thumb," an error of about 1 mil in guide position results in jogs that are offset by about 1.25% of the picture width. Guide position is correct at the point where the jogs completely disappear. (Review Section 2-5 for details of time space errors.)

In both the Ampex and RCA vacuum-guide servo systems most of the circuits are mounted on a subchassis. The circuits represent an adaptation of a standard servo system designed for a variety of positioning-type applications. The main output device for the system is a motor that normally remains stationary and moves only slightly in one direction or the other in response to error signals. In general, the motor automatically seeks to position itself so as to keep the error signal at zero.

The main error detector for the RCA guide servo system is not mounted on the guide-servo chassis; it is located on the  $2 \times 1$  switcher, where it also performs additional functions related to

the head-switching operations. The error detector is a simple adaptation of a conventional *Synchroguide* circuit; a circuit tuned to 960 cps is inserted in the plate circuit of the *Synchroguide* control tube to sense the presence of timing variations at the head-switching rate. (See Fig. 4-22.) The polarity of the 960-cps signal developed in this circuit indicates the direction of the timing errors. In the circuitry of the shoe-servo chassis, the 960-cps signal is amplified, clipped, and rectified. To preserve the direction sense in the error signal, the rectifier is a bidirectional type,

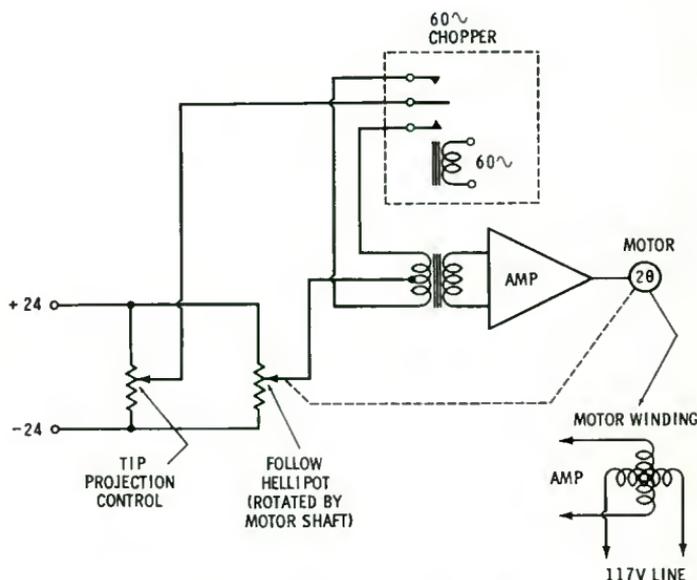


Fig. 5-18. The basic idea of the tape guide servo.

utilizing 960-cps clamping pulses derived from the tonewheel attached to the headwheel motor. The clipping is severe enough if there is any significant error signal at all, the rectifier produces a fixed DC level of a polarity indicating the direction of the error. The rectifier error signal is converted to 60 cps AC by the action of a chopper-type modulator (Fig. 5-18) and then amplified to the power level necessary to drive the guide-positioning motor. The motor is a two-phase type in which one phase is continuously excited by the power line, while the other is driven by the amplifier. The motor develops torque only when a signal is delivered by the amplifier; the direction of this torque depends

on the polarity of the amplifier signal. The motor then drives the guide through an appropriate mechanical coupling. The motor movement is limited to only a few revolutions, and the maximum displacement required for the guide is only about 5 mils. The servo loop is completed through the video heads, slip rings, video-playback system, and a sync separator (the sync separator is also mounted on the  $2 \times 1$  switcher chassis).

A much smaller servo loop is used for manual positioning of the guide during recording operations and during special cases of playback operation. For manual operation, a potentiometer on the motor shaft is compared with the setting of a second potentiometer, which is mounted on the control panel. The motor turns until the voltage at the arm of the motor potentiometer (follower) is the same as that on the manual Guide-Position control, resulting in zero signal at the output of the chopper.

## 5-5. SYSTEM BLOCKS

For the purpose of complete system description, the functional block diagram of the RCA recording mode is given in Fig. 5-19. NOTE: The dashed arrow lines with the identification "CRO" encircled indicate monitoring points provided on the waveform monitor panel. Note also that all units have been described in previous subsections except the reference generator and the tonewheel (TW) amplifier.

In the Record mode, the reference generator receives separated sync from the video signal being recorded. This is represented by waveforms A and B in Fig. 5-20 which also indicates the half-line difference of the two fields. By means of a precise vertical-sync separation and differentiation of the vertical-rate pulses, the 60-cps reference pulse is formed at the leading edge of the second vertical-sync pulse in each field (waveform C). This reference is delivered to the headwheel (HW) servo where it is used as described in Section 5-2.

Incoming sync is also differentiated to trigger a multivibrator which has a fixed duration of  $\frac{3}{4}H$ , as shown by waveforms D and E. A coincidence detector which receives both the 60-cps reference pulse and the  $\frac{3}{4}H$  pulse triggers a separate multivibrator when coincidence occurs. Note that this can occur only on field 2, which is the field with the half-line spacing between the last horizontal-sync pulse and the first equalizing pulse of the vertical interval. The resulting 30-cps frame pulse (waveform F) is fed to the cap-

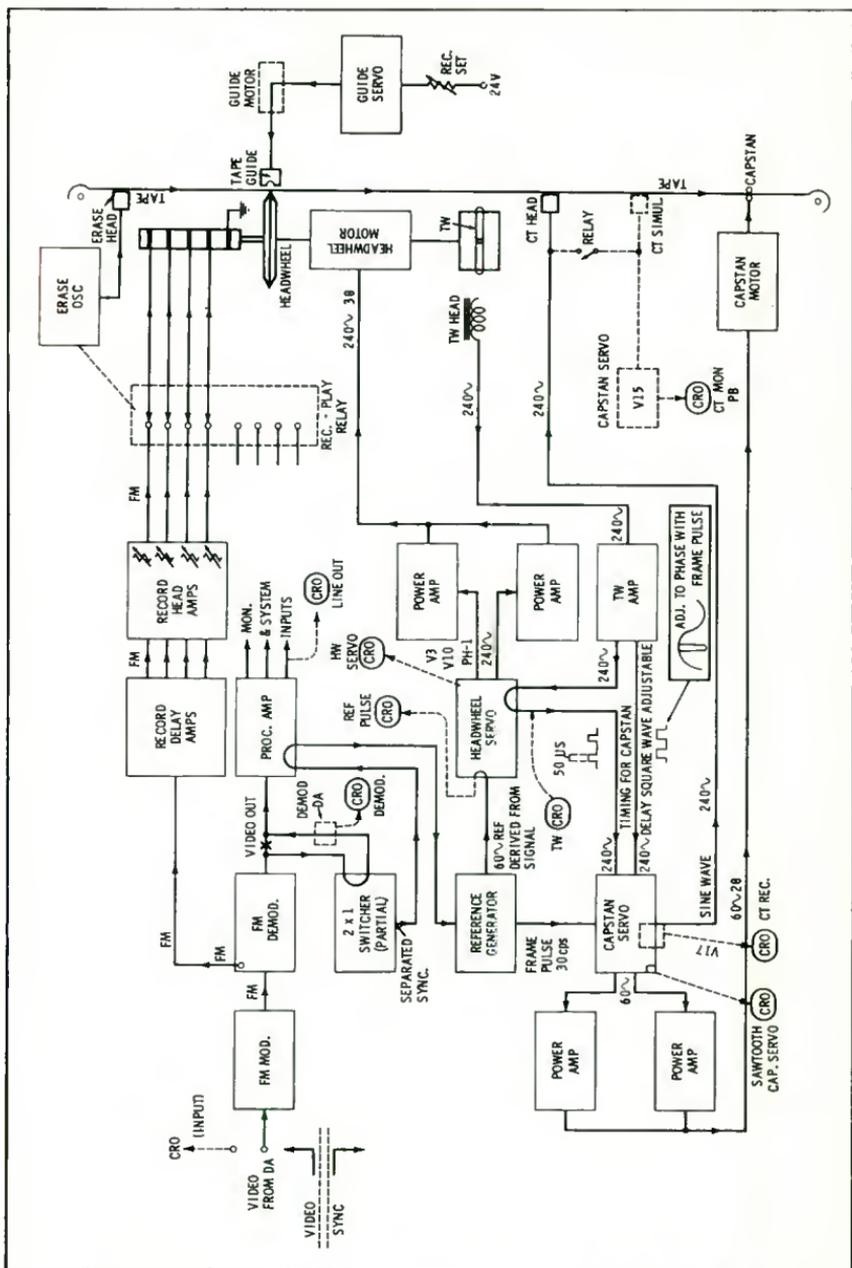


Fig. 5-19. Complete block diagram of the RCA record mode.

stan servo where it is mixed with the control-track sine wave recorded. The 240-cps square wave (which is converted to a sine wave) from the tonewheel amplifier is adjusted in delay so that the frame (edit) pulse is centered on the positive alternation of the sine wave, as shown in Fig. 5-13.

Fig. 5-21 is the over-all functional block of the RCA Playback mode. The Delay 960 control (on TW amp block) adjusts the switching point of the  $2 \times 1$  switcher so that switching occurs during the overlap intervals of the rotating heads as previously

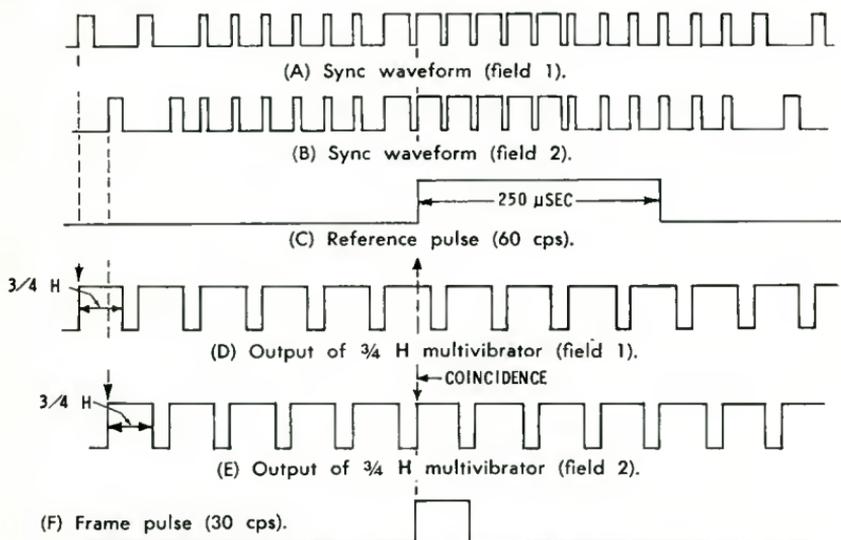


Fig. 5-20. Operation of the reference generator.

described. The tracking control (labeled Control Track Phase on the control panel) is provided to allow any head to scan any track for optimum playback results. As noted previously, the Ampex system tracking control uses the control track signal rather than the head-tachometer signal for this purpose. (This is also the case for RCA systems modified for *Switchlock* and *Line-lock* which makes the tape output-signal synchronous with the local sync generator. The Ampex terminology for this function is *Intersync*.)

The reader should now be able to visualize the entire over-all function from a theoretical standpoint of Record and Playback modes from the complete blocks and previous analysis of the individual units.

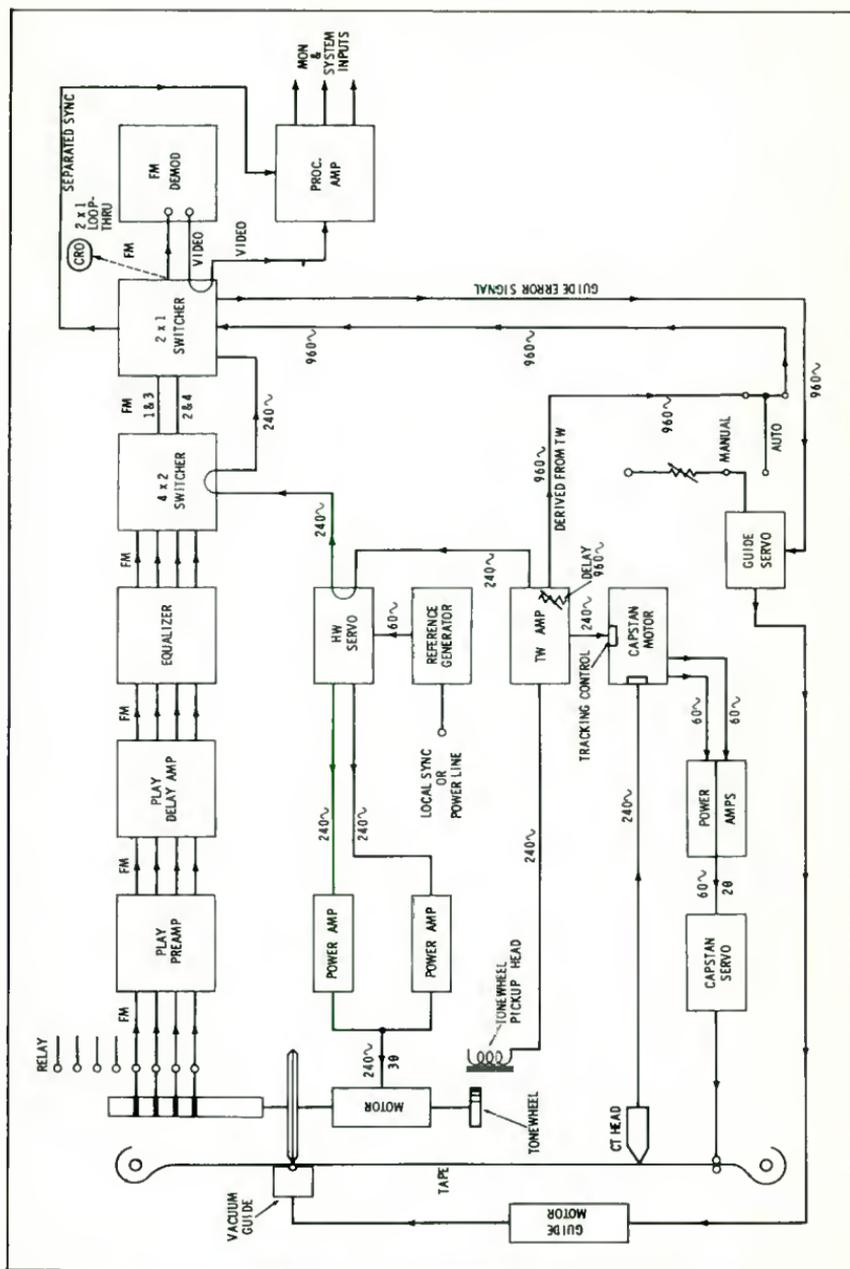


Fig. 5-21. Complete block diagram of the RCA playback mode.

## 5-6. THE AMPEX INTERSYNC

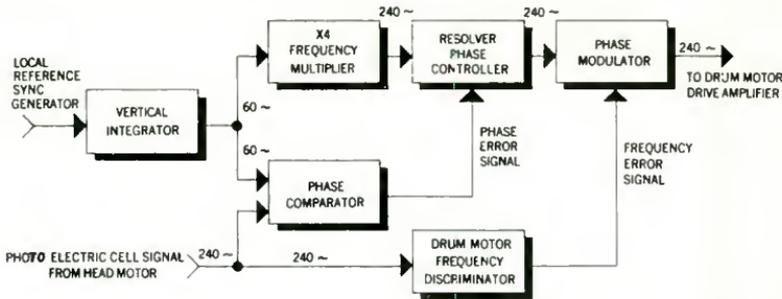
The Ampex *Intersync* unit replaces the conventional drum servo and capstan signal generator in the associated racks. With *Intersync* it is possible to lock one or more Ampex recorders to any external sync source or to each other with sufficient precision to permit integration of the recorder output into normal studio programming. This allows no-roll switching, lap-dissolving fades, wipes, and special effects to be utilized between tape signals and local or remote studio sources.

The first question which occurs to the experienced studio engineer is, "Why not Genlock the local sync generator with the separated sync from the tape recorder?" This is the normal method of superimposing local inserts over network or remote pickups when tape machines are not involved.

The answer is that with a standard drum servo the only information available that indicates the head drum is speeding up or slowing down comes from a phase comparison of the 240-cycle signal developed by the PE cell (Ampex head tachometer) which scans the timing ring, and the fourth multiple of the incoming vertical sync. The head must complete a full half-rotation ( $180^\circ$ ) before the required coincidence of these two signals can be measured. Since each head scans 16 to 17 television lines and two of them go by in one-half the drum rotation, some 32 or 33 TV lines have been scanned before the drum servo is even aware that a time base error is occurring. Thus, smaller increments of information are needed to hold the head drum to a more precise and uniform angular velocity before a means of sync lock is attempted.

Since it is necessary to frame the picture vertically before horizontal locking is achieved and since no signal off tape is available from the video head until the tape guide snaps in (2 to 5 seconds depending on the mode of operation), preliminary vertical information is obtained from the frame pulses on the control track. (The control track gives a signal as soon as the tape rolls.) These pulses provide a useful signal for the vertical phase comparator to start the course correction. As soon as the female guide pulls in, the more precise vertical sync signal takes over. This technique significantly cuts down pull-in time of the *Intersync* unit.

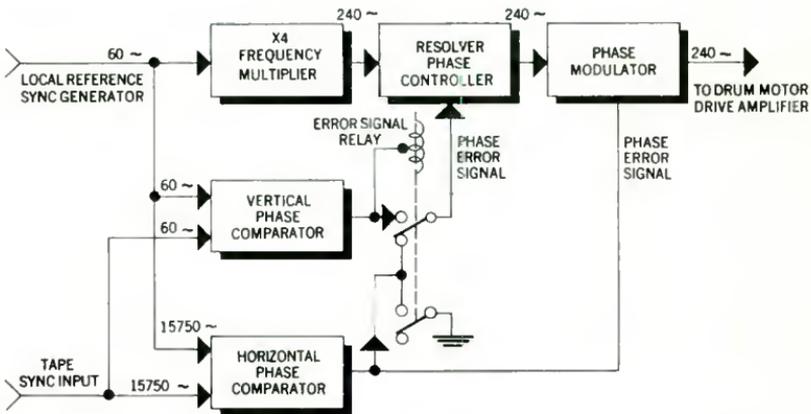
Two basic block diagrams, Figs. 5-22 and 5-23, will serve to illustrate a simplified description of the actual operation of *Intersync* in both the record and playback modes. In the record



Courtesy Ampex International Operations, Inc.

Fig. 5-22. Simplified block diagram of Ampex *Intersync* record mode.

mode, the incoming reference sync, which can be either terminated or looped through, is stripped of vertical sync, and the 60-cycle sync information is applied to a  $\times 4$  multiplier. This develops a 240-cycle signal that is locked to the incoming vertical sync. This 240-cycle signal is then phase controlled by a coarse resolver and a high-speed vernier phase modulator. The phase-controlled 240-cycle signal is now used to drive the drum-motor amplifier, which in turn powers the drum motor. Simultaneously, a 240-cycle signal developed by the PE cell on the head-drum assembly is applied to a phase comparator and altered into a sawtooth waveform. This sawtooth is then sampled by the 60-cycle pulse which is derived from incoming vertical sync and is utilized



Courtesy Ampex International Operations, Inc.

Fig. 5-23. Simplified block diagram of Ampex *Intersync* playback mode.

to develop an error signal which drives the resolver-phase controller, if a phase differential is present.

The 240-cycle PE signal is also applied to the drum-motor frequency discriminator, which is basically a damping circuit operating as a rate change detector and developing a frequency-error signal that controls the phase modulator. Through this arrangement, the video-head assembly is precisely controlled during record so that it achieves both maximum uniformity of angular velocity and precise physical position with reference to the vertical sync in the composite video signal. A recording made under these conditions guarantees the utmost in interspliceability with other such tapes.

In the playback mode, the same reference-sync signal provided by either the local-sync generator or network sync is utilized. The composite sync is divided into its two components—60-cycle vertical information and 15,750-cycle horizontal information. Timing information is derived from the composite sync coming off the tape; it, too, is divided into its 60- and 15,750-cycle elements. Because it is necessary to frame vertically before horizontal lock in is attempted, the two 60-cycle components are compared in a vertical-phase comparator, and an error signal is developed that drives the resolver-phase controller and establishes vertical framing and some coarse degree of horizontal framing. To avoid dual functions occurring simultaneously while vertical framing is being achieved, an error-signal relay operating from the voltage developed by the vertical-phase comparator holds the output of the horizontal-phase comparator grounded, thereby keeping the phase-modulator input in a steady-state condition during vertical framing.

With vertical coincidence established between reference sync and tape sync, the error-signal relay drops out. An error voltage developed from a phase comparison of the 15,750 coming from the two sync sources is now used to hold the resolver-phase controller in its correct position while applying a high-speed phase-error signal to the phase modulator, which provides the small instantaneous corrections necessary to maintain the drum-motor angular velocity within the tolerances required.

With the system described here, it is possible to maintain a time coincidence between local reference sync and tape sync of approximately .1 microsecond for periods under 1 second and with a long term stability of .2 microsecond for periods of 1 minute or over. The viewed image will show a degree of jitter, which is

noticeable under close inspection of stationary test patterns but not objectionable with normal program material.

## 5-7. AUTOMATIC TIME-ERROR CORRECTION

The introduction of the Ampex Time-Error Compensation (*Amtec*) has resulted in a great improvement of time-base stability and provided the broadcaster with a much needed tool which can expand his utilization of TV tape as a program source.

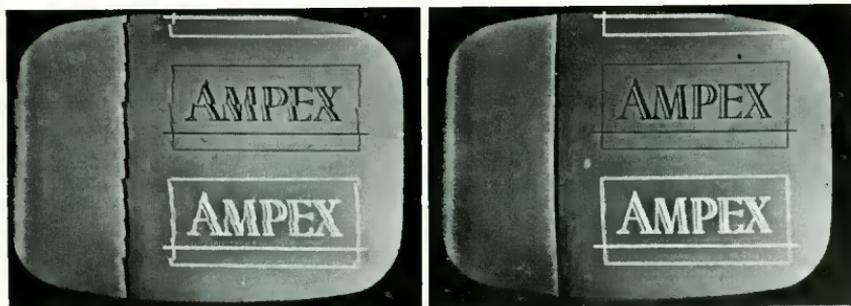
*Amtec* provides two operating modes, both of which achieve the same degree of correction. During the picture-straightening mode, it time-compares each horizontal-sync pulse with a reference signal that is the average of the *interval* between the leading edges of successive horizontal-sync pulses in the incoming video signal. During the *Intersync* mode, it time-compares the horizontal-sync pulses in the incoming video signal with their counterpart in an external-reference signal (for example, from the station's local-sync generator).

The *Intersync* mode permits the combination of video information from other video sources (i.e. another television recorder, studio cameras, or remote cameras) that are controlled by the same sync source to produce lap-dissolves, split-screen, or other special effects without subjective loss of picture stability.

*Amtec* functions as an open-loop electronic servo placed in the system (between the demodulator and the processor) to reduce the timing errors in the signal received by the processor to a level rendering them invisible in the reproduced picture. The incoming video signal is not altered in any way, hence *Amtec* is not a closed-loop system. The effectiveness of *Amtec* operation in minimizing time-base errors is shown by Fig. 5-24.

A basic diagram of the *Amtec* System is given in Fig. 5-25. The non-corrected incoming composite video signal from the demodulator passes through a voltage-controlled delay line. The noncorrected incoming-sync information is routed to an error detector where it is time compared with a stable timing reference signal.

The error detector produces a bias voltage that is approximately proportional to the fourth power of the timing difference between the compared signals. This bias voltage becomes a control voltage that is applied to the voltage-controlled delay line, causing the latter to insert a varying delay affecting the lines of video information and partially correcting the horizontal-sync pulses. The inserted delay is the precise opposite of the original timing error in



(A) Input with time-base error.

Courtesy Ampex International Operations, Inc.

(B) Output of Amtec with input of A.

Fig. 5-24. The effect of Amtec on time-base errors.

the reproduced signal. It thus causes error cancellation. The time-corrected composite-video signal is then delivered to the processor.

The incoming noncorrected composite video signal (from the demodulator) is routed through the video driver in Fig. 5-26. The video driver adjusts the signal level and impedance to the requirements of the voltage-controlled delay line.

The signal is also routed by two converging paths through a clamped video stage to the sync gate. In the first path, the signal passes through a video amplifier to the clamped stage. In the second path horizontal sync is stripped from the composite signal and is then used to form the clamp pulse generator, whose balanced push-pull output is routed to the clamped stage.

The 15,750-pps 5-microsecond pulse generator controls the action of the sync gate, which allows a 5-microsecond sample of the

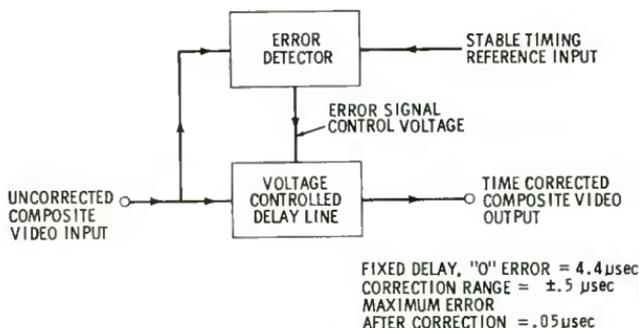


Fig. 5-25. Basic block diagram of Amtec.

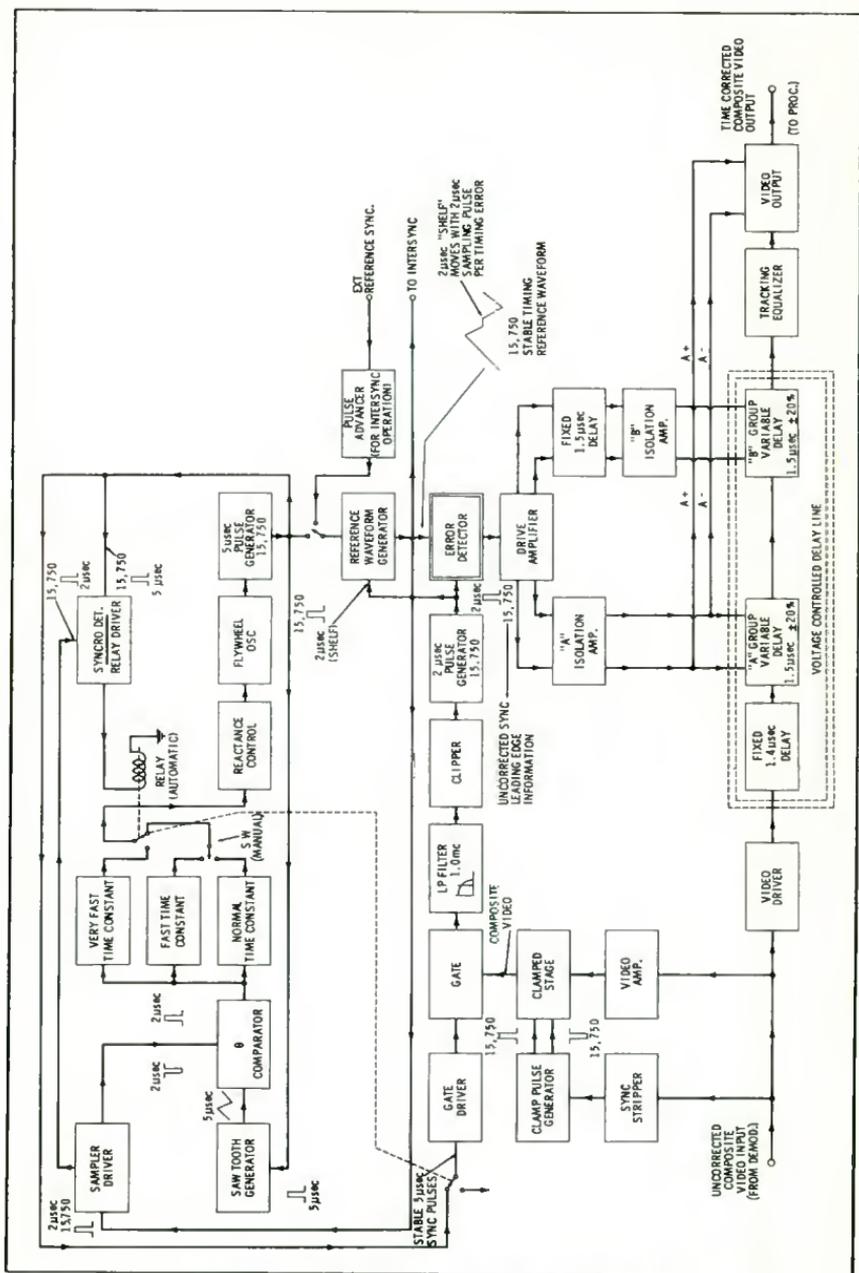


Fig. 5-26. Over-all block diagram of Amtec.

noncorrected sync pulse, and its timing edge, to pass through the low-pass filter and a clipper stage in route to the 2-microsecond pulse generator that is formed by the sample.

The 2-microsecond nontime-corrected pulse is routed to one input of the error detector, and to the reference sawtooth-generator shaper. The latter generates a stable sawtooth waveform at the (average) horizontal rate, and adds the voltage received in the 2-microsecond pulse to form a 2-microsecond step on the slope. Because the peak-to-peak descending-slope time is 5 microseconds, the 2-microsecond step appears at a higher voltage level when the pulse is early, than when the pulse is late.

The noncorrected 2-microsecond pulse is also routed to the sampler/driver. The latter provides two outputs, one of which is routed to the synchro detector/relay driver and the other to the phase comparator. The latter also receives a 5-microsecond sawtooth waveform from the sawtooth generator, which is triggered by the signal from the 5-microsecond pulse generator. This signal is the long-term average of the incoming horizontal-sync rate, and is established in the reactance-controlled flywheel-oscillator loop.

The resulting phase-comparator output voltage is routed to the inputs of three selectable time-constant circuits, that are graded normal, fast, and very fast. Manual switch selection offers the choice between normal, and fast; supplementary relay switch selection adds the choice of very fast to the particular time constant selected by the manual switch position. One of the time constants is always in the circuit and conducts the comparator output to the reactance control circuit of the flywheel oscillator.

The filtering action of the time-constant circuits eliminates high rate-of-change components in the reactance control voltage, which causes the oscillator to remain locked in frequency and phase to the long-term average of the incoming horizontal-sync rate. Because the output of the 5-microsecond pulse generator is formed from the output of the flywheel oscillator, the pulse is timed at the long-term average rate.

As previously stated, the synchro detector/relay driver receives the noncorrected incoming horizontal-sync information from the sampler driver. It also receives the long-term average of the rate of incoming horizontal sync from the 5-microsecond pulse generator. When the two signals are in coincidence, the synchro detector recognizes the condition and causes the output of the relay driver to be at the level that energizes the relay coil. Under this condition, the connected-circuit time constant is the one selected by the

manual switch position, and the correction rate is either normal or fast.

The synchro detector also recognizes the condition of non-coincidence of the two signals by causing the relay-driver output to fall to the minimum. This de-energizes the relay coil, which causes the insertion of the very fast time-constant correction rate in the circuit and disables the gate.

The 5-microsecond time averaged sync pulse is routed through a switch to the reference sawtooth generator/shaper. The shaped sawtooth is routed to the error detector, where it is phase compared with the 2-microsecond noncorrected sync-pulse sample. It is here that the primary error signal is derived that ultimately biases the voltage-controlled delay line.

NOTE: During *Intersync* mode, the pulse advancer samples a 5-microsecond portion of reference sync, including the timing edge. This reference sample is applied (by switching) to the reference sawtooth generator/shaper, and replaces the long-term average sync-pulse information that is used during the picture-straightening mode. Under either mode, the gate driver (and the gate) continue under the control of the 5-microsecond long-term average of the rate of incoming horizontal sync.

The output of the reference sawtooth generator/shaper is used exactly as before to correct the sync timing errors contained in the incoming video signal. It corrects them to coincide with the external reference instead of the long-term average of incoming horizontal sync. At the same time, the *Intersync* television-signal synchronizer receives the 2-microsecond noncorrected sync-pulse sample from the *Amtec* and is thus enabled to coordinate its precise control of video head-drum rotation with the correction of sync timing errors provided.

The output of the error detector is routed to the driver amplifier which provides twin push-pull outputs. Output No. 1 drives isolation amplifier A directly, and No. 2 drives isolation amplifier B through a 1.5-microsecond fixed-delay line.

The push-pull output of isolation amplifier A is routed to 1.5-microsecond variable-delay group A, and the 1.5-microsecond delayed (but otherwise identical) push-pull output of isolation amplifier B is routed to the 1.5-microsecond variable-delay group B.

These delay groups (in the voltage-controlled delay line) are controlled by the error bias previously mentioned. This is applied to silicon-junction capacitors that serve as the delay control ele-

ments. The total of the delay that can be caused is 3 microseconds  $\pm 20\%$ .

NOTE: The error bias referred to is raised to approximately the fourth power of the error-detector output voltage by the amplifiers and is the mirror image of the timing error present in the input signal.

Because the incoming (noncorrected, and corrected) video signals follow electronic paths of different length before they converge at the voltage-controlled delay line, a 1.4-microsecond fixed delay of the signal from the video driver is inserted to time equalize the two paths.

The video-bandpass characteristics of the voltage-controlled delay line vary with changes in delay and must be compensated for. The tracking equalizer provides the required compensation. Its balanced input is connected to the push-pull bias-voltage output of isolation amplifier A; its single-ended input receives the output of the voltage-controlled delay line.

The tracking equalizer exhibits variable bandpass characteristics that are the mirror image of those exhibited by the delay line. It thus causes the over-all bandpass of the *Amtec* to be flat to 4.2 mc (through its range). This signal passes through the video-output stage from which it is routed to the processor in the television recorder system.

SECTION 6

# OPERATIONS

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## SECTION 6

# OPERATIONS

Television-tape systems, now refined to a rather high degree of performance, utilize many unique mechanical and electronic arrangements, each of which makes an important contribution to the final production. Any complex system of this nature requires the development of a certain amount of skill in setup and operation.

Obviously the degree of skill and knowledge required for operation depends on the *modus operandi* of any particular station. If the tape operator is charged only with threading, selecting the proper video and audio feed, and starting and stopping the system on cue, he will likely not be interested in this notebook, except out of curiosity or as a means of advancement. However, there are two other more common operating practices which may be listed as follows:

1. A practice where TV tape operators are charged with the responsibility of cleaning, adjusting modulator frequency and deviation, calibrating and adjusting video and audio levels, head optimization, transport and head degaussing, and checkout of the system with a short trial recording and playback. In this type operation, maintenance personnel are called to service equipment in case of abnormal operation, and may also be required to carry out the more time-consuming functions, such as head optimization.
2. In the second type of operation, the TV-tape operators are charged with all the responsibilities under 1, plus all preventive and emergency system maintenance. All of the normal operational functions listed under 1 will be considered in this section. Section 7 will cover preventive and emergency maintenance as well as system performance measurements.

### 6-1. TERMINOLOGY AND CUEING

The terms most commonly used in tape production techniques may be defined as follows:

**Original**—The first tape recording of a given program. If multiple machines are used to simultaneously record this signal, then this number of originals exist.

**Master**—The first tape recording that is complete in all production elements. (NOTE: An original recording which is complete in all production elements can also be the master.) A master may also result from either of the following techniques:

- (A) A tape which consists of any number of different originals (or copies) spliced together.
- (B) A tape which is recorded from any number of other type system playbacks (which may also include other sources such as film and live inserts) fed through a switching system just as any original production is performed. In this case, all tape systems and any other source used must be under the control of a common-sync generator such as the Ampex *Intersync* or the RCA *Pixlock*. This technique eliminates the necessity of mechanical or electronic splicing.

**Copy**—A recording made from another tape signal, whether a master or a copy. The term *copying master* is sometimes employed for a master tape which has been designated for use in making copies. A *first generation* copy is a copy made from a master. A *second generation* is a copy of a copy, etc.

**Leader**—The portion of a tape immediately preceding program content, usually containing visual and/or aural cues. The term is also applied to a tough protective strip before the leading edge of the recording tape, used to protect the first part of the tape.

**Run-Out**—The portion of tape following program content, usually containing only sync information to allow fade or cut-out before going to "noise." (Tape playback without signal.)

**Standby Tape**—Production term given by the director to cue the operator to get ready to start the tape rolling. In many instances, the operator starts the capstan action (capstan turns without the tape being engaged) on receiving this cue. This is always done when the fast-start method of operation is followed. This method allows only 2 or 3 seconds after the tape is rolling to the actual "take" by the video switcher. The tape recorder switch for this function is labeled *Override* by Ampex, and *Standby* by RCA. This procedure is also sometimes practiced even when the more normal 6-second lapse between roll and

take is used, as the system normally stabilizes more quickly when the capstan is already up to speed before engaging the tape.

**Roll Tape**—Term used by the director for the operator to start the tape rolling by depressing the Play button. The capstan engages the tape immediately, and video signal is delivered from the tape as soon as the vacuum guide engages the tape with the rotating heads. This interval is normally  $1\frac{1}{2}$  to 2 seconds, depending on the setting of the associated time-delay relay. (This time may be as long as 4 seconds.)

**Cue-In**—Method used to enable the operator to stop the tape at the proper section of tape prior to start of actual program content. Visual or aural cues may be used; the aural portion being either on the regular program sound track or on the cue track. One common visual method is the televising of a second-clock with the second hand started about 15 seconds prior to program, turning counter-clockwise toward zero. The signal is brought to black level 2 seconds before program start to provide a clean take interval by the video switcher.

## 6-2. OPERATIONAL RESPONSIBILITIES

Tape recording setup and operational techniques become more rigorous as the limits for which the tape is made are expanded. A program to be recorded one day and run the next day on the same head may be considered as a highly limited application of responsibilities. Recorded characteristics may be entirely incompatible with other heads or recording systems but result in entirely satisfactory playback in this instance.

To go a step further, consider the case where a number of spot commercials are to be recorded for the station's own use. Even though the same tape systems will now be used for these spots, there is certainly no guarantee that the same head will be used throughout the life of the commercial commitment. Some degree of standardization is now highly desirable.

The next step is interchangeability with other heads and other systems. Important standardizations may be tabulated as follows:

1. Video Heads—Quadrature and gap-azimuth alignment; vacuum-guide position horizontally (controlling tip penetration); and vacuum-guide position vertically (for correct concentricity at the standard tip penetration).
2. Video Signal—Carrier frequency; deviation related to 100%

- modulation; type of pre-emphasis; and video bandwidth within limits of good transient response and linear gray-scale.
3. Control Track—Recorded 240-cps level; edit-pulse level and phasing; and track width.
  4. Audio Head—Track width; accuracy of placement; and gap-azimuth alignment.
  5. Audio Signal—Recorded signal level within limits of distortion components; pre-emphasis; and audio bandwidth.
  6. The final and most exacting step is *interspliceability*.

In addition to all of the preceding factors, the control-track signal phasing relative to the reference pulse (hence recorded video tracks) must be standardized. A spliced-in section which is different in control track phasing relative to the preceding and succeeding sections will need to be manually retracted when entering and leaving the spliced portion. Under the most fortunate operating conditions, a disturbing discontinuity will occur.

### 6-3. PRELIMINARY SETUP PROCEDURE

At the start of the operating day before the tape is threaded on the transport, ample time should be scheduled for the operator to administer the following procedures. (Actually the cleaning procedure should be exercised before every recording, and before playback of programs more than 5 minutes in length. Once a day is normally sufficient for the remaining procedures.)

1. *Cleaning*. Naptha, *Energine*, or *Freon TF* are the most widely accepted cleaning agents for video and audio heads and all other metal contacts on the tape transport. *Chlorothene* may also be used, but only with the utmost caution. This agent (although cheaper than *Freon TF* in bulk quantities) will soften the oxide binder of the tape if ample time is not allowed to dry thoroughly. Denatured alcohol is also used for all items other than audio and video heads.

Use lint-free tissue or a soft brush (toothbrush or camels hair) moistened with the solvent to clean the following items: (See Figs. 3-1 and 3-2, for identification and location.)

- A. Supply tension arm (upper tension arm in RCA system).
- B. Supply idler (upper air guide in RCA).
- C. Video (master) erase head.
- D. Rotating-head panel. (Headwheel or drum, pole tips, vacuum guide, nylon bearings under vacuum-guide block,

vacuum-guide screw contact with the movable servo arm, control-track head).

- E. Audio and cue heads (and simulplay audio and control track heads in RCA).
- F. Takeup idler (lower air guide in RCA).
- G. Capstan and capstan pinch roller.
- H. Counting roller.
- I. Takeup tension arm (lower tension arm in RCA).
- J. Takeup and supply reel hubs.

The video heads should be cleaned by hand-rotating the shaft while holding a moistened tissue or brush against the heads and rotating with a slight circular motion. Use the agent on the tape-supporting surface of the vacuum guide while the vacuum pump is working, and inject a little of the agent into the slots with an eye dropper or hypodermic injector. Inject a slight amount into the slip-ring assembly on the head panel and rotate the shaft by hand to clean the brush assembly. **INSPECT EACH BRUSH TO BE CERTAIN THAT THE SLIM SPRING CONTACT ARM IS PROPERLY SEATED IN THE BRUSH GROOVE.** A pipe cleaner or cotton applicator dampened with a solvent is handy for cleaning the control-track head.

2. *Degaussing.* As a precautionary measure, the tape transport should be demagnetized at least once daily. Fig. 6-1 shows the

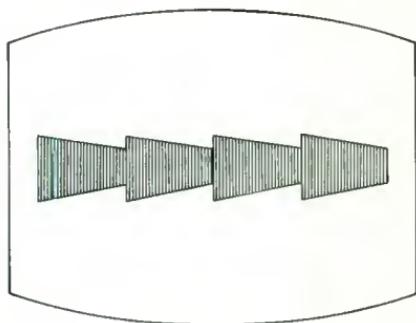


Fig. 6-1. Oscilloscope presentation of switcher RF output, indicating magnetic path.

usual tell-tale indication of the switched RF output at the switcher unit when magnetic paths exist. **NOTE:** A tape which was originally good can be harmed with this condition.

The small hand degausser, which is normally purchased with the equipment, should be energized at least 4 feet from the tape

transport and brought slowly up to the panel. Keep the unit slowly rotating in a small circle while going over the entire tape path from supply reel to take-up reel—be sure to include the master video erase head. Start the video heads rotating (push the Override switch on the Ampex or the Standby or Setup switch on the RCA) as the degausser is passed over the rotating head panel. Degauss the audio heads with the conventional audio-head unit. Slowly pull the degausser away from the panel and de-energize after the unit is at least 4 feet away.

The fact that no magnetic tools, such as screwdrivers, allen wrenches, etc., should be allowed to be stored near the transport or tape is often forgotten. Always degauss tools before use on the equipment or storing in nearby shelves.

3. *Modulator frequency and deviation.* The first step is to be certain that the video input to the system (which usually consists of a test pattern or window signal) is the proper amplitude—normally 1 volt (p-p) of composite signal. The multiburst signal may be used, providing the white reference pulse is at least 8% of a full TV line in width (minimum width of 5 microseconds).

All modern tape systems employ built-in facilities for setting carrier frequency and deviation. For monochrome adjustment, the function switch is set on the Mono position with the toggle switch set to the Sync Tip position. In the RCA system, the clamping reference is the tip of the sync; therefore the slug labelled Carrier Freq. is adjusted to obtain maximum indication on the panel meter. This indicates that the carrier is set at 4.3 mc looking only at the sync tip portion of the composite video signal. Then with the toggle switch set to the White Tip position, the Deviation control (which sets the amplitude of video reaching the reactance tube) is adjusted to obtain maximum meter indication. This indicates the carrier frequency is swung to 6.8 mc at peak white signal. Checking the accuracy of the reference tank circuits (wavemeters) is normally a maintenance procedure and will be covered in the next section.

In the Ampex modulator, the carrier frequency is adjusted at blanking level (5 mc) since the clamping reference is on the back porch of the horizontal sync. With the deviation adjusted to obtain 6.8 mc on peak white, the application of normal 1 volt p-p signal (0.714 volt video, 0.286 volt sync) swings the carrier downward to 4.3 mc (nominal, actual value is 4.28 mc) at sync tips.

#### 6-4. LEVEL CHECKS

Always check to see that the monitoring oscilloscope is properly calibrated before setting levels. The usual run-thru is as follows:

Input—1 volt (p-p).

Demodulator Output—1 volt p-p. (This is also the processing amp input.)

Processing Amp—1 volt p-p with 5 to 10% setup (interval between maximum pix black and blanking level), and 0.4 volt blanking to sync tip. These controls are all included in the processing amplifier.

#### 6-5. HEAD-ALIGNMENT AND SELF-CHECK PROCEDURES

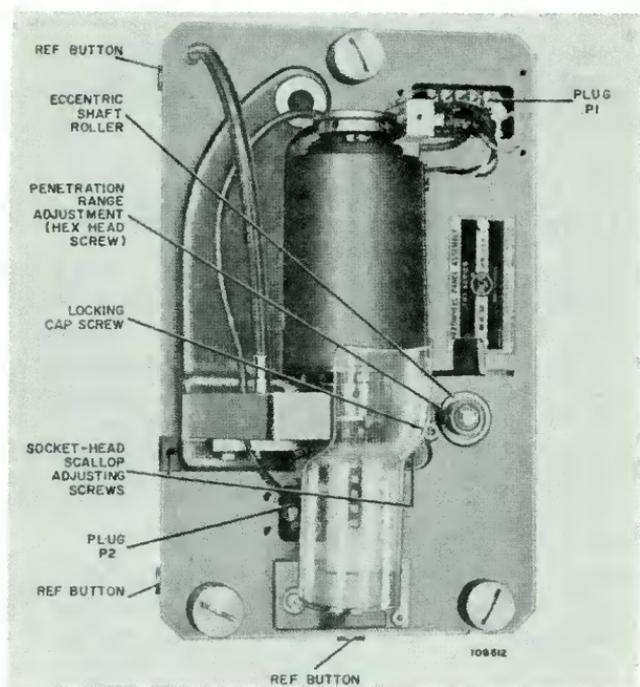
The normal sequence of checks (and adjustments where required) is: vertical (height) alignment of vacuum guide for maximum concentricity, horizontal alignment of the vacuum guide for proper tip penetration of the particular rotating head assembly, and electronic or mechanical alignment for quadrature.

These checks, and other self-check procedures which are not a normal operational procedure unless questionable conditions exist (such as a doubtful alignment tape, or temporary loss of such tape) are described in the following:

1. Vertical (Scallop) Adjustment—(See Figs. 2-12 and 2-13 for monitor display of alignment tape when vacuum guide is too high or too low.) When properly set, the video head tips exert the same degree of tape stretching (resulting in the same relative velocity throughout the entire arc of contact). This indicates maximum concentricity of the vacuum guide with the arm described by the pole-tip radius of rotation.
  - A. Thread the manufacturer's alignment tape, usually consisting of vertical lines recorded under precise laboratory measurements, onto the tape transport and place the system in the Play mode.
  - B. Place the vacuum-guide servo in the Automatic mode of operation so that the tip penetration is somewhere near standard. Note: With a brand new or rebuilt head assembly, a rough *skew* or *jog* adjustment (Step 2 to follow) may need to be made before height adjustment. The need is apparent if the tips are obviously not contacting the

tape, or if the pole tips are obviously digging too deep (overloading the servo system). In either case, the tape will not play.

- C. While watching the monitor, the guide-height or scallop-adjustment screw (Allen type) is turned to eliminate any scalloping of the vertical lines. The alignment points are

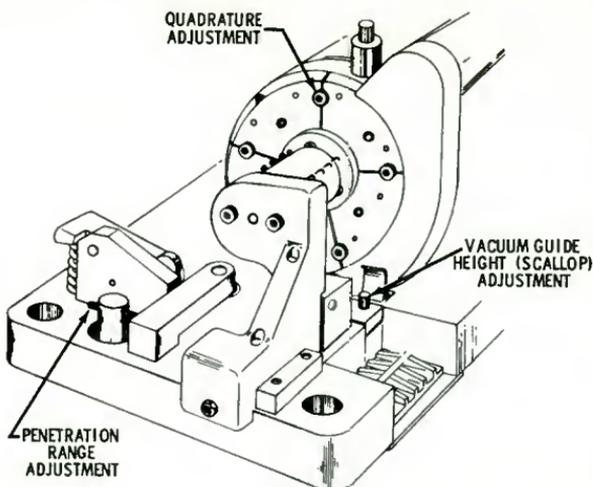


Courtesy Radio Corporation of America

Fig. 6-2. Adjustment points on RCA headwheel panel.

shown in Fig. 6-2 and 6-3. (NOTE: The photo of the RCA assembly (Fig. 6-2) shows two adjustment points. In more recent construction, the screw to the right has been factory sealed; only the left-hand point is used for proper adjustment.)

- D. One method of rapid self-check without the alignment tape is to use the principle that there is normally some slight eccentricity of the vacuum-guide center of curvature with the axis of the rotating heads. This means that as the guide is moved farther away from the pole tips,



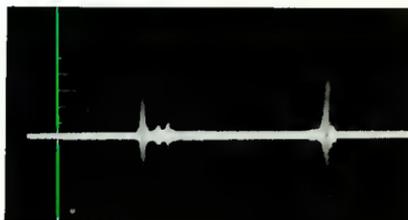
Courtesy Ampex International Operations, Inc.

Fig. 6-3. Adjustment points on Ampex drum assembly.

contact is first lost at the center of the tape (Fig. 2-6). With the scope looking at an individual-head playback-channel output, back the vacuum guide away from the heads by means of the electrical Tip-Projection control with the guide servo placed in the Manual mode of operation so that contact exists only at the edges of the tape. Fig. 6-4 shows a typical pattern obtained under these conditions. If the guide is perfectly concentric to the pole tip rotation (the same pressure at top and bottom of tape), the height of pulses will be equal. Adjust the height-adjustment screw until the pulses are as nearly equal as possible. Then return the Tip Projection control to Normal. (NOTE: This method of height adjustment is only a reasonably approximate procedure).

E. A more accurate method of self-check for height adjust-

Fig. 6-4. Single-channel playback waveform with guide adjusted to barely contact tape.



ment is to make a recording consisting of vertical lines, such as a grating pattern generator signal, and simultaneously feed the control-track signal to the audio track. Let the tape run through to the take-up reel and *do not* rewind the tape. Simply place the take-up reel with the run-off tape onto the supply reel hub and thread in the normal manner. It is now obvious that the tape is reversed—the audio track (which also contains the control track in this case) is on the bottom instead of top, and as the pole tip sweeps across the tape in playback will be reversed from the recording mode. Thus, playback of the tape will reveal scalloping, if the vacuum-guide height adjustment is improper. This self-check method is accurate, but time-consuming.

2. *Horizontal (Skew or Jog) Adjustment*—NOTE: This adjustment is normally required only on the initial installation of a new or rebuilt head assembly. When the vacuum guide is once set to the standard distance from the rotating-headwheel axis, the heads will record and playback tape interchangeably over a wide range of head wear without resetting. (Review Section 2.)
  - A. Place the vacuum-guide servo in the Manual mode of operation. With the standard alignment tape threaded, place the system in Play mode. Remove all high frequency post-emphasis (where used) to avoid possible geometric distortions of the vertical lines from transient effects on leading and trailing edges.
  - B. Set the Tip-Projection (electrical) control on the control panel to the position designated by the manufacturer for standard. (This is zero on new systems, 3 or red arrow on earlier Ampex models.)
  - C. Adjust the penetration-range adjusting screw on the head panel (Figs. 6-2 and 6-3) for straight vertical lines. (See Figs. 2-10 and 2-11 for time errors resulting from improper positioning of the guide horizontally.)
  - D. If the operator has a basic understanding of what constitutes standard position of the vacuum guide, he can set this position without the standard alignment tape, but not with the same laboratory precision. In practice, the following data can be used to obtain a reasonably approximate setting of the guide. (See Fig. 6-5.)

- (1) The distance from the axis of rotation of the heads to the center of curvature of the vacuum guide is 1.0334 inches.
- (2) The nominal tape thickness is 1.4 mils.
- (3) The minimum radius of rotation of the magnetic head-pole tips is 1.0329 inches and the maximum is 1.0356 inches.
- (4) The vacuum guide is adjusted to the Standard Recording Radius which is calculated as follows:

$$\begin{array}{r}
 1.0334 \text{ inches (distance to guide)} \\
 - 0.0014 \text{ inches (nominal tape thickness)} \\
 \hline
 1.0320 \text{ inches}
 \end{array}$$

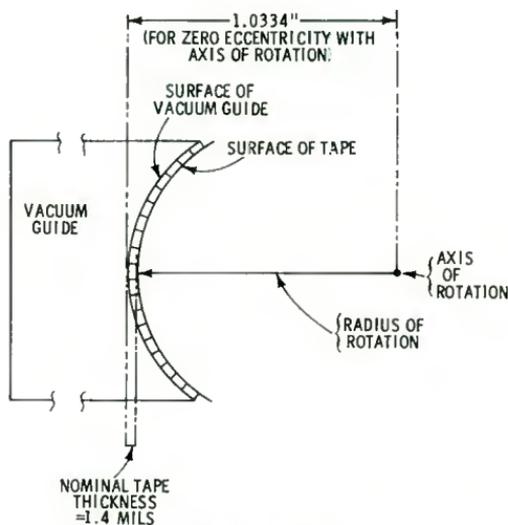


Fig. 6-5. Relationship of standard recording radius to departure point.

This figure (1.0320 inches) is necessary to find the "departure point," or the distance from the axis of rotation where the pole tips just touch the tape surface. This distance also defines the radius of pole-tip rotation.

- (5) Measure the diameter of the drum rim with a micrometer and divide this by 2 to obtain the radius.
- (6) Measure the actual tip projection above the drum

- rim with the tip-projection gauge that is provided with the system.
- (7) Add the tip projection to the radius of the drum to obtain the radius of pole-tips rotation.
  - (8) With any prerecorded tape threaded, place in Play mode and back the guide away from the heads until the signal is just lost, as revealed by zero output of the RF at the switcher.
  - (9) Subtract the Standard recording radius of 1.0320 inches from the total pole-tip radius of rotation. Move the guide in from the departure point by this amount, as measured with the tip projection gauge jiggged to the vacuum-guide block. This places the guide to the standard tip projection within the tolerances of measurements.

Two examples follow:

Example 1:

$$\begin{aligned}
 \text{Drum Diameter} &= 2.064 \text{ inches} \\
 \text{Radius} &= 1.032 \text{ inches} \\
 \text{Tip Projection} &= 2 \text{ mils} \\
 \text{Radius of rotation} &= 1.032 + 0.002 \\
 &= 1.034 \text{ inches} \\
 \text{Move in from departure point} &= 1.0340 - 1.0320 \\
 &= 2 \text{ mils}
 \end{aligned}$$

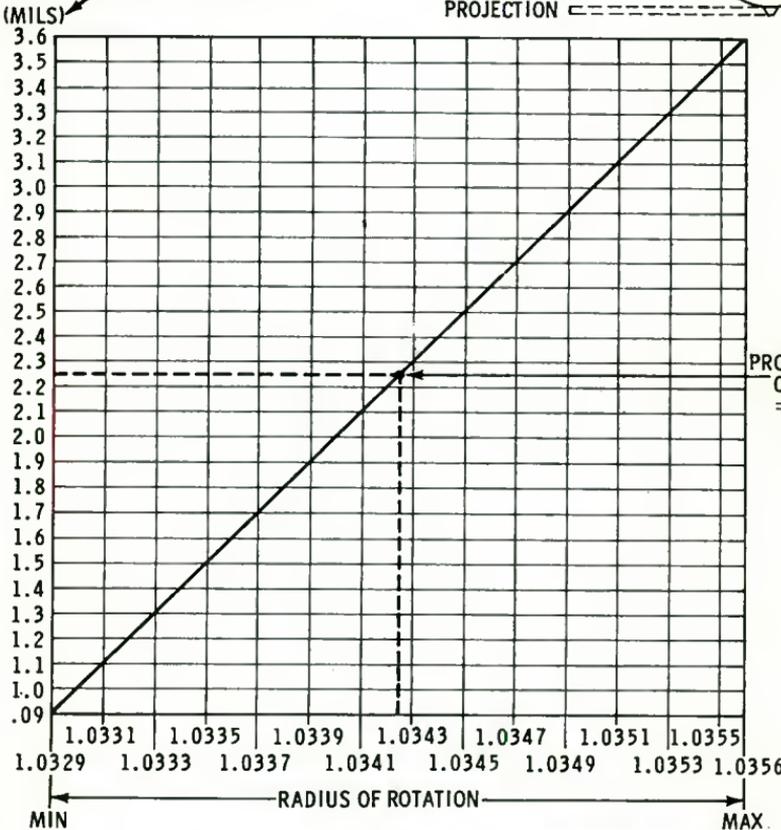
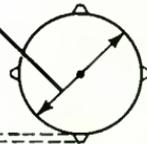
Example 2:

$$\begin{aligned}
 \text{Drum Diameter} &= 2.062 \text{ inches} \\
 \text{Radius} &= 1.031 \text{ inches} \\
 \text{Tip Projection} &= 2 \text{ mils} \\
 \text{Radius of rotation} &= 1.031 + 0.002 \\
 &= 1.033 \text{ inches} \\
 \text{Move in from departure point} &= 1.033 - 1.032 \\
 &= 1 \text{ mils.}
 \end{aligned}$$

Note that in both cases the measured tip projection was 2 mils, but the tolerances in the head drum resulted in 1 mil difference of the radius of rotation. The foregoing procedure places the vacuum guide to the standard, but the actual *tip penetration* depends on the effective radius of rotation, and not on tip projection alone.

The graph and drawing of Fig. 6-6 illustrates the fore-

- (A) Measure diameter with micrometer.
- (B) Divide by 2 to obtain radius.
- (C) Add tip projection above drum surface to radius.
- (D) Back guide off to obtain departure point.
- (E) Subtract 1.032 inches from C.
- (F) Move guide in from departure point the value obtained in E.



TIP PROJECTION CENTER = 2.25 MILS

Fig. 6-6. Instructions for "move-in from departure point."

going procedure and gives the proper adjustment from the departure point over the normal range of rotation radius.

NOTE: Some stations employ a *dual standard* positioning of the vacuum guide. Tapes to be used *only* by the local station can be recorded at lighter-than-standard tip pressures for new heads until worn to the point where standard SMPTE projection can be used. This increases tape life and results in less head wear per hour, *if not carried to extremes*. A head assembly is normally retired (returned to manufacturer on an exchange basis for a rebuilt assembly) at 1-mil measured tip projection. This is due to the fact that the pole-tip gap widens somewhat below this projection and is apt to become useless during a recording or playback. However, if too little recording radius is used, the tape may not play back on a tip projection of, for example, less than 1.3 mils. This would require premature retirement of the head assembly and be more costly in the long run. The dual standard should not be used on an interchanged basis, since recordings are not completely interchangeable between heads at different points on the head-wear curve.

3. Quadrature Adjustment—RCA employs electronic delay correction (see Sections 4-2 and 4-7) in both the Record and Play modes. Ampex supplies a delay equalizer as optional equipment for the Play mode only. (See Fig. 2-14 for monitor display of alignment tape when quadrature error exists.) In the following procedure, Steps A, B, and C apply to Ampex; Steps D through K are for RCA.
  - A. Reproduce the test pattern recorded on the alignment tape and identify channel 1 by reducing the Channel 1 gain control on the switcher unit. Outputs appear in the picture in a 1, 4, 2, 3, order; that is, channel 4 is directly below channel 1, channel 2 is directly below channel 4, etc. (Review Fig. 4-8.)
  - B. Observe the relative position of the four bands of information as they appear horizontally on the picture and choose a band which occupies a mean position. Hereafter, use that band as a reference. Assume here that channel 3 is the reference. In respect to channel 3, channels 1 and

2 are early; that is, they are displaced to the left on the monitor, and channel 4 is late, displaced to the right on the monitor.

- C. The angular position of any head can be changed by adjusting the tapered Allen-head screws (Fig. 6-3). To advance a head, it must be moved in the direction of rotation of the head drum; conversely, to retard a head, it must be moved opposite the direction of rotation. To advance a head (in our example the channel-4 head), first loosen the tapered screw leading the head, and then tighten the tapered screw following the head. (This simply shifts the quadrant which contains the head in the direction of rotation of the head drum.) To retard a head (in our example channels 1 and 2), first loosen the screw following the head and then tighten the screw leading the head. Make these adjustments in small increments (not more than  $\frac{1}{8}$  turn of the adjusting screws), checking with the alignment tape after each adjustment. The head which corresponds to a given channel can be identified by marks scribed on the bakelite hub of the slip-ring assembly just forward from the terminals where the head leads are connected.

NOTE: Where the playback-delay amplifier unit is employed in the Ampex system, playback adjustments may be made with this unit, and the relative calibrations of the individual channel knobs may be read for a direct indication of which segments need be adjusted and the direction of adjustment. This unit also permits proper playback of any tape made from another source which may have quadrature errors relative to the Ampex head.

- D. Place the Guide Position switch on the control panel in the Automatic position.
- E. Install the alignment tape and place the tape recorder in the Play mode.
- F. Adjust the Control Track Phase control to produce the optimum picture. Set the four High-Frequency Compensation controls to zero.
- G. Set all four Delay knobs on the playback-delay amplifier to zero and observe the picture. The presence of steps in the vertical lines (Fig. 2-14) indicates that the heads are not exactly in quadrature ( $90^\circ$  apart). Identify the head

which produces an average amount of horizontal displacement with respect to the other heads (steps about halfway between the extreme left and the extreme right) and leave the Delay knob corresponding to that head at zero. Adjust the other three Delay controls to minimize the horizontal displacements. NOTE: Since the delay steps are quite small, this adjustment must be made with care to insure optimum alignment of the vertical bars. In addition, penetration and scalloping adjustments should be retouched to achieve the best results.

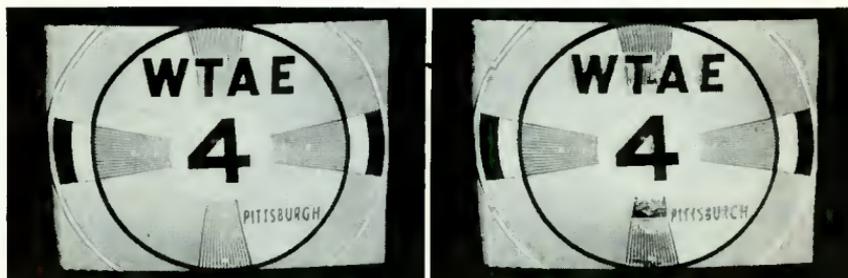
- H. The quadrature relation of the heads is the same for record- or playback, except that the relative sense (lag or lead) is reversed. Consequently, the Delay controls on the Record-delay amplifier should be adjusted as follows:
- (1) Note the channel on which the Delay control is set to zero on the playback-delay amplifier. Set the Delay control for same channel to zero on the record-delay amplifier.
  - (2) Turn each of the other three Delay knobs on the Record-delay amplifier to the same numeral as that of the corresponding Playback Delay knob, but in the opposite direction from zero. (For example, if the Delay knob on the playback-delay amplifier is set to +3 set the Delay knob on the Record-delay amplifier to -3.
- I. Remove the alignment tape from the machine.
- K. Record a test pattern or other test signal with vertical lines; playback of this recorded signal should produce vertical lines. In addition, when the Control-Track Phase knob is turned to another track position, the vertical lines should contain a minimum of horizontal displacements. Large displacements indicate that the corrections should be rechecked.

NOTE: The video heads can be self-checked for quadrature quite simply, but only after head optimization, as described in Section 6-6 is followed. The reason for this is that one head that may be overdriven with FM signal in the Record mode will play back with a slight effective quadrature. The procedure is to make a recording of vertical lines and play back with the Tracking control adjusted sequentially through all four head-tracking positions, while watching the playback monitor. For example, if head No. 1

recorded vertical sync and tracking is adjusted so that the same head plays back vertical sync, no quadrature error will result even though it may exist. However, if tracking is adjusted so that each of the four heads picks up the track recorded by the adjacent head, any quadrature error between any two heads will be revealed.

## 6-6. OPTIMIZING THE VIDEO HEADS

The record currents for each of the four video heads must be separately adjusted (by means of record-channel Gain controls) for optimum results. Fig. 6-7A illustrates the playback of a test pattern with proper deviation and head optimization in the recording process. Fig. 6-7B shows the breakout into black of white areas following black-to-white transitions caused by overdeviation of the modulator (excessive level) with properly optimized heads; and/or normal deviation, but one or more heads overdriven with FM signal.



(A) Properly adjusted.

(B) Improperly adjusted.

Fig. 6-7. Playback of test pattern with record channel gain controls properly and improperly adjusted.

The result shown by Fig. 6-7B is inevitably called *overdeviation*, even though this is not necessarily the case. In fact, this photo was taken of the playback of a tape with the test pattern recorded with exactly the same deviation as used for the tape of Fig. 6-7A. The difference is in the levels fed to the heads during the Record mode. Since the optimum record currents change with head wear (heads may wear unequally) optimization procedures must be carried out at frequent intervals. Wear is greatest during the first hours of operation of a new head assembly; therefore, checks should be made approximately every 10 operating hours for the first 30

hours, then after every 20 hours of use. Poor signal-to-noise ratio, or banding (bands of unequal contrast), usually indicate the procedure is past due, regardless of hours.

When heads wear, there is less shunting effect of the pole tips and less signal is required for optimum recording. This is the reason why tapes sometimes play back with what appears to be overdeviation, even though normal video levels are maintained. Tapes which are very objectionable in this effect can sometimes be greatly improved by removing all high-frequency equalization (where used) in the playback channels. The resulting picture may be *soft* (lacking in fine detail), but it is normally less objectionable than the severe white-level noise.

Video-head optimization procedures have become well standardized as follows:

1. Feed signal with large area white reference (such as monoscope or window signal) to system. Check to see that deviation is normal.
2. Place system in Record mode. Speak into microphone and identify channel 1 by turning the Channel 1 Record Gain control maximum counterclockwise (zero). For example: "This is channel 1 on zero."
3. Rotate gain clockwise, stopping momentarily on each dial number to aurally identify this number. When the maximum clockwise position is reached, reverse the gain and again identify each dial number at the momentary stops. When completed, return the gain control to midpoint.
4. Repeat the preceding procedure for channels 2, 3, and 4. Rewind the tape to the start of the recording.
5. With the scope set on the wideband-response position and connected to the switcher unit output, play back the recording. Remove any high-frequency compensation that may exist in playback circuits. Keep playback channel gains and scope gains sufficiently low so that there is no chance of RF compression.
6. Track the playback so that the same head which records vertical sync is playing back vertical sync. Watch the scope display of the switcher output. Monitor the voice identification of channel 1 gain. At some point, the RF envelope of channel 1 will cease to increase as gain is raised. Make a record of this point.
7. Repeat Step 6 for each of the remaining channels.
8. Set each channel Record Gain control to the point where gain

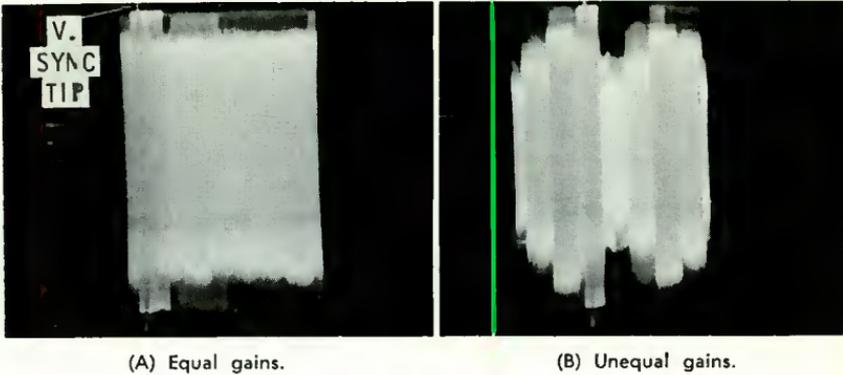
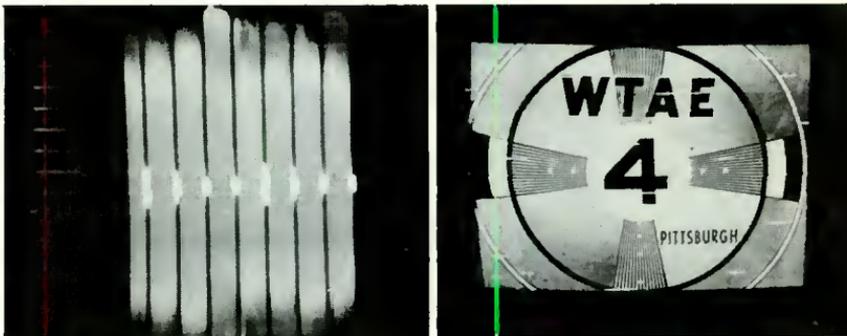


Fig. 6-8. Switcher output waveforms.

for that channel was maximum. Make a new recording. Rotate the head Record Current Meter switch to each channel in turn and make note of the current readings for reference. When playing back this recording, should any banding be apparent, identify the head(s) causing the banding and repeat procedure of optimization for these channels. Be sure all playback channel gains are equal as shown by Fig. 6-8A. (Ignore the vertical sync tip in setting gains.)

9. Fig. 6-9 shows the oscilloscope and monitor displays if the switcher phasing is improperly adjusted. (Switcher Phasing on the Ampex, 960 Delay on the RCA.) Adjust for elimination of holes on the scope, and white streaks in the picture. The white streaks are similar to drop outs, except that switcher phasing error is synchronous while drop outs are random.



(A) Switcher output waveform.

(B) Monitor presentation.

Fig. 6-9. Switching pulse misphased.

10. It should be common practice during any of the preceding Record modes to check phasing of the control track relative to the edit (hence reference) pulse. Proper adjustment is shown in Fig. 6-10. If two tapes are spliced together with slightly different control-track phase relative to the recorded tracks, the effect in Fig. 6-11 will occur. If the phase difference is large, complete loss of signal may result as the heads are between tracks. It is then necessary to manually readjust the tracking control immediately following a splice.

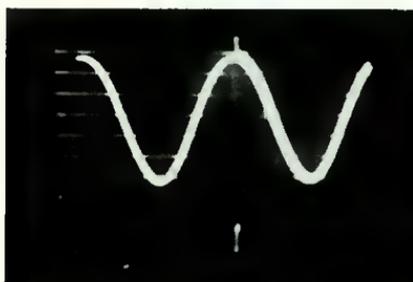


Fig. 6-10. Proper phasing of control track with edit pulse.



Fig. 6-11. Monitor display of poor signal-to-noise ratio due to slight mistracking.

The operator is now ready to make a short trial recording as a double-check on system operations. All of the preceding procedures, of course, are not necessary before each recording. The entire setup procedure has been described in the interest of completeness. Experience with a particular installation will dictate the setup scheduling for optimum results on a consistent basis.

## 6-7. CHECKS DURING RECORDING

The following checks should be made periodically during a recording:

Control-track meter for normal current.

Master-oscillator meter (or panel light) for proper erase current.

Record-current meter for proper head currents as called for in the optimization procedure.

Head-servo waveform for stability.

Capstan-servo waveform for stability.

Audio-head erase meter for proper erase current.

Audio-recording level on VU meter.

## 6-8. CHECKS BEFORE PLAYBACK

The following procedure should be followed before playback of a tape:

1. *Control-Track Phase (Tracking) control.* If the recording was made on the same head used for playback, adjust it so that the same head plays the vertical sync that records vertical sync (No. 1 for RCA, No. 4 for Ampex). This procedure will result in optimum match of heads. However, if the recording was made with a different head, the capstan tracking should be adjusted to obtain maximum RF output from the switcher unit. This normally indicates the best match of heads.

NOTE: Where *Intersync* or *Switchlock* is used, a given head must play back vertical sync for proper operation, depending on the particular system and mode of operation.

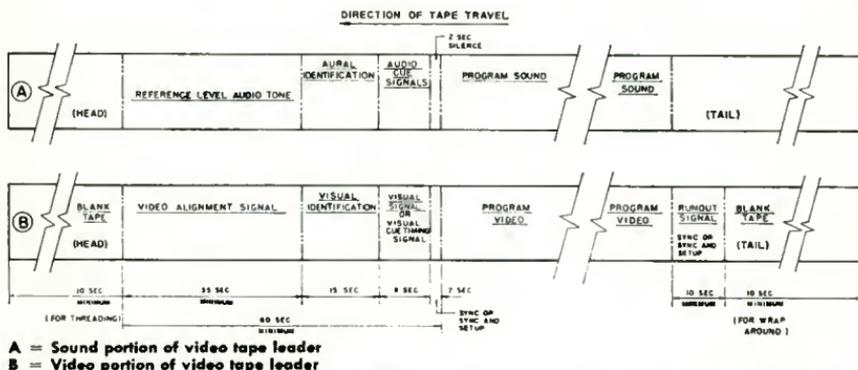
2. *Vacuum-Guide Position (Tip Projection) control.* For playback of any tape, the guide servo is normally placed in the Automatic control so that skew is eliminated. If the automatic circuitry should fail to work and time is not available to repair, simply place in the Manual position and adjust the position (Tip Projection) control to eliminate skew.

NOTE: It is very important to bear in mind that the mechanical adjustment *should not* be changed from standard. The worst condition that can exist is that scalloping can be so noticeable in the picture (which may be a recording made elsewhere) as to require guide height adjustment, which *must* be done mechanically (Section 6-5). If the mechanical adjustment for skew has not been tampered with, it is normally a simple matter to give the height adjustment a slight turn with the Allen wrench to eliminate the scallop. When this is necessary, remember to recheck the height adjustment with the standard alignment tape before making a recording.

3. Adjust playback-channel gains for equal outputs, as shown by Fig. 6-8.
4. Adjust individual channel high-frequency compensation controls (where used) for the "snappiest" picture without transients, and best match of individual head response for contrast (minimum banding).
5. Adjust processing amplifier controls for proper video, setup and sync levels to line output.
6. Set Audio Output Level control for standard level.
7. Rewind tape and cue-in to proper Roll point.

## 6-9. RECORDING TAPE LEADER AND RUN-OUT

Whenever a tape is recorded for distribution to other stations, it is becoming increasingly important that a standardized leader and run-out be used. The proposed American Standard (VTR 16.3) concerning video tape leader and run-out signals (Fig. 6-12) fol-



Courtesy Society of Motion Picture and Television Engineers.

Fig. 6-12. Proposed American standard (SMPTE VTR 16.3) on standard leader and run out.

lows. The operator should keep himself abreast of current SMPTE standards and proposed standards, since modifications occur from time-to-time.

### Proposed Standard (SMPTE VTR 16.3)

#### 1. Scope

This standard specifies the audio and video information that precedes and follows the recorded program material (for purposes of insuring uniformity of reproduction), and provides the necessary identification cue-up and run-out information. The standard also specifies the minimum lengths of tape required to ensure proper threading and wrap around for monochrome video-tape recordings.

#### 2. Alignment signal

2.1 At the head end of the tape, at least 35 seconds of test pattern shall be recorded at the same level and under the same conditions of equipment adjustment used for recording the video program material. (It is desirable that the test pattern or test signal include reference black and reference white information. The signal should be of such a nature as to facilitate vacuum-guide adjustment, e.g., staircase signal.)

2.2 Simultaneously, a reference-level audio tone of 400 cps (cycles per second)  $\pm 5\%$  shall be recorded at the same level and under the same conditions of equipment adjustment used for recording the audio portion of the program material.

2.3 The alignment signal shall be preceded by at least 10 seconds of blank tape for threading purposes.

### 3. Identification Information

3.1 Visual-identification information shall be recorded for at least 15 seconds following the video-alignment signal specified in Section 2. The identification shall contain, as a minimum:

- (1) title
- (2) subject
- (3) production number
- (4) "take" number
- (5) recording studio name
- (6) date of recording

3.2 Simultaneously, an aural identification of the information specified in Section 3.1 should be recorded under the same conditions, as defined in Section 2.2.

### 4. Cue Timing Signals

4.1 Audio-cue signals, as described below, shall be recorded on the audio program track following the visual-identification signal specified in Section 3.

4.1.1 The audio-cue tone signals shall consist of a series of 400 cps  $\pm 5\%$  bursts, each of  $\frac{1}{5}$  second duration, occurring at 1-second intervals over the range from 10 or more seconds ahead of the program material to 2 seconds ahead. The recording level shall be as defined in Section 2.2.

4.1.2 In addition, a steady component of the audio-cue tone shall be recorded approximately 20 db (decibels) below the level used in Section 4.1.1 above, starting with the first tone burst and ending with the last one, to leave a two-second silent interval before the start of program material.

4.2 A visual signal shall be recorded during the entire period of the steady component of the above-described audio-tone signals. (Sync or sync and setup)) only shall be recorded during the two-second interval from the end of the tone bursts to the start of program. The recording level shall be as described in Section 2.1.

If a visual-cue timing signal is used, it shall be coincident with and identify the tone burst in Section 4.1.

### 5. Continuity of Recorded Signals

Continuity of recorded signals, beginning with the video-alignment signal, shall not be interrupted. This continuity shall be achieved by continuous recording or by equivalent splicing, provided that the requirements of Section 2.1 are fulfilled.

### 6. Run-Out Signal

6.1 There shall be at least 10 seconds of sync (or sync and setup) recorded immediately following the conclusion of program material.

6.2 The run-out signal shall be followed by at least 10 seconds of blank tape for "wrap around" purposes.

## 6-10. ADDITIONAL OPERATIONAL NOTES

1. To tell if a tape has been rewound without the necessity of playing it, standardize the top plate of all reels as shown in

- Fig. 6-13. Label one side of all reels with the word "TOP." With the tape placed on the supply reel so that the word top is visible, the leader will leave the reel from the left if the tape is rewound. If it has not been rewound, the tail will leave from the right. Thus, it is possible to tell at a glance if the tape has been rewound.
2. In playback of a signal which shows signs of overdeviation or overdriven heads during recording (Fig. 6-7B), remove any high frequency playback compensation. This often "saves" an otherwise unsatisfactory program.

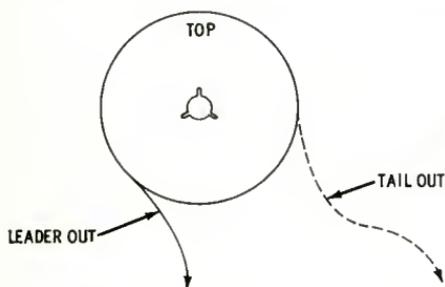


Fig. 6-13. Method of determining if tape has been rewound.

3. If a tape being played shows excessive horizontal jitter in the picture, try reducing the "damping Gain" on the drum servo (Ampex 1000-A) or the loop gains affecting playback in head servos. If this is done, a maintenance checkout should be made after the program is over to check the system for standard adjustments.
4. Since video pre-emphasis has not been solidly established at the time of this writing, problems sometimes occur in interchangeable tapes between Ampex and RCA systems. It is also obvious that even after standardization is established, all systems (even of the same manufacturer) may not be closely maintained. If a tape which exhibits instability (such as vertical roll or tearing on line-output pix monitors) is played, observe the demodulator output on a wideband oscilloscope. If the pattern is stable here (indicating faulty switching or processing amplifier troubles which follow the demodulator), examine the waveform for spikes on the pedestal or sync pulses. For example, a tape recorded on Ampex, using the optional AMVE (Ampex Master Video Equalization), will on occasion not play back on RCA with normal demodulator settings. On the RCA system, when

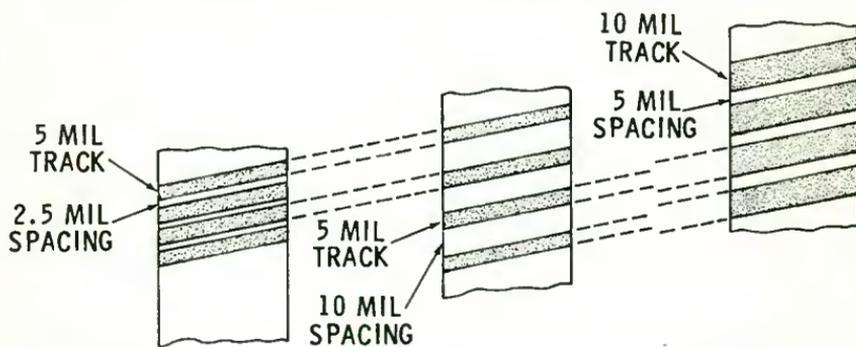
any indication of spikes is observed at the "DeMod" output, place the response switch on Roll-Off or Variable position. Excessive spiking out of the demodulator upsets switch gates and/or processing-amplifier functions.

- On RCA systems employing the dual capstan speeds ( $7\frac{1}{2}$  ips or 15 ips), be sure to check the position of the Tape Speed switch. Using  $7\frac{1}{2}$  ips speed for "in-house" recording (locally produced programs and commercials, delay broadcasts, etc.) cuts tape cost in half and reduces tape storage space. The system works basically as follows:

Dual-speed operation employs standard quadruplex recording techniques, using standard two-inch recording tape. All the advantages of quadruplex recording are retained, and the cue track, audio track, and control track are untouched. Only the method by which video tracks are laid down is modified.

The headwheel employs four video heads which record a track only 5 mils wide, as compared with 10 mils for conventional recording. Fig. 6-14A shows how the 5-mil tracks at half speed are spaced with respect to the video portion of the tape (5-mil track with  $2\frac{1}{2}$ -mil spacing). The capstan motor pulls the tape at  $7\frac{1}{2}$  ips; thus, twice as much video information is packed into each foot of tape. Because the speed of the headwheel rotation is the same as in normal operation, each recorded track contains the same number of TV lines, approximately 16.5.

When operating at 15 ips, video tracks are recorded by the half-track heads, as shown in Fig. 6-14B. In this case, the track width remains at 5 mils but the spacing between tracks becomes



(A) Half-track at  $7\frac{1}{2}$  ips. (B) Half-track at 15 ips. (C) Full-track at 15 ips.

Fig. 6-14. Dual-speed recording tracks.

approximately 10 mils. The tracks in Fig. 6-14B correspond to every other track in Fig. 6-14A.

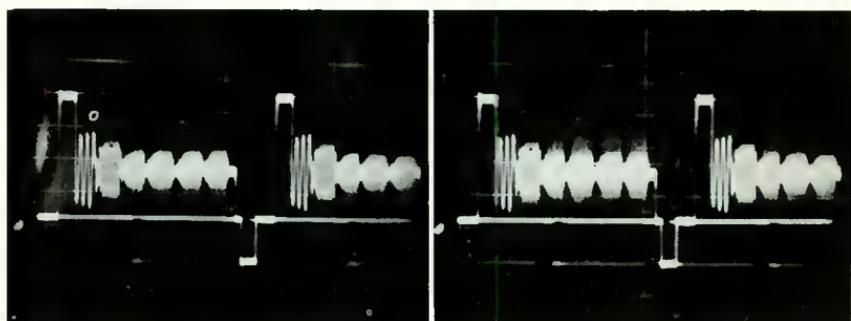
Standard video-headwheel panels recording 10-mil tracks which have approximately 5 mils spacing between them (Fig. 6-14C) are oriented in the same manner as in Fig. 6-14B. Comparison of Figs. 6-14B and C will show how interchangeability is achieved.

If a 10-mil head traces a 5-mil track, the head is in contact with the signal included on the track and, in addition, it traces over 5 mil of blank tape. It encounters the next track after a 5-mil spacing interval which brings the head into position to read all the information on the next track.

In the case of a half-track head (5-mil) reading a fully recorded track (10-mil), the principle is reversed. Here, the half-track head reads enough of the video information (5 mils) on the full recorded track to produce high-quality pictures.

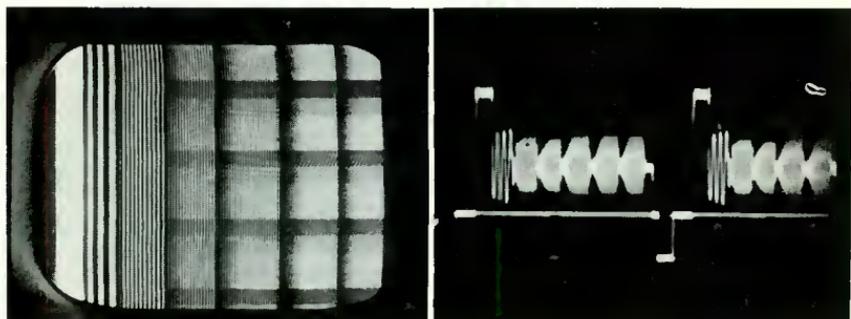
6. When a multiburst signal generator is available, it is convenient to use this signal for head optimization, provided the white reference pulse is at least 5 microseconds wide. This also allows a quick standardization of the RCA four-channel playback equalizer (Fig. 4-13) for playback of all recordings made on the particular system used. The procedure is as follows:
  - A. After heads have been properly optimized, remove all of the individual channel high-frequency compensation by rotating all four knobs maximum counterclockwise. Fig. 6-15A shows the multiburst and playback waveforms with all high-frequency compensation controls in the Off position.
  - B. While playing back the multiburst signal, observe the waveform (scope on wideband position) at the output and rotate the single channel High-Freq Comp control clockwise so that the faint trace is equal in height for all burst as shown in Fig. 6-15B.
  - C. Now ignore the waveform and observe only the picture monitor presentation of the multiburst signal. Bring all other channel compensation controls clockwise for the best match (no banding) on the *first two burst frequencies* (normally 0.5 mc and 1.5 mc). It may be necessary to slightly readjust the first channel adjusted (Step B) to get optimum response.
  - D. A typical picture monitor display, when equalized, is

shown by Fig. 6-15C. It is seldom possible to match response at all discrete sine-wave frequencies. MOST OF THE AVERAGE PICTURE CONTENT OF NORMAL PROGRAMS IS IN THE SPECTRUM OF THE FIRST TWO SINE WAVE BURSTS. The operator will find that he can almost inevitably get a completely band-free pic-



(A) Waveform with all high-frequency compensation controls off.

(B) Waveform with one channel equalized.

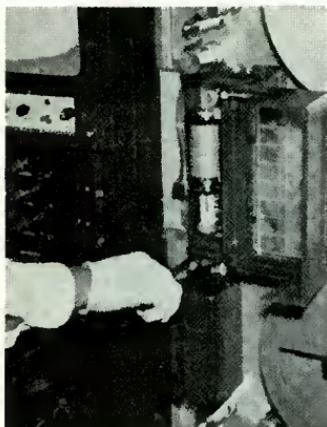


(C) Monitor display with all controls adjusted for best reproduction.

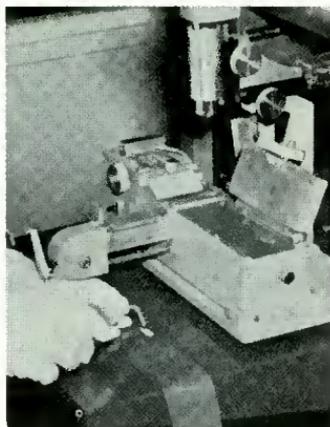
(D) Waveform after optimization of monitor of first two bursts.

**Fig. 6-15. Playback of recorded multiburst signals.**

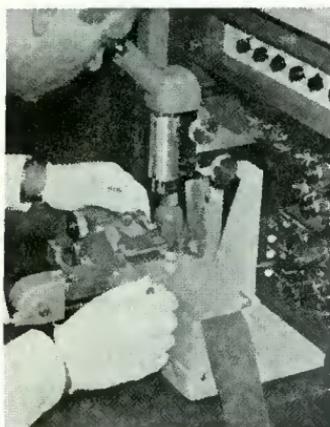
ture of a recording made on this particular video-head assembly when equalization has been accomplished in this manner. The oscilloscope waveform obtained when the display shown in Fig. 6-15C is obtained is given in Fig. 6-15D. Note the bursts are not "solid," since the higher frequency gains are not the same.



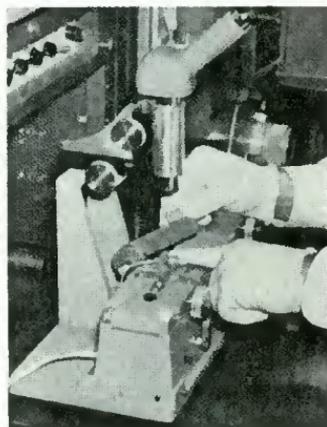
(A) Stop recorder at desired location and cut tape.



(B) Develop magnetic tape with liquid solution of iron oxide to locate nearest edit or frame pulse.



(C) Align edge of video track on built-in reticule to cut tape half-way between adjacent video tracks.



(D) Bring cutter into position and make cut.

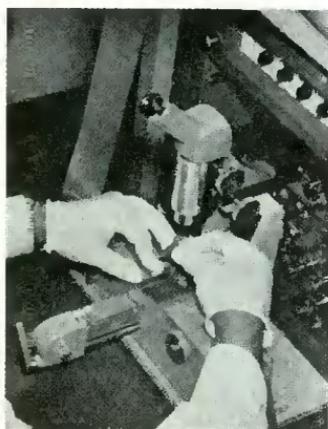
**Fig. 6-16. Steps in splicing**



(E) Drape tape from supply reel over tape support post and position under left hold-down door.



(F) Align tape track prior to making cut.



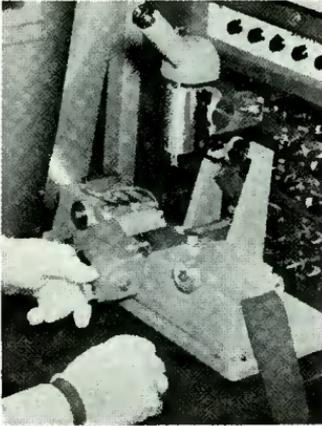
(G) Shear tape containing new information and for joining to tape already in splicer.



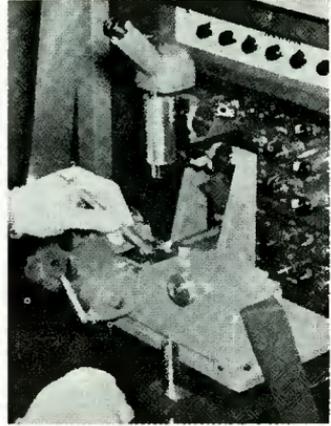
(H) Dispense splicing tape and prepare to place it in the proper position.

Courtesy Radio Corporation of America

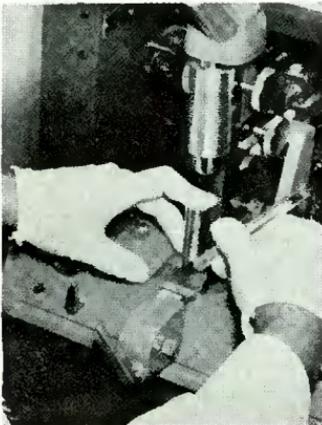
tape. (Continued on next page.)



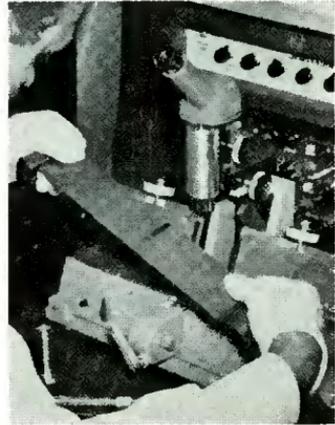
(I) Insert splicing tape beneath the lifted ends of the two tapes to be joined.



(J) Press both ends of tape firmly to provide a perfect butt joint.



(K) Trim excess splicing tape off with trimming tools.



(L) Examine the completed splice.

Courtesy Radio Corporation of America.

**Fig. 6-16. (Cont'd). Steps in splicing tape.**

7. When using Ampex *Intersync* or RCA *Pixlock*, it is good operating practice to use both the composite and noncomposite outputs of the system. Since a certain amount of residual jitter occurs, the composite output should be used, except when calling for supers, fades, or lap-dissolves. Thus, jitter with local sync inserted after switching will be visible only during dissolves or mixing with other signals.
8. If jitter is excessive with *Intersync* or *Pixlock* and the local-sync generator is locked to 60-cycle line, try switching the generator to crystal control. A wandering through "S" distortion of the picture normally reveals sync generator troubles on recording or playback, when playback is on different mode of sync generator lock than was used in recording. Certain types of local-sync generator problems will be practically unnoticed until tied in with television-tape recorders. (Discussed more fully in Section 7.)

## 6-11. TAPE EDITING

Fig. 6-16 illustrates the steps in splicing video tape using the RCA optical-tape splicer. A 40-power microscope is employed for location and precise alignment of frame pulses. To eliminate roll-over and/or temporary horizontal instability following a splice, the cut must be properly framed with the edit pulse and formed to a clean, solid, square butt-splice.

Ampex also supplies an optical splicer when desired. However, a more recent development by Ampex uses electronic means of editing tape. The recorder may be started and stopped at random between scenes for costume or scenery changes, for animation effects, or any other special purpose. In addition, the recorder may be used to insert new scenes or commercials at any chosen point in the middle of a previously recorded program. This feature permits the correction of production "fluffs" that may have occurred anywhere in an otherwise perfect recording.

The heart of the Ampex system is the *Electronic Editor*, a solid state unit that modifies the switching logic of a standard Ampex television recorder. In order to appreciate the functions of this device, it is pertinent to consider the situation that would exist on an unmodified recorder, if a tape bearing recorded program information were threaded onto the machine, and, at some point during the replay of this tape, the record button were operated to record a new scene into the middle of the existing program.

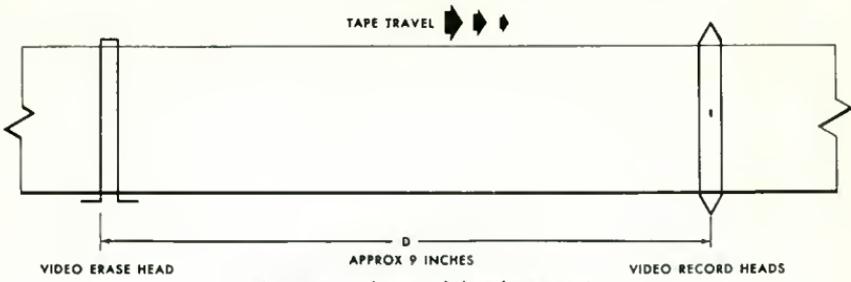
Record current would be fed to the video-record heads to record the new scene, and erase current would be fed to the erase head to erase the old scene. However, a number of problems would arise which would make the attempted transition from the original recording to the new recording impossible to achieve. These problems would involve servo-mechanism disturbances, incorrect phasing of the reproduced tape signal and incoming video signal, and the distance between video record and erase heads causing an overlap of recordings.

Fortunately there are straight-forward solutions to each of these problems. It is possible to arrange the servo system so that it uses the same sources of drum and capstan drive signals on entering the Record mode that it uses during the Play mode. Specifically, the drum drive signal remains phase locked to the system vertical sync, and the capstan drive source remains a 60 cps Wien bridge oscillator. During the Record mode, this oscillator is free-running, but no difficulty from long-term drift occurs because any minor variation in frequency will be tracked-out during replay.

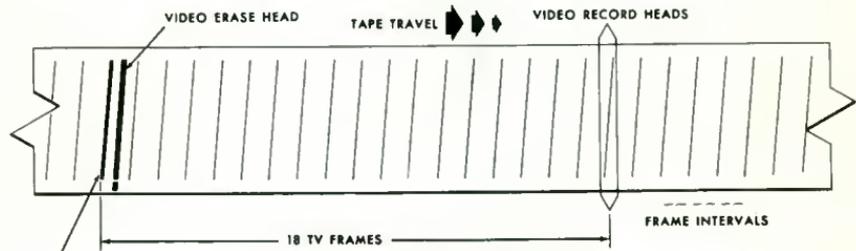
The correct phasing of the reproduced tape signal to the incoming video may be obtained by using an *Intersync* television signal synchronizer. This unit is a precision servo-control mechanism that guarantees that synchronizing pulses recovered from tape are in very close time relationship with the studio synchronizing pulse generator.

The problem of the distance between the video record and erase heads remains. This distance, as shown in Fig. 6-17A would cause a double recording to exist for 9 inches of the tape. The double recording, in turn, would cause both the sync processing and servo mechanism circuits to malfunction. To deal with this problem, the distance must first be translated into units precisely and readily measurable by electronic means. It has been found convenient to do this by considering it as a time interval corresponding, at the linear-tape speed of 15 ips, to slightly less than 18 television frames. Fig. 6-17B shows how a line S on a tape that is exactly 18 frames ahead of the video record head would be slightly ahead of the video erase head. The line S marks the location of the splice that it is intended to make, and it is further defined as existing in the guard band following a video track bearing vertical synchronizing pulses, as shown in Fig. 6-17C.

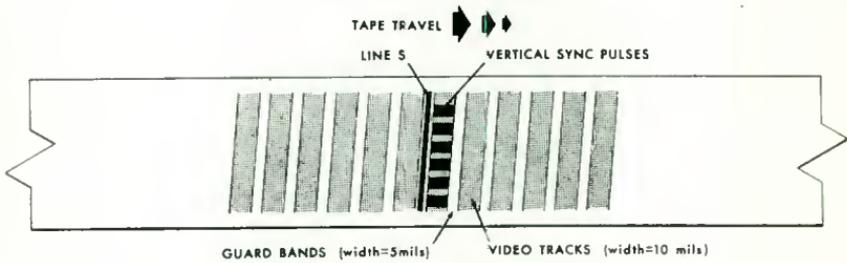
In the operation of the Electronic Editor, the location of the line S is determined after a random cue by means of a vertical-



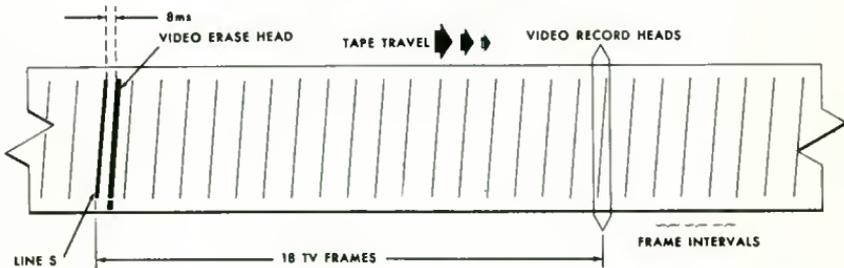
(A) Erase and record head separation.



(B) Measuring head separation.



(C) Detail of splicing point.

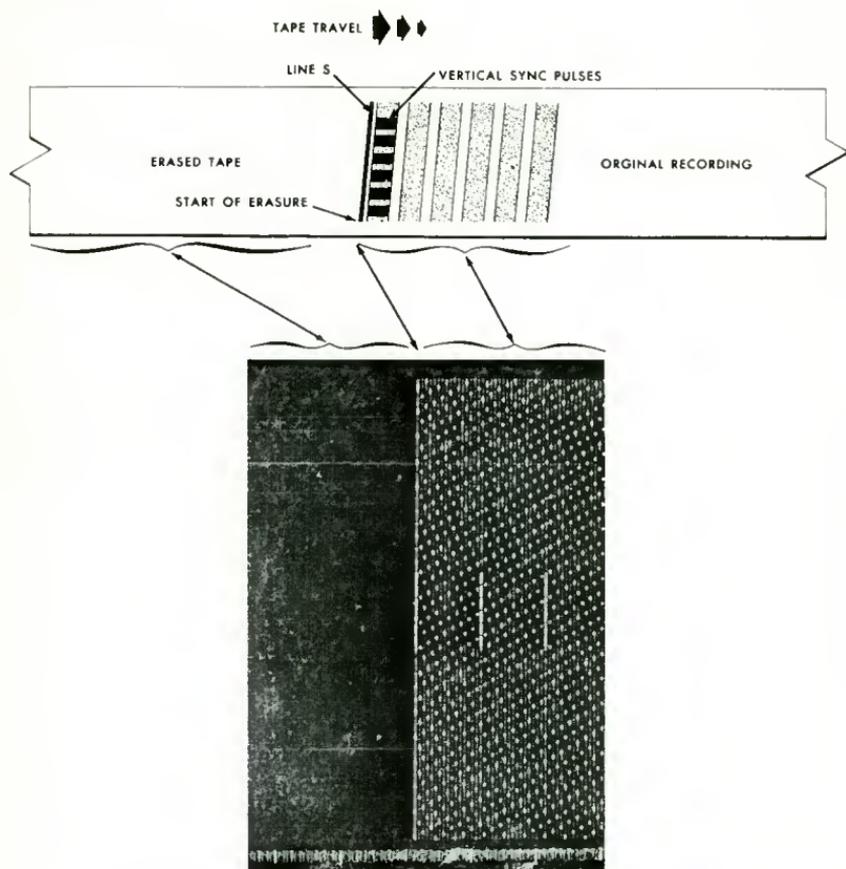


(D) Initial position of splicing point.

Courtesy Ampex International Operations, Inc.

Fig. 6-17. Head separation and splicing point location.

gating circuit, which detects the first-frame synchronizing pulse following the cue. At this instant in time, the tape lies under the heads, as shown in Fig. 6-17D. The time taken for line S to travel to the video-erase head and video-record heads may be defined as 8 milliseconds and 18 frames, respectively.



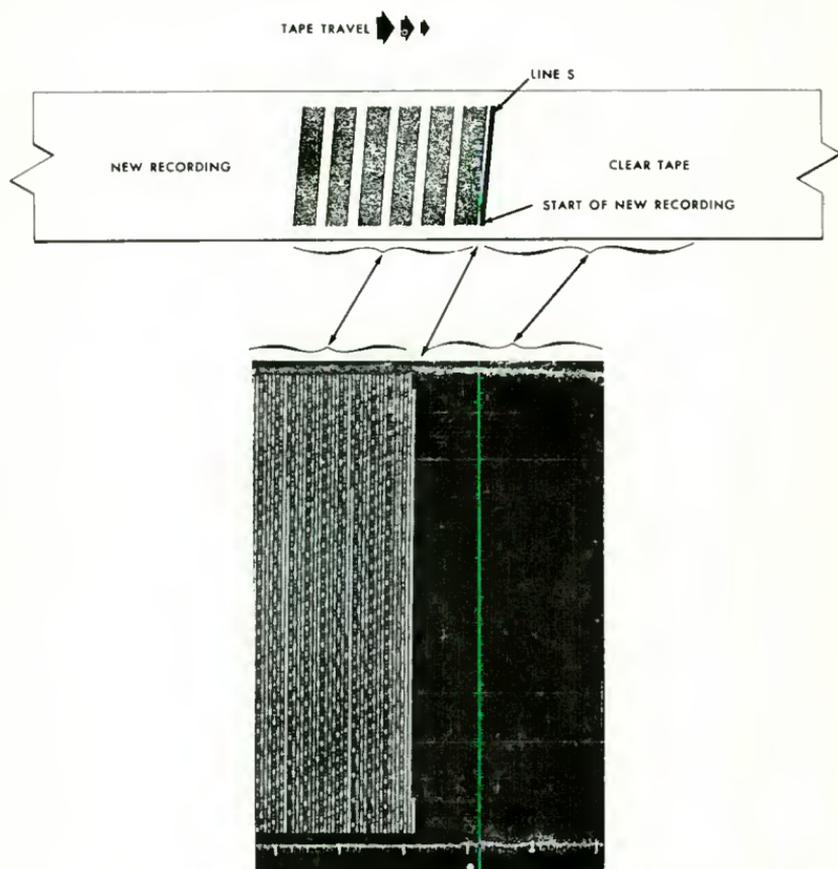
Courtesy Ampex International Operations, Inc.

Fig. 6-18. Start of video erasure.

The 8-millisecond delay is obtained from a delay multivibrator; at the end of this period, the erase head is energized by an electronic gating circuit. Turn-on time is approximately 30 microseconds, and erasure starts exactly on line S (Fig. 6-18). The 18-frame delay is computed by a binary counter system. At the end

of this period, the record current is gated on electronically. Turn-on time in this case is 2 microseconds, and the new recording starts immediately following the line S as shown in Fig. 6-19.

The accuracy obtained from the foregoing system is in the order of 0.05%, which enables the operator to make perfect butt splices



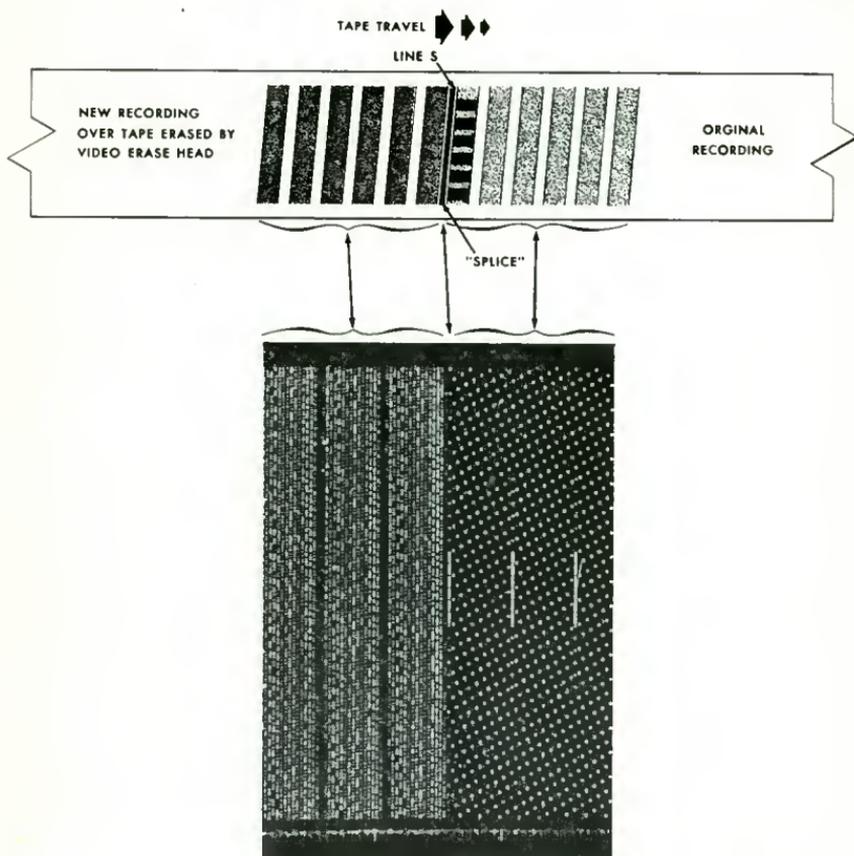
Courtesy Ampex International Operations, Inc.

Fig. 6-19. Start of video recording.

by merely pressing the record button. The preservation of all video information at the splice and the accuracy of tracking is evident from an examination of Fig. 6-20.

The Editor has two modes of operation, referred to as insert and assemble. In the latter mode, the unit may be used to add

further program material to the end of an existing program, and, in this way, assemble a complete program from individual short scenes. In fact, a completely edited tape may be prepared using only one camera and one recorder.



Courtesy Ampex International Operations, Inc.

Fig. 6-20. Electronic splice configuration.

The Insert mode, on the other hand, is used to insert fresh material into the middle of an existing tape. In this mode, commercials, for example, may be added to a recorded program at any time following its original preparation. Also, because any information behind the inserted material is erased, and there is no loss of sync, it is possible to correct errors in the original production. If the action is repeated and the Record button is pressed,

the scene containing the production error is replaced with a new scene.

Obviously, in the Insert mode, it is necessary to make two splices per operation and still maintain synchronism. The first (or in-going) splice was described previously. The second (or out-going) splice is made in a similar manner, except that at the end of the measured time intervals, the erase and record currents are turned off instead of on. This is performed with the same precision as that of the first splice.

During the recording of the insert, the capstan oscillator frequency is not controlled; therefore, it may drift slightly if the inserted material is of considerable length. This drift, in turn, will cause a variation in the wavelength of the recorded control-track signal and result in an abrupt phase shift in the reproduced control-track signal at the out-going splice.

One solution would be to employ a phase-correction system in the capstan-oscillator output circuit during Record. This, however, would be extremely complex. The adopted solution utilizes the fact that, in the Insert mode, a control track signal already exists on the tape. This information would normally be erased by the full-width video-erase head; however, a new head which has a separate section of the control-track erasure has been developed (Fig. 6-21). This section is disconnected when the Insert mode is selected and, although the machine is placed in the Record mode, reproduction of the control track continues. Thus, it is possible to retain normal control of the capstan oscillator and any possibility of control track phase shift is avoided.

The video-erase head is a new design which gives an improved erase efficiency. It uses only a half-turn in contact with the tape and the electrical gap width is 5 mils—the same as that of a guard band. The gap is optically straight, and inclined to the perpendicular at an angle of 33 minutes of arc. Thus, the erasure pattern is exactly parallel with the video record pattern. The audio and cue tracks are not affected by the new head, and control-track erasure is optional.

It will be seen that the functions of the editor are of the logic type and serve to provide precisely-timed and electronically-gated video erase and record currents. A block diagram is given in Fig. 6-22. The component sections of delay multivibrators, flip-flops, gates, and binary counters are all classic circuit configurations that do not warrant discussion at this time. The over-all functions, however, may be traced as follows.

Following the initiation of the Record mode, a delay multivibrator provides a 60-millisecond delay during which all normal record relays have time to operate. Flip-flop No. 1 then operates, and places AND Gates No. 1 and No. 3 in a *ready* state. Pulses, derived from the *Intersync* unit, that mark the third vertical-sync pulse in every frame interval, are reshaped in a pulse former and routed to AND Gates Nos. 1 and 2. Gate 1, which is in a ready

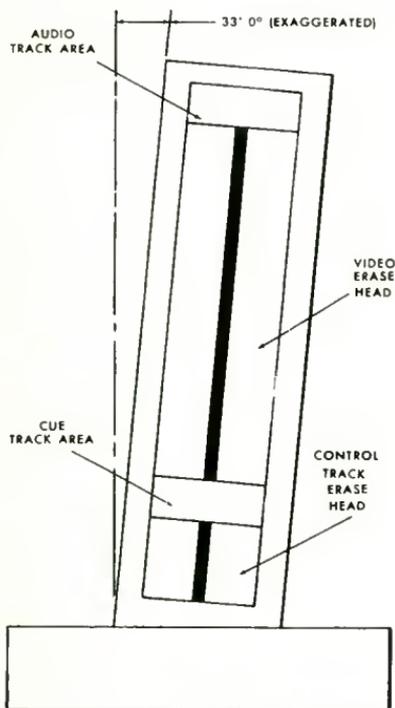
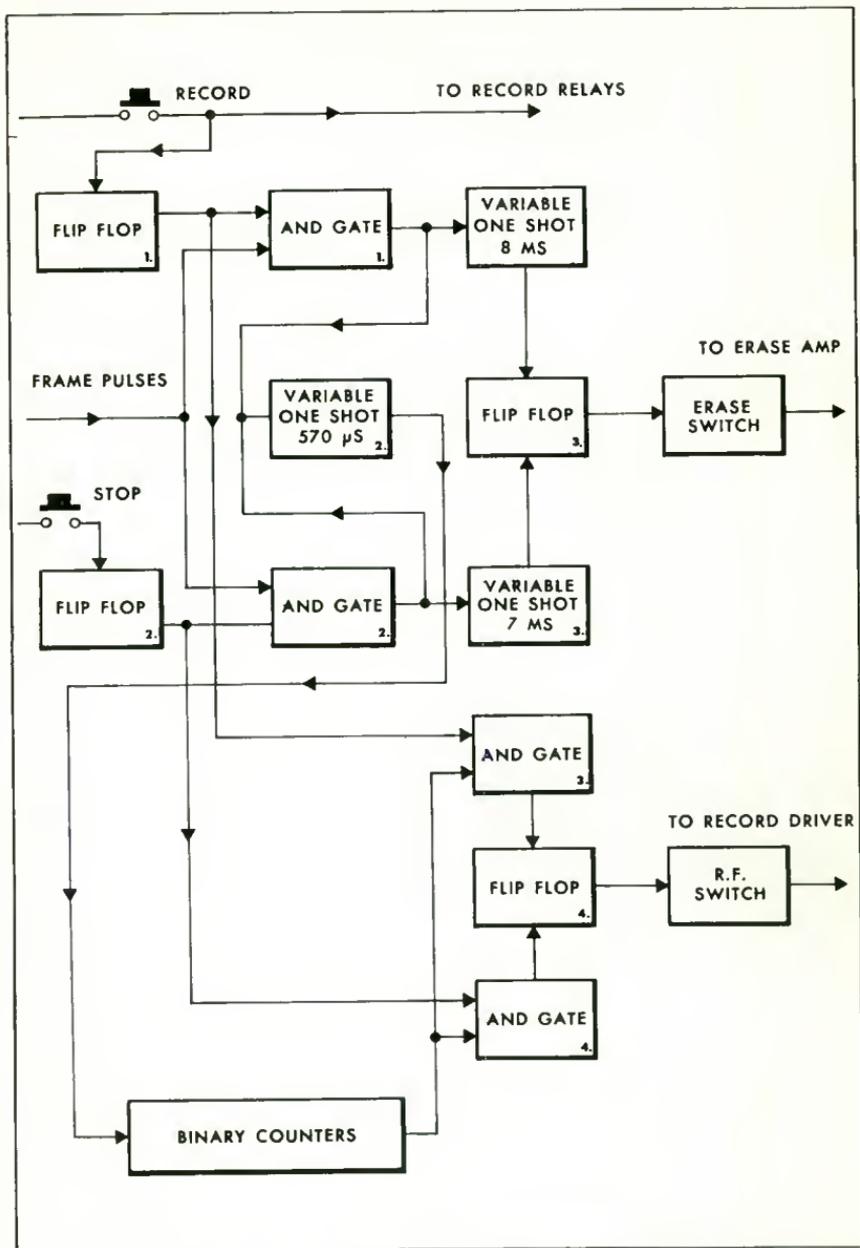


Fig. 6-21. Erase-head assembly detail.

Courtesy Ampex International Operations, Inc.

state, therefore operates at the first frame pulse and triggers variable delay multivibrators Nos. 1 and 2. Multivibrator No. 1 serves to provide the necessary 8 milliseconds of delay before the video erase current is turned on. Erasure turn-on is accomplished by flip-flop No. 3 and an electronic switch.

Because timing is referenced to the third pulse in the vertical-sync train, and at this time the rotating video-head drum is positioned to place the active head tip at the center of a video track, a 570-microsecond delay is provided by multivibrator No. 2. This allows the head to travel to the end of the track, at which time the



Courtesy Ampex International Operations, Inc.

Fig. 6-22. Block diagram of Ampex Electronic Editor.

succeeding head on the drum periphery is positioned at the beginning of the next track. From this timing reference, 18 television frames are counted off by the binary counter system and at the end of this period gate No. 3 operates. Video record current is then turned on by the action of flip-flop No. 4 and a second electronic switch.

Timing for the out-going splice is provided by the operation of gates Nos. 2 and 4, and variable delay multivibrator No. 3, which together with the reuse of the counter train, resets flip-flops Nos. 3 and 4 and places the two electronic switches in the off condition.

An additional flip-flop (not shown on the block diagram) is operated by the binary counters exactly 18 frames after the video-record current is turned off. This permits the audio track to be cleared of all extraneous video information by the action of the audio-erase head. (New audio information has, of course, accompanied the new video information.) A time-delay circuit allows all audio functions to revert to normal before stopping the machine. In this way, any possibility of transients on the audio track is avoided.

The quality of the finished splice can be observed in Fig. 6-23, which is an unretouched oscillogram of the video, blanking and

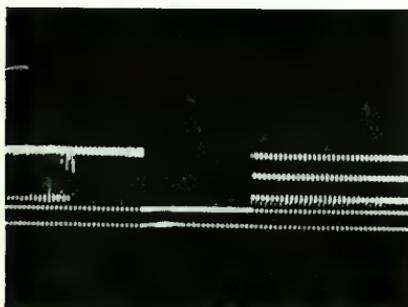


Fig. 6-23. Vertical waveform at moment of splice.

Courtesy Ampex International Operations, Inc.

synchronizing information in the video waveform at the moment the electronic splice passes the video heads. The splices appear the same as a change of picture content caused by camera switching.

The rapidity with which the editing function is performed becomes apparent when it is realized that the entire splicing operation is performed while the recording medium is in motion at normal speed.

SECTION 7

# MAINTENANCE

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## SECTION 7

# MAINTENANCE

This section concerns general testing and maintenance techniques as applied to any quadruplex recording system.

Oiling and lubrication schedules as recommended by the manufacturer for the specific system used should be faithfully executed. This is of extreme importance due to the electromechanical nature of the TV tape system.

Complete service records of work performed or adjustments made, correlated with the elapsed-hour meter, are invaluable to increasing efficiency in tests and maintenance.

### 7-1. OVER-ALL PERFORMANCE EVALUATION

An over-all performance evaluation of a television-tape system helps to pinpoint need for specific maintenance areas. A professional job of cleaning of the tape transport and video-head assembly is of vital importance before testing or maintenance procedures.

Major troubles that can result from lack of cleanliness may be summarized as follows:

1. Drop outs (white flashes) due to oxide accumulation between heads.
2. Dots at a 960-cycle rate from scratches on the coated surface of the tape caused by oxide accumulation.
3. Oxide in the vacuum guide or hose can cause scallop or skew due to lack of concentricity with the tape. A wandering type of skewing can result from oxide shedding into the vacuum guide which may alternately clog and clear the air path. This effect can also be caused by an alignment tape with many hours of use; or even after only a few hours if the transport tensions are such as to cause excessively rapid stops, or jerking of the tape when the Stop button is depressed. Another cause is bent reels which place undue stress on the edges of the tape.

4. Contamination of the nylon bearings underneath the vacuum-guide block or a contaminated screwhead contact with the arm that is actuated by the guide servo (to position the vacuum guide) can result in a slightly different tip penetration each time the tape is stopped and restarted.
5. Erratic tracking from a contaminated capstan or capstan-pinch rollers resulting in tape slippage.

CAUTION: New tape from the factory will often exhibit what seems to be an excessive number of white flashes (drop outs) when the first recording is played back. When tape is first received, a spot check should be made (recording sync only, about the first 5 minutes, then 5 minutes near the middle and end of the reel), to observe the playback raster. If drop outs are numerous, the tape should be polished by allowing the entire reel to run through the heads two or three times. A worn head is best for this polishing operation.

Over-all evaluation can be either an evaluation of the recording and playback functions on the routine operational basis considering only the composite video signal or an evaluation which also includes the following items:

1. Time required after tape roll time for complete stabilization of the servos.
2. Maximum input level to the video-processing amplifier tolerable before clipping occurs, and minimum input level tolerable before sync gating and/or sync formation is affected. This is a means of anticipating trouble before the unit ceases to function properly over the normal operating range.

NOTE: The trademark of a qualified maintenance man is knowing his *safety margins*. When the safety margin begins to slip; he goes to work. In fact, 90% of the effectiveness of any preventive maintenance schedule is in knowing and using the safety margin.

3. Evaluation of adjustment control ranges. Some controls are normally set at one extreme (CW or CCW). Others, however, such as frequency controls, pulse widths, and video-level controls (including blanking and sync) should be checked to determine if proper operation is obtained near an extreme end of the range.
4. Modulator-demodulator amplitude linearity range. Extent of overdeviation possible before amplitude compression occurs or picture plays back with visible transients in black-white transitions (Fig. 6-7). NOTE: The video heads must first be checked

for optimization (proper driving currents) before this evaluation. (Described in Section 6-6.)

- The playback signal-to-noise ratio of a recording made by the system concerned. This is an excellent indicator of any system degradation other than amplitude-frequency response. (Amplitude-frequency response is usually revealed by the composite video-signal evaluation.)

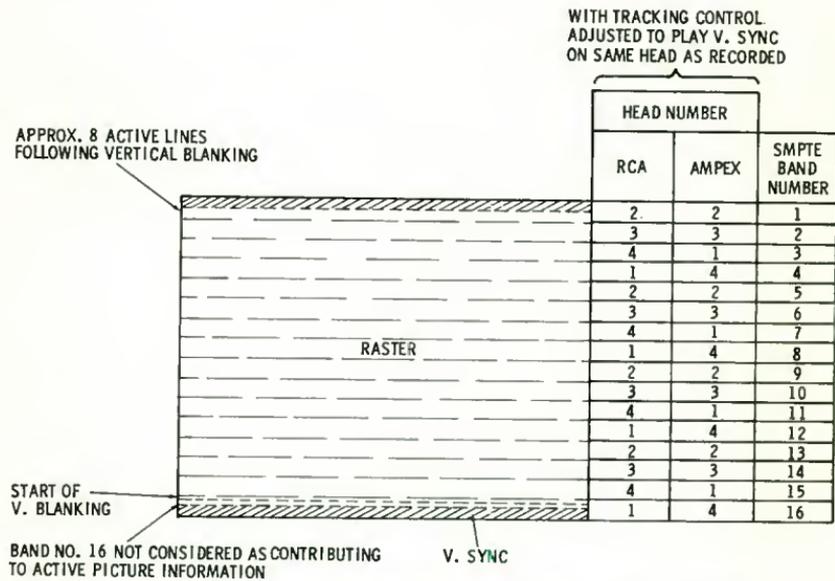


Fig. 7-1. Raster makeup related to heads and SMPTE band number.

One of the most convenient methods of over-all evaluation on an operational basis is provided by the use of the SMPTE alignment tape, based on Recommended Practice (RP10).

In the "Signal Specifications for a Monochrome Video Alignment Tape for 2-Inch Video Magnetic Tape Recording" (Proposed SMPTE Recommended Practice RP10), which follows, sequential bands from top to bottom of the raster (each band of 16 to 17 lines representing a single pole-tip sweep across the tape) are identified as bands number 1 through 16. The first band of lines after that which contains vertical sync is identified as band No. 1; therefore band No. 1 is at the top of the raster. Fig. 7-1 correlates the video-head number with the SMPTE band number. This correlation assumes that the capstan tracking is adjusted so that the same head

plays vertical sync that records vertical sync (head No. 1 on RCA, and No. 4 on Ampex).

It should also be noted that the manufacturer records the Standard Alignment Tape according to the SMPTE specifications; the SMPTE does not manufacture the tape. The customer obtains his alignment tape from the manufacturer of his particular system.

## Proposed SMPTE Recommended Practice RP10

### 1. Scope

1.1 This recommended practice specifies the signals to be recorded on a magnetic video tape for use in evaluating and adjusting the performance of monochrome video-tape recording and playback equipment on a routine operational basis. The characteristics which can be checked primarily are related to the video performance although a cursory check of the audio channel is included for operating convenience.

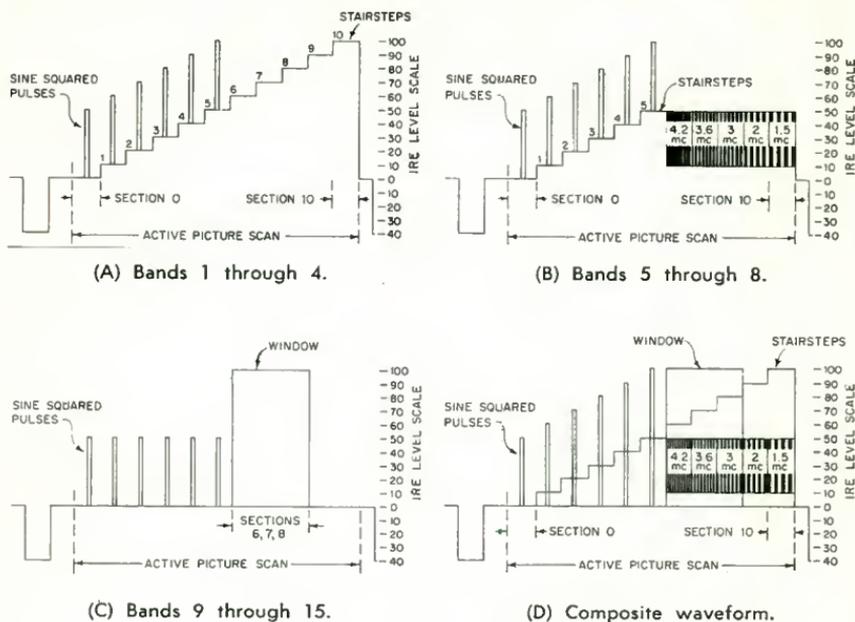
1.2 Specifically, the recorded signals on the tape provide a means for checking the following characteristics or adjustments:

- (a) Video-head quadrature.
- (b) Tape vacuum-guide position.
- (c) Video levels.
- (d) Video amplitude-frequency response.
- (e) Video transient response.
- (f) Video low-frequency tilt.
- (g) Video amplitude linearity.
- (h) Video-head playback sensitivity.
- (i) Relative noise banding.
- (j) RF-carrier deviation frequencies.
- (k) Program and cue-track audio levels.
- (l) Control-track levels and phase.

### 2. Recorded Signal Characteristics

2.1 The video signals recorded by the video heads shall occupy sequential bands from top to bottom in the reproduced picture, each of which corresponds to a single traverse of a video head across the tape. For the purpose of identification, these bands are designated as 1 through 16. The first band after that containing the vertical synchronizing-pulse interval shall be designated as band 1. (Band 1 will contain fewer active lines than the other bands, because it contains a portion of vertical blanking.) The active picture portion of the horizontal scan shall be divided into 11 equal sections. For the purpose of identification, these sections are designated as 0 through 10. Information shall be recorded as follows:

<i>Information</i>	<i>Bands</i>
2.1.1 A staircase signal consisting of a 10-step linear gray scale extending from blanking level to 100 IRE units respectively (Fig. 7-2A).	1 through 4
2.1.2 A staircase signal consisting of a 5-step linear gray scale extending from black level to 50 IRE units, respectively (Fig. 7-2B).	5 through 8



Courtesy Society of Motion Picture and Television Engineers.  
**Fig. 7-2. SMPTE waveforms.**

*Information*

*Bands*

2.1.3 A series of 5 sine-wave bursts (Fig. 7-2B) described as follows: The time sequence of the burst frequencies shall be 4.2, 3.6, 3.0, 2.0, and 1.5 mc. The axis of the multiburst shall be at 30 IRE units, and the peak-to-peak amplitude shall be 40 IRE units. Each burst duration will be at least 75% of the section width.

5 through 8

2.1.4 A window signal at reference white level (100 IRE units) 3 sections wide and 6 bands high to be positioned horizontally in sections 6, 7, and 8 (as shown in Fig. 7-2C) and vertically between the centers of the ninth and fifteenth bands. The remaining section shall be at blanking level (0 IRE units).

9 through 15

2.1.5 Vertical synchronizing-pulse interval and a portion of vertical blanking.

Band 16 Only

2.1.6 Sine-squared pulses of  $\frac{1}{8}$ -microsecond width (measured at half level) and 50 IRE units in height at horizontal positions corresponding to the center of each of the first six sections. The base level of each sine-squared pulse shall be as follows:

1 through 15

- (a) Bands 1 through 8, the same as the accompany-

- | <i>Information</i>                                                                                                                                                                                                                                                                                                                                                                                       | <i>Bands</i> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| ing staircase section level, as shown in Figs. 7-2A and B.                                                                                                                                                                                                                                                                                                                                               |              |
| (b) Bands 9 through 15, at blanking level, as shown in Fig. 7-2C.                                                                                                                                                                                                                                                                                                                                        |              |
| 2.2 The waveform of the composite signal shall appear as shown in Fig. 7-2D.                                                                                                                                                                                                                                                                                                                             |              |
| 2.3 All synchronizing waveforms and signal amplitudes shall conform with EIA Standard RS-170 or the latest revision thereof.                                                                                                                                                                                                                                                                             |              |
| 2.4 All video signals shall be within $\pm 1$ IRE unit of specified amplitudes.                                                                                                                                                                                                                                                                                                                          |              |
| 2.5 The leading and trailing edges of the window signal shall correspond in shape and rise time to the sine-squared pulse specified in paragraph 2.1.6.                                                                                                                                                                                                                                                  |              |
| 2.6 Overshoot of the staircase signal shall not exceed 5% of the amplitude of transition. An exception is the trailing edge of staircase (leading edge of horizontal blanking) which is limited to 2% in accordance with EIA Standard RS-170 or the latest revision thereof.                                                                                                                             |              |
| 2.7 Multiburst frequencies shall conform with specified values within 1%. Total harmonic distortion content of the multiburst frequencies shall not exceed 2%.                                                                                                                                                                                                                                           |              |
| 2.8 The audio tone and cue records shall consist of an audio tone interrupted periodically with voice announcements.                                                                                                                                                                                                                                                                                     |              |
| 2.9 (a) The audio tone shall be 400 cps $\pm 2\%$ recorded at a level 10 db below that corresponding to a 3% total harmonic distortion at 400 cps.                                                                                                                                                                                                                                                       |              |
| (b) The audio response-frequency characteristics shall be as specified in "Proposed American Standard Characteristics of the Audio Records for 2-In. Video Magnetic Tape Recordings" (VTR 16.5) or the latest revision thereof.                                                                                                                                                                          |              |
| 2.10 The voice announcements shall be made at 1-minute intervals and shall not exceed 20 seconds in duration. The announcement shall provide identification of the tape as regards the applicable SMPTE recommended practice, the tape issue number, and the manufacturer of the standard tape. Additional identification (such as serial number) may be included at the discretion of the manufacturer. |              |
| <b>3. Recording Conditions</b>                                                                                                                                                                                                                                                                                                                                                                           |              |
| 3.1 The video-alignment tape shall conform with applicable American standards and SMPTE recommended practices.                                                                                                                                                                                                                                                                                           |              |

Special care and precautions should be taken with handling of alignment tape. The following quotes are from the RCA instructions on the MI-40793 alignment tape (SMPTE):

"Since the tape can be affected by changes in temperature and humidity, extreme changes are to be avoided. The following atmospheric conditions are recommended for the area in which the tape is stored:

Humidity: 40-60% RH  
 Temperature: 60-80° F

“Do not attempt to use the tape until it has been stabilized for at least 16 hours at room temperature.

“Take precautions to avoid erasing the tape accidentally. Do not place or store the tape in the region of magnetic fields.

“Make certain that the heads and guides on the recorder are clean before using the tape.

“Check the setting of the reel brakes. Rapid stops with improperly set brakes can damage or distort the tape.

“Be careful to wind and rewind the tape properly; the edge of the tape must not climb up the side of the reel.

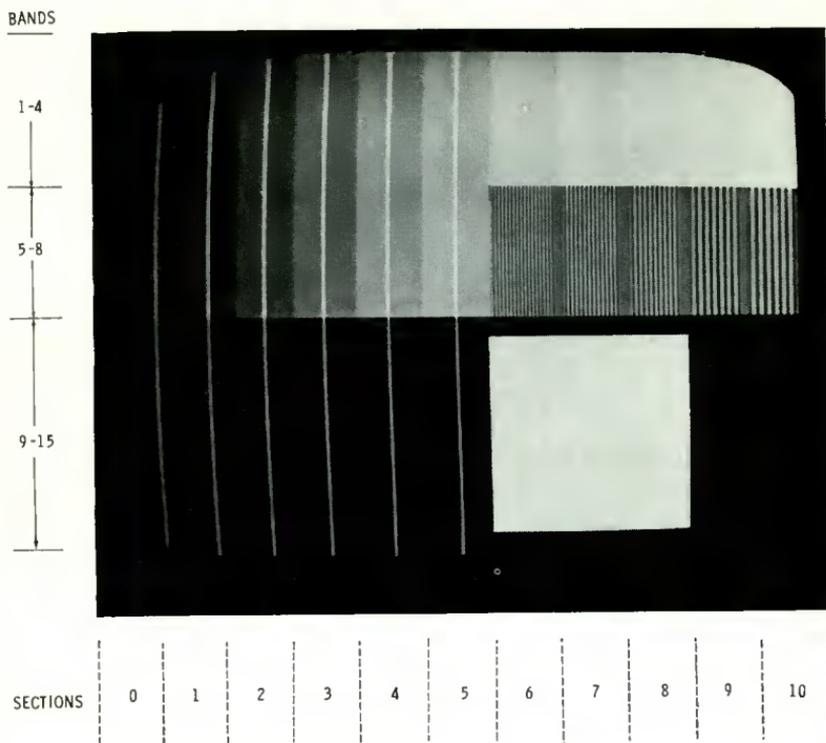
“After long usage, short duration small pressure changes on the order of 0.0001 of an inch (0.1 mil) may begin to appear in the tape, during playback. However, the tape may still be used by choosing the average vacuum guide position.”

A photograph of the monitor display of the input signal for the SMPTE tape at the time a recording is being made is given in Fig. 7-3. The bands and sections as established by RP10 are identified on the photograph for convenience. Fig. 7-4 is the oscilloscope display (horizontal-rate sweep) of the monitor signal in Fig. 7-3.

It is obvious from Fig. 7-3 that adjustments for quadrature and vacuum-guide position may be made to eliminate geometric distortion of the vertical lines, as previously described.

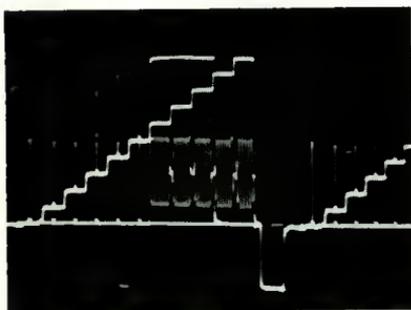
Most of the remaining system evaluation is obtained by analysis of the oscilloscope waveform display. Photographs of the output signals taken from an RCA TRT-1B recorder while playing the alignment tape are shown in Fig. 7-5. Since the signals are keyed only onto definite portions of the composite signal, the Line Selector trigger must be used on the oscilloscope. By selecting the appropriate sweep speed, any particular line or lines can be displayed. Normal horizontal-rate sweep is used for the composite signal display shown in Fig. 7-5A.

NOTE: The maintenance engineer should bear in mind that any standard test tape such as the one just described is a check of the playback function *only*. For over-all recording-playback checks, it is necessary to have access to pertinent test-signal generators. Conventional signal-analysis techniques are used when dealing with individual test signals. The test signal input to the recorder *must* be a standard composite signal. Some test-signal generators contain only horizontal sync so that clamping circuits will function properly. Fig. 7-6A is the vertical-rate display of a typical



Courtesy Radio Corporation of America

Fig. 7-3. Monitor display of SMPTE input signal at time of recording.



Courtesy Radio Corporation of America

Fig. 7-4. Oscilloscope display of SMPTE input signal at time of recording.

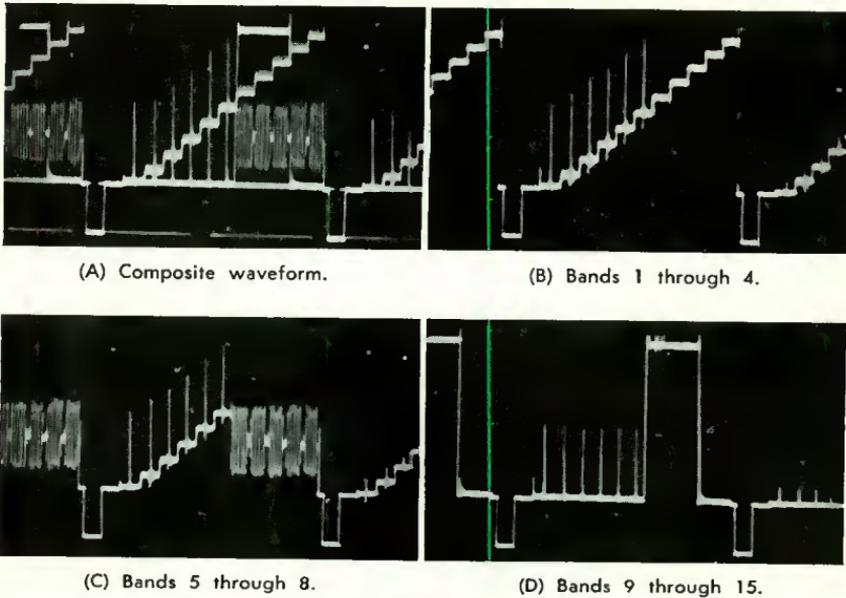


Fig. 7-5. Playback of SMPTE waveforms.

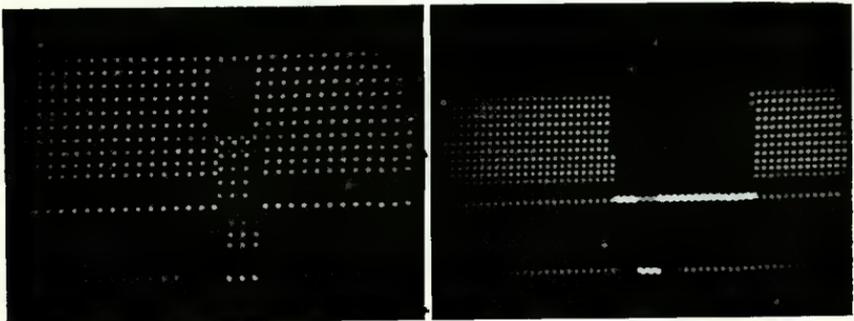
stairstep generator, which indicates that horizontal pulses are contained in the vertical-sync interval. A television tape recorder will not make a satisfactory recording of this signal. The same signal fed through a unit (such as a monoscope amplifier with external input provision) with keyed blanking so that horizontal pulses are eliminated during the vertical interval is shown in Fig. 7-6B. This type of signal is necessary to make a recording on television-tape systems which generate a reference pulse at a specific time in the vertical synchronizing interval (all recorders after the Ampex 1000). The vertical pulses are not only integrated, but they are also effectively differentiated so that a particular time reference is available for generation of the reference pulse. When a signal such as that in Fig. 7-6A is fed to the system in the Record mode, no reference pulse is generated (or if it is generated, it will be erratically keyed) and playback may be either erratic or impossible.

## 7-2. THE VIDEO-HEAD ASSEMBLY

Video-head assembly maintenance is primarily concerned with cleaning, proper positioning of the vacuum guide, and video head

optimization. All of these items have been covered previously.

If the head clogs easily, measure the tip projection with the guage provided. Heads should normally be retired when worn down to 1-mil tip projection, as a slight widening of the gap is apt to occur at any point below this value. The gap is quite easily clogged by iron-oxide particles from the tape and may become useless on the passage of a splice. NOTE: If a rolling-thru amplitude change occurs during a program as observed on the RF envelope from the switcher (with resultant degraded picture) try holding a very soft brush (moistened with *Freon TF*) lightly against



(A) Direct output, showing horizontal-rate pulses vertical sync.

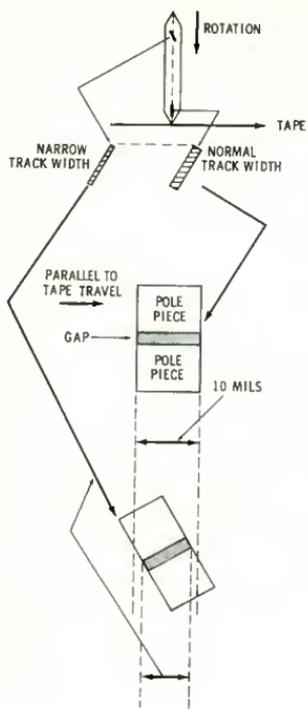
(B) Output of a unit which inserts keyed blanking and sync pulses.

Fig. 7-6. Vertical-rate display of a typical staircase generator display.

the rotating-pole tips while in motion. Some operators grasp the vacuum guide gently with the thumb and middle finger to steady the hand while extending the forefinger (in the direction of head rotation) and lightly grazing the pole tips as they rotate. While this method must be used with extreme care to avoid injury to the finger, a clogged head is almost immediately cleared.

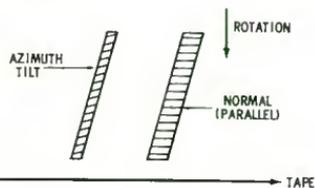
There are two head faults over which the operator has no control—azimuth alignment and axial position (See Figs. 2-15 and 2-16). However, it is possible to check the heads for these conditions; such checks should normally be made by the maintenance engineer immediately on receipt of a rebuilt head assembly.

1. *Check for Azimuth*—The head with gap tilt lays down as a narrow track as shown in Fig. 7-7A. This results in a loss in amplitude, bandwidth, and signal-to-noise ratio. An exaggerated azimuth error is shown in Fig. 7-7B to illustrate how the recorded track is narrowed. This is equivalent to widening the

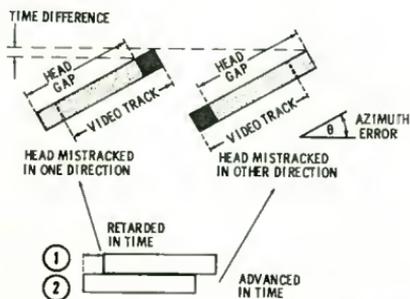


(A) Wheel.

(B) Exaggerated tilt of gap.



(C) Track tilt.



(D) Mistracking.

Fig. 7-7. Azimuth alignment check.

playback gap of a normal head. The tilt of tracks recorded when the gap is not parallel to tape travel is shown in Fig. 7-7C and the method used to detect this error is given in Fig. 7-7D. Make a recording of vertical lines. Playback should be done with the tracking adjusted so that the same head plays vertical sync as recorded. When tracking is perfect, the head gaps are directly over the recorded tracks. By slightly mistracking each side any apparent quadrature effect will reveal azimuth error. The mistracking in the direction of 1 (Fig. 7-7D) will retard the band in time and mistracking in the direction of 2 will advance the band in time. If the lines are parallel to tape travel, no error will occur. The head assembly must first be properly optimized and aligned as outlined in Section 6.

2. *Check for Axial Position*—As shown by Fig. 2-16, axial misalignment of a head results in nonstandard spacing for one band of 16 lines. After heads have been optimized, make a recording of a suitable signal (test pattern is best) and play back with the Tracking control adjusted so the head that records vertical sync plays it back. The playback picture should be optimum under this condition. Now change tracking one head. (This is obtained simply by moving the Tracking control either CW or CCW until lock-in is again achieved.) If axial misalignment exists, one band will become noisier than the rest. This will result for three out of four head trackings. In many cases, an effect known as *half-banding* occurs, which simply means that approximately one-half of a given band is noisy. Half-banding is the result of the pole tip properly scanning across a portion of the track while the remaining portion of the track is curved relative to the standard track. Thus, a uniformly high noise level throughout one band indicates that one head is not in the same vertical plane (axial position) as the other three heads. Half-banding results from the plane of pole tip rotation not being perpendicular to the tape. In either case, the manufacturer will allow full rebate on such a head assembly if returned within the first 10 hours of operation.

### 7-3. OPTIMIZING THE LOCAL-SYNC GENERATOR

Certain characteristics of the local-sync generator are more exacting in requirements when integrated with TV-tape systems than is the case for other studio gear. Optimizing the station sync generator neither indicates a different adjustment nor nonstand-

ard adjustment to make compatible with the tape recorder. It does, however, indicate more critical adjustment of frequency and more thorough maintenance of stability of counters, AFC circuits, and pulse distribution.

After the sync generator has been adjusted per the manufacturer's instructions, perform the following check:

Set the master oscillator in the free-running mode. Insert the scope probe to observe any 60-cycle signal (such as counter-chain output, vertical drive, or blanking), with the scope trigger selector on 60-Cycle Line position. This reveals any slip of the vertical-frequency generator output with the line frequency. Adjust the master-oscillator frequency so that the trace is stabilized with the line frequency; this provides a *vernier* adjustment of the oscillator frequency, provided that the counters are properly functioning and centered. A very slight drift back and forth may occur, but no sudden changes should exist.

Setting the master oscillator control to line-lock should immediately stabilize the trace after the initial phase slip to lock. If this does not occur or if the trace becomes unstable on line-lock position, the AFC circuitry is in need of service. When individual counter stages employ adjustable controls, always check to see that such controls are centered in the range midway between extremes where proper countdown is lost.

With the sync-generator frequency adjusted, no difficulty should be experienced in tape-system operation using local sync as the playback reference. The same is true when employing the Ampex *Intersync* or RCA *Pixlock* with the local-sync generator in Line-Lock position. However, both Ampex and RCA recommend using crystal control for the local-sync generator in the latter case for maximum playback stability. When, for any reason, it is desirable to operate in Line-lock sync position, the preceding vernier tuning of the master oscillator along with stable AFC circuitry will normally result in satisfactory operation.

Sync crosstalk is another problem. This term applies either to crosstalk within the sync generator itself or to the so-called "windshield-wiper" effect, similar to the horizontal motion resulting from cochannel interference on a home receiver.

Crosstalk within the generator itself is usually caused by very small leakage of any of the counter frequencies to the master-oscillator. This trouble is most evident on video monitors employing pulse-width (*Synchroguide*) horizontal circuitry. Crosstalk produces a slight horizontal-line displacement at the vertical-

raster edges and vertical lines in the picture. The engineer can check by observing any pattern consisting of vertical lines (such as a grating signal or keyed-burst signal driven from local sync) preferably on a *Synchroguide*-type monitor. The frequency of any existing crosstalk can be determined by considering the number of horizontal line displacement occurring from top to bottom of the raster as follows:

<i>Frequency</i>	<i>Number of Displacements</i>
4,500	70
900	14
180	3

Thus, crosstalk from the 900-cycle output of one of the counters results in 14 displacements, which is quite close to the 16-band (960 cps) raster construction of a tape-recorder output. Sometimes a scallop effect, which can cause the operator to misadjust the vacuum-guide height adjustment in an attempt to eliminate an error, is actually caused by the local-sync generator. However, this effect will be observed at the input to the tape system when crosstalk exists. Certain types of master monitors employ a synchronization which, for all practical purposes, results in a line-to-line sync. This tends to start each active line of picture information at the same spot following horizontal sync, and minimizes any effect of line displacement that normally would be quite apparent on an average-sync monitor, and most modern home receivers. For this reason, the station should monitor TV-tape systems with an averaging-sync monitor.

When "synchronous"-type crosstalk is found, the indicated counter should be additionally shielded or the wiring rerouted until the interference is eliminated.

A more prevalent type of sync crosstalk occurs between two nonsynchronous sources, such as local and network, or local and video-tape signal. This trouble is evident as a vertical bar or line moving nonsynchronously back and forth horizontally on the video monitors when the network or television tape is fed to the program line. (Of course, this will not occur if the tape is operated in *Intersync* or *Pixlock* modes, because the tape output is in phase with the local-sync generator.) The condition is caused by local-sync crosstalking with the nonsynchronous tape or network signal.

This trouble is usually the result of ground loops. A ground loop in an otherwise well designed installation is most often the

result of an open or intermittent ground at one end of a coax cable. When an open occurs, the signal at the open-shield end must pick up its ground return through a number of racks. Each cable should be disconnected from the sending end and checked with an ohmmeter from center conductor to shield to determine if the termination resistance is obtained. If the shield is open, no continuity will exist. Always twist both sending and receiving connectors while making this check so that loose, intermittent, or high-resistance connections will be made evident.

#### 7-4. CHECKING VIDEO GAINS AND AMPLITUDE VS FREQUENCY RESPONSE

Knowing the normal gains of individual amplifiers (such as preamps, modulator video up to the reactance tube grid, RF gain from modulated stage to modulator output, demodulator unit, etc.) is an important factor in preventive maintenance procedures. This step in preventive maintenance will help in keeping the system signal-to-noise ratio within specifications and will indicate when the need arises for tube-transconductance checks and replacements.

As a specific example, measure the video-head output (directly at each commutator brush with a scope) on playback of a standard tape such as the alignment tape. This output is normally from 2 to 5 millivolts. Then measure the output of the individual head preamps and compare this peak-to-peak value to the normal value, determined when the system is known to be properly functioning. All of these values should be recorded and available to the maintenance personnel.

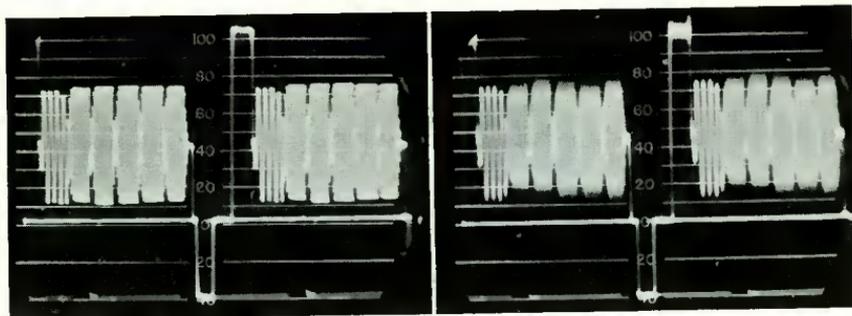
The general condition of the video-processing amplifier can be interpreted if the normal range of input level to output level is known. An example of a specific tabulation follows:

Normal input—1 volt (p-p).

Minimum input—0.5 volt (p-p) for same signal-to-noise ratio.  
0.25 volt (p-p) just above sync breakout.

The need for tube replacement or a complete video realignment of amplifiers is best and most conveniently checked by the keyed-burst signal, as illustrated in Fig. 7-8.

Care should be taken to proportion the amplitudes of the single-frequency bursts, as shown for the input signal of Fig. 7-8A. The energy of frequency components in the normal picture is quite low



(A) Proper proportionment at input.

(B) Acceptable reproductive of A.

Fig. 7-8. The Multiburst signal.

above 1.5 mc. If sine waves are fed into the system with the higher frequencies at the same amplitude as the white pulse reference considerable high frequency power exists and high-frequency overload of the modulator due to the previously discussed pre-emphasis may occur. The same type of overloading occurs in the demodulation process due to natural limitations in high power, high-frequency linearity. The response obtained from such adjustment of the input signal will indicate some loss of higher frequencies as compared to the photo of Fig. 7-8B. Also a shift in the AC axis occurs, indicating selective-frequency clipping. This type of input signal exceeds the normal limits of the modulation-demodulation process and is of little value, except as a safety-margin check.

Fig. 7-9 shows the proper proportionment of keyed single-frequency sine waves when this method is used for over-all system video-response checks. This will be recognized as that which is recommended by the FCC for single frequency runs on TV transmitters.

If a video sweep is used for FM circuit alignment, remember that the highest video frequency (4 mc) is represented by a carrier frequency of 1 mc (lowest carrier frequency). Thus, peaking

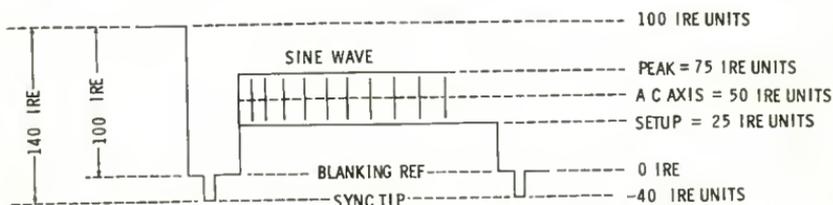


Fig. 7-9. Proper proportionment of single-frequency keyed sine wave.

the carrier at the lower end increases the response at the higher video frequencies.

When it is necessary or desirable to insert a test signal into the video preamplifiers, use a wideband video pad such as shown by Fig. 7-10. The pad is inserted between the test signal generator and the preamp input by means of short coax cables. The test signal generator should be adjusted for no more than 0.5-volt (p-p) signal output, insuring that the 46-db attenuation will prevent any possible overloading of the preamplifier.

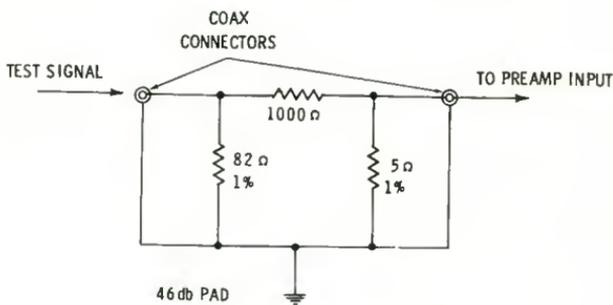


Fig. 7-10. A 46-db video pad.

Inability to bring a video amplifier into proper amplitude-frequency response specifications by adjustment of the appropriate peaking circuits may be due to any one or a combination of the following faults:

1. Changed plate load. An increase in plate load will reduce higher frequencies. A decrease in plate load will reduce gain and increase higher frequencies.
2. Defective peaking coil or swamping resistor across coil.
3. Low-transconductance tubes. (However, in certain types of negative feedback amplifiers, loss of highs may result from tubes that check normal transconductance on a tube checker. *Always* replace tubes in negative feedback amplifiers *first* before further checks for troubles when video-response checks indicate loss of high-frequency response.)

Always bear in mind the turn-around in FM peaking circuitry due to the nature of the modulation system. In this case, for example, an increase in plate load, causing reduced response of the higher carrier frequencies, results in a loss of low-frequency video and an increase in high-frequency video.

## 7-5. CHECKING CARRIER AND DEVIATION FREQUENCIES

The operational technique of setting carrier and deviation frequencies is covered in Section 6. At periodic intervals (or whenever doubt arises as to the accuracy of the operational method) the maintenance engineer should run a calibration check on the reference circuitry involved. Wrong carrier frequency may be suspected whenever visible RF (herringbone) begins to appear on the playback of a recording made by the system in question.

No built-in calibration for carrier or deviation is provided on the original Ampex 1000-A television-tape recorders. The most convenient method of adjusting the modulator is to use a 5 mc and a 6.8 mc crystal in series with the scope probe. The Ampex procedure is as follows:

1. With the first video tube removed (to remove clamping), the 5-mc series crystal probe is inserted at the Detector In test point, and the oscillator frequency is adjusted to obtain zero beat with the crystal. Since the circuit is a series resonant probe, "on frequency" is indicated by the sudden jump in amplitude as displayed on the CRO tube.
2. With the first video tube replaced and a standard window signal (or suitable white area signal), the 6.8-mc crystal probe is inserted at the same test point, and the Deviation control is adjusted to obtain the sudden jump in CRO display. (Set the time base to display an entire field.)

Later model Ampex systems employ crystal-controlled carrier frequencies with crystal calibration of peak-white deviation. Crystal accuracy is checked in the conventional manner using an external frequency standard. For example, an external 5-mc frequency is displayed on the oscilloscope with the time base adjusted to a convenient number of cycles in 10 centimeters, for example. The recorder frequency may then be compared on the scope with the same time base. Most stations employ a dual trace scope for tape-system checks; in this case, the standard frequency is displayed on one trace and the recorder frequency on the other for direct comparison.

In the Ampex system, clamping reference is at blanking level; therefore, the carrier is also at blanking level, or 5 mc. In the RCA system, carrier frequency is at sync-tip level and clamping is at sync tip. In both cases, blanking occurs at 5 mc. With the standard 1-volt (p-p) composite signal of 0.714 volt video and

0.286 volt sync and with deviation adjusted to swing the carrier 1.8 mc on video, sync tip actually occurs at 4.28 mc. Since the tolerance is established as  $\pm 50$  kc, 4.3 mc is the nominal frequency. However, in using the external-frequency standard to check the wavemeters in the RCA modulator, the frequency should be set to 4.28 mc to make allowance for any tolerance in the frequency standard. The procedure for the RCA TRT-1B recorder is as follows:

1. Set the external-frequency standard to 4.28 mc and couple it into the mixer input of the modulator (across C14). With the switch in the Sync Tip position, turn the adjustment slug for the 4.3 mc wavemeter for maximum meter deflection.
2. Set the external-frequency standard to 6.8 mc. With the switch on the Peak White position, adjust the slug on the 6.8-mc wavemeter for maximum meter deflection.

NOTE: The recording frequencies of any tape can be checked with the system in the Play mode of operation as described below. This technique can be used to self-check the recorder or to ascertain the frequency limits of any tape of questionable quality or outside origin.

1. Use a properly calibrated variable-frequency generator to feed the demodulator input without removing the playback signal (e.g., at the demodulator-input test point).
2. With the recorded tape threaded, place the system in the Play mode. Place the scope probe at the demodulator video-output test point and adjust the external generator for a suitable level to show beats with the tape signal on the scope. Vary the external-generator frequency around the 4.3 mc region until a beat is obtained, as shown by Fig. 7-11A. The beat pattern will disappear when "on frequency," as shown in Fig. 7-11B. The sync-tip frequency of the recording can be read on the external-generator dial.
3. Slowly increase the frequency of the external generator toward 6.8 mc. Just below the peak-white deviation, beats above the white level will occur (Fig. 7-12A). When the recorded peak-white level is reached, normal signal (Fig. 7-12B) occurs.

## 7-6. CHECKING VIDEO TRANSIENT AND LOW-FREQUENCY RESPONSE

The evaluation of low-frequency response is important in determining absolute values of picture streaking. It is important to



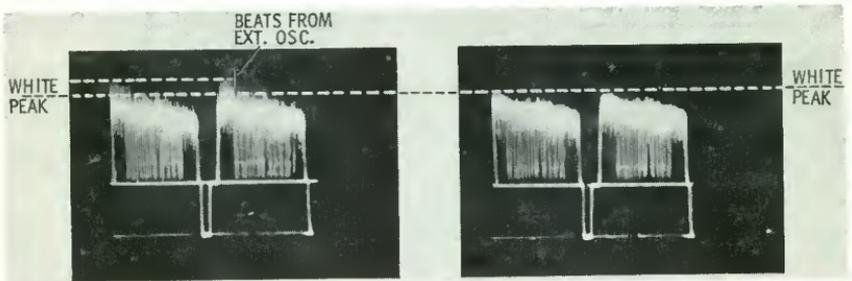
(A) External oscillator adjusted near sync-tip frequency.

(B) External oscillator adjusted to zero beat with sync frequency.

Fig. 7-11. Demodulator output waveforms—sync-tip position.

understand that the degree of streaking observed on a picture monitor depends not only on the monitor amplifier characteristics, but also on the ratio of brightness- and contrast-control settings. There is almost always some visible streaking when displaying a window signal, or any other white bar on black background, if the bar extends an appreciable length of the scanning line. This was the primary reason for development of the white-window test signal; so that a truly accurate measurement can be obtained from the CRO presentation in quantitative terms.

The phase characteristic related to the low-to-high frequency response ratio is closely related to the absolute measurement of the low-frequency response. The shape of the passband response curve determines the transient response of the system. Depending on the rise time of the window signal, an indication of transient response may be determined to some degree, but this characteristic is more accurately shown by the  $\text{Sin}^2$  (sine-square) pulse.



(A) External oscillator just below frequency of peak-white level.

(B) External oscillator set on white tip frequency.

Fig. 7-12. Demodulator output waveforms—peak-white position.

The  $\text{Sin}^2$  technique essentially involves transmission of a pulse at the line-repetition rate with a half-amplitude diameter (abbreviated h. a. d.) equal to the time of either 1 or two picture elements. It is important to remember here that one TV cycle is equal to two picture elements. This is to say that the pickup-tube scanning beam sweeping across the vertical black-to-white bar of the image on the photocathode (or target) will produce one cycle of the frequency representing the fineness of transition.

One cycle occurs in a time equal to the reciprocal of its frequency, for example:

$$1 \text{ cycle at } 4 \text{ mc} = \frac{1}{4(10^6)} = 0.25 \mu\text{s}$$

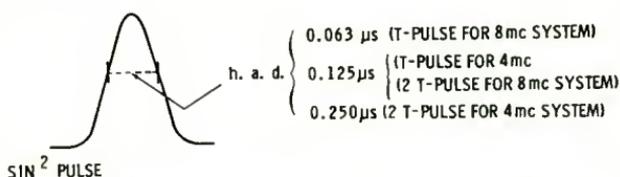
This means that a black-to-white transition of a vertical bar with a width representing 4 mc will occur in 0.25 microsecond, but black is one picture element, and white is one picture element. Therefore a picture element of a 4-mc system is 0.125 microsecond (one alternation of the complete cycle). In the  $\text{Sin}^2$  technique, a time duration of one picture element is given the symbol T, while a time duration of two picture elements (for the system bandwidth under test) is symbolized by 2T.

Fig. 7-13A shows this definition in terms of T and system bandwidth. Fig. 7-13B is the horizontal timing of the Telechrome Model TMC 1073-D2  $\text{Sin}^2$  pulse-window generator manufactured by Telechrome. The  $\text{Sin}^2$  pulse appears as a thin vertical white line on the left of the raster, immediately following blanking, and the white window is on the right side, equally spaced vertically on the raster as shown by the field display of Fig. 7-13C. The window signal has a rise time equivalent to that of the  $\text{Sin}^2$  pulse.

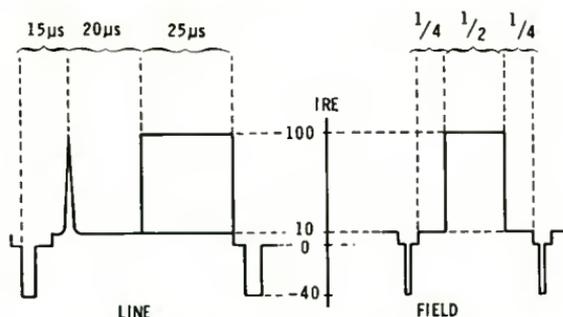
The frequency spectrum of the  $\text{Sin}^2$  pulse is such that at a frequency where  $f$  equals  $1/T$ , the spectrum amplitude remains at least 35 db under the fundamental. Thus, for a 2T pulse of a 4-mc system (0.25 microsecond), no harmonics beyond 4 mc are present, and the system is checked over the intended frequency range. Conversely, a T pulse (0.125 microsecond) will contain frequencies to 8 mc and will reveal the characteristics of a 4-mc system (such as the video-tape recorder) when being hit with the usual 8-mc signals from studio gear. The characteristics of the pulse are always the same and fixed by definition just as for the VU meter in audio work, and from this standpoint appears to be a step in the right direction toward obtaining a standard test signal for video applications.

The pulse measurement through a system under test is made in terms of the first lobe (negative) and second lobe (positive), by the ratios of the leading and trailing edge lobe amplitudes, by the h. a. d. and (with the combination window and pulse) by the relative heights of the pulse and window.

Fig. 7-14 illustrates this terminology. In general, the T-pulse measurement for a given complete system may be considered



(A)  $\text{Sin}^2$  pulse in terms of T and bandwidth.



(B) Horizontal rate CRO display.

(C) Vertical rate CRO display.

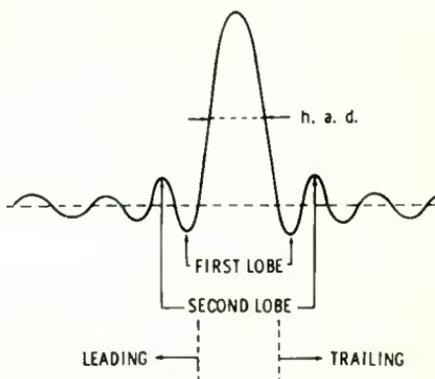
Fig. 7-13. Signal proportionment of Telechrome TMC 1073-D2  $\text{sin}^2$  pulse-window generator.

satisfactory if the h. a. d. is within 0.18 microsecond; the first (negative) lobe overshoots within 12% and the second (positive) lobe overshoot is within 8%.

An increase in attenuation, such as that produced by a sharp cutoff above the desired passband, will cause increased phase distortion below the upper limit of the passband. This is indicated by reduction in T-pulse height, increase in h. a. d. and a large amplitude ring on right-hand side of pulse.<sup>1</sup>

NOTE: The SMPTE alignment and test tape designates  $\text{sin}^2$  pulses of 0.125 microsecond. This is a T-pulse for a 4-mc system and should be interpreted as such on system analysis.

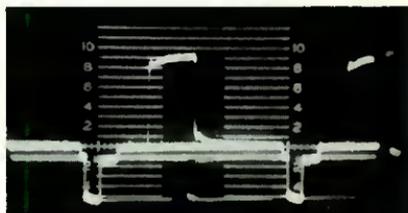
<sup>1</sup> Reference: MacDiarmid, "Waveform Distortion in Television Links," *Post Office Electrical Engineers Journal*, July and Oct., 1959.

Fig. 7-14.  $\text{Sin}^2$  pulse terminology.

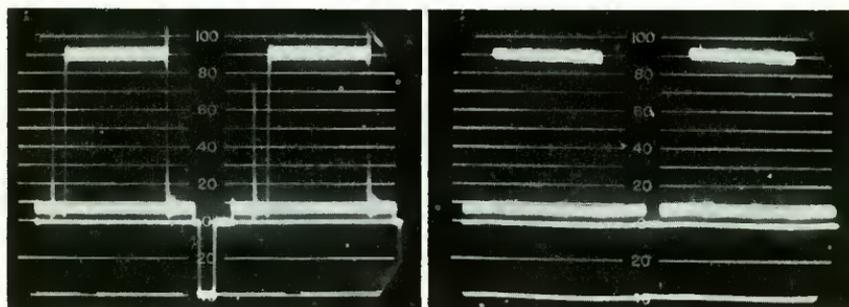
The T-pulse should be observed on an expanded scale. Adjust the scope time base to 1.25 microsecond per centimeter and set the Magnifier control to 10X. The Scope-Response switch must be set to Wideband position, and the operator must know the normal response of his scope amplifier, which is his standard of measurement. This, of course, is most easily obtained by observing the direct output of the test-signal generator on the scope to be used for measurement. Of course, the same probe and probe cable length should be used.

In general, if the high-frequency gain exceeds gain at the low frequencies the window-step response overshoots its final amplitude and returns on an exponential whose time constant is related inversely to the frequency at which distortion occurs. If low-frequency gain is greater than gain at high frequencies, an undershoot occurs at the window-leading edge and the top gradually increases for the pulse duration (Fig. 7-15). Note that the trailing edge of the white window does not fall completely to the base line until an interval following the transition. This type of distortion is termed *positive streaking*, since the monitor effect is white following white. The magnitude of overshoot or undershoot is related to the magnitude of gain change.

Fig. 7-15. Window signal playback indicating excessive low-frequency gain.



The window is much more sensitive to low-frequency distortion than the  $\sin^2$  pulse; the pulse is much more sensitive to high-frequency distortion than the window. Distortions affecting the h. a. d. (duration) will normally also effect the bar-to-T-pulse amplitude ratio which is actually easier to detect for small changes. In general, the pulse will be less in amplitude for excessive low-frequency gain, and greater in amplitude for excessive high-frequency gain.



(A) Horizontal rate.

(B) Vertical rate.

Fig. 7-16. Display of  $\sin^2$  pulse window signal at output of recorder.

The horizontal-rate display of the playback of the combination window- $\sin^2$  signal showing approximately average response characteristics of video-tape playback is given in Fig. 7-16A. (In this case, the input signal  $\sin^2$  pulse was adjusted to 70 IRE units, which is the same as the reproduced signal.) The trailing edge of the window actually overshoots slightly, indicating a slight amount of negative streaking (black following white). Such type of (slight) distortion is not objectionable since it actually overemphasizes outlines, giving an apparent sharpness. The vertical-rate display of the same signal is given in Fig. 7-16B. Approximately 2% tilt at 60-cycles, which is about the maximum allowable for complete freedom from observable shading, is indicated.

## 7-7. CHECKING AMPLITUDE LINEARITY

The slope detector in modern television-tape recorder systems is normally capable of linear demodulation from 4 mc to 8 mc (Fig. 7-17). It is helpful for the maintenance engineer to determine how far he can overdeviate the modulator without degrading the amplitude linearity. In this way, an indication of sagging tubes

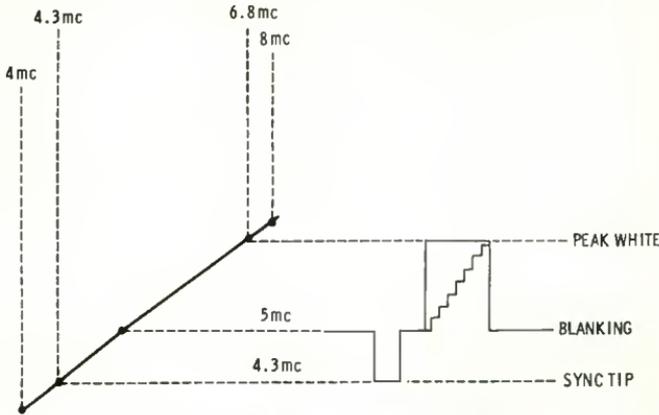
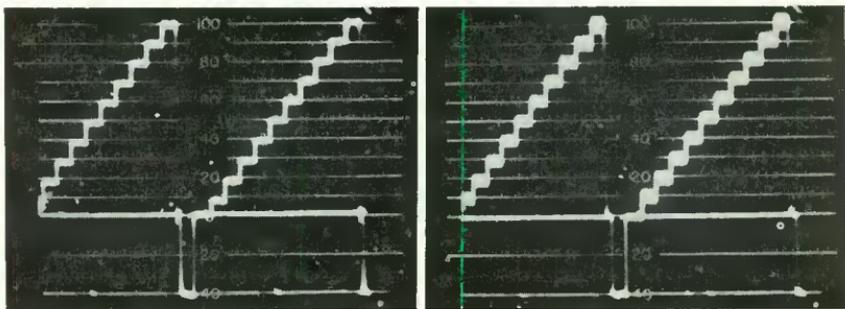


Fig. 7-17. Slope-detector curve.

or weak transistors may be revealed before white level or sync compression takes place under normal modulation.

The stairstep signal normally consists of ten discrete steps, at ten IRE units each, for an over-all total of 100 IRE units of video. The first step is at the reference black level of 10 IRE units. When this signal is recorded and played back, amplitude linearity may be conveniently measured in percent. Black or white stretch or compression, or gray nonlinearity is immediately evident by a departure of each step from that which existed at the input of the recorder while recording the signal.

Fig. 7-18A shows the input signal during recording. The reproduced signal showing the excellent gray-scale response that can be obtained with a properly adjusted system is given in Fig. 7-18B. If a recording of the stairstep signal is made and the playback



(A) Input of tape recorder.

(B) Playback of A.

Fig. 7-18. Stairstep signal waveforms.

reveals obvious compression at sync tip or white level, the question occurs as to whether the compression is taking place in the modulator unit or the demodulator unit. The demodulator is most conveniently checked by feeding a video sweep-test signal to the demodulator input and observing the demodulator output curve, as shown by Fig. 7-19. Make sure the peak-to-peak amplitude of the input signal is no greater than the normal RF input—usually

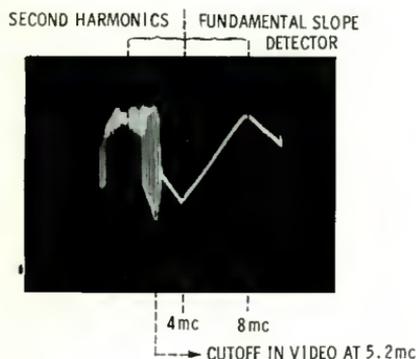


Fig. 7-19. Video sweep response—input to output of demodulator.

about 1 volt (p-p). When the fundamental carrier is properly balanced, unbalanced second harmonics of the carrier, (shown at the left of Fig. 7-19) still exists. This is the reason for the second harmonic filter, which prevents the unused signals from being passed to the video output. In Fig. 7-19, which is the response of an RCA TRT-1B recorder, the cutoff occurs at 5.2 mc.

When compression exists at the demodulator video output with properly operating demodulator circuitry, as revealed by the foregoing procedure, check for video compression up to the reactance-tube grid in the modulator, carrier and deviation frequencies, and particularly any built-in carrier and deviation frequency-calibration circuits for proper adjustment with an external standard as described in Section 7-5. If the compression does not exist at the video output of the demodulator unit, then the trouble is obviously in the following signal processing amplifiers and/or distribution amplifiers. There will be no doubt as to whether the non-linearity is occurring in the recording or playback process if a standard staircase test tape (such as included in the SMPTE-sponsored alignment tape, Section 7-1) exists at the station. However, this also points up the importance of checking the recording

process occasionally by recording and playing back the stairstep test signal.

## 7-8. SIGNAL-TO-NOISE RATIO

Measurement of recording-playback signal-to-noise ratio is an excellent indicator of the need for a complete run-through on tube checks, amplifier gains, and demodulator limiting stages.

There are a number of generally satisfactory methods of measuring video-tape signal-to-noise ratio, two of which will be described here. The oscilloscope method is less time-consuming and most convenient, but less accurate than the VTVM method.

### 1. *The Oscilloscope Method*

NOTE: The tape used should not be completely new and unpolished, nor old and worn or scratched; a tape should be used that is in the condition employed for normal satisfactory recording and playback in the daily schedule. The heads should be optimized, demodulator properly balanced, switching transients minimized, and critical (optimum) tracking adjustments made. To make the readings significant, the signal-to-noise ratio should be determined on a peak-to-peak video to rms noise basis.

- A. The test signal to be recorded should be a "doorstep" (three steps: one at black, one at gray or midway between the black and white peaks, and one at reference white level), or the standard stairstep signal described in the preceding Section. Many prefer the "one-line-in-five" stairstep signal shown in Fig. 7-20A adjusted for a 50% duty cycle. It provides a convenient method of swinging the modulation over the reference frequencies to provide the reference level, while simultaneously providing for a gray step measuring point.
- B. With the system optimized for recording, make about 5 minutes of recording of the test signal.
- C. With the system optimized for playback, observe the playback of the preceding test signal at the demodulator output on the oscilloscope.
- D. Fig. 7-20B illustrates a typical playback of the test signal of Fig. 7-20A. Note the additional thickness of the gray step. Adjust the video output level to obtain the standard 0.714 volt (p-p) of video.

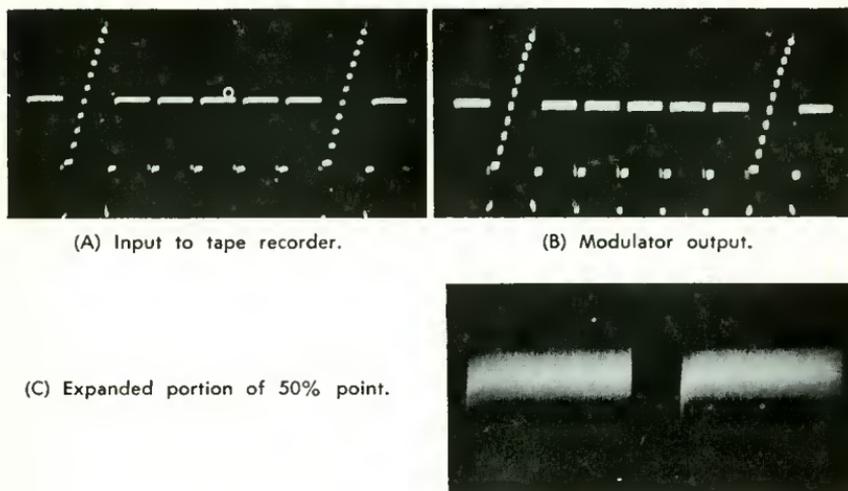


Fig. 7-20. The one-in-five stairstep signal, 50% duty cycle.

- E. Expand the vertical deflection by using maximum scope gain. Read the peak-to-peak excursion of the noise (at the 50% steps) with the scope on wideband (10-mc) response. Assume for the moment that the measured value is 100 millivolts (0.1 volt p-p).
- F. To convert the 100 millivolts (p-p) to rms value, multiply by 0.35:

$$100 \times 0.35 = 35 \text{ millivolts} \\ = 0.035 \text{ volt}$$

- G. The voltage ratio is now  $0.714/0.035$  or 20.4. The db equivalent for a voltage ratio of 20.4 is 26. This is on a peak-to-peak video to rms noise basis.
- H. To convert the 10-mc bandwidth reading to a 4-mc bandwidth, which is the useful passband of the video information, add 7 db to the above computation:

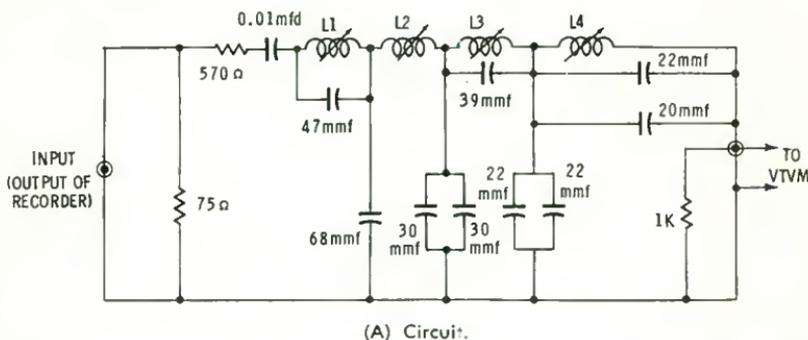
$$26 \text{ db} + 7 \text{ db} = 33 \text{ db}$$

NOTE: If a 4-mc scope amplifier or high-gain preamp is used, delete Step H. The bandwidth is given in terms of the 3-db down point. Note also that from the analysis, 100 millivolts of noise is approaching the maximum allowable to meet specifications for a 35-db signal-to-noise ratio. Thus, the 100-millivolt (p-p) noise level becomes the warning flag.

Due to the limitations in accuracy of reading the noise peaks on the oscilloscope trace, the preceding method is subject to a variable error, depending entirely on the operator's care and his familiarity with his particular scope-amplifier characteristics. The result under optimum conditions should be within a few db of actual signal-to-noise ratio. The VTVM method which follows is more accurate and is limited only by the accuracy of the instrument used. (This method is essentially that used by Ampex in factory checkout of completed assemblies.)

2. The VTVM Method

A. The equipment required includes a bandpass filter, such as shown in Fig. 7-21 (or equivalent), and a 4-mc VTVM, such



(A) Circuit.

NORTHILL COILS			CREST (MICROTRAN) COILS	
COIL	PART NO.	VALUE IN $\mu$ h	PART NO.	VALUE IN $\mu$ h
L1	1000-F	14.5-22	200-3	6.6-20
L2	1000-I	55-110	200-5	33-110
L3	1000-H	29-55	200-4	16-55
L4	1000-F	14.5-22	200-3	6.6-20

(B) Coil values.

FREQ.	RELATIVE ATTENUATION (db)
< 100 cps	45 db
< 10 kc	6 db
10 kc - 4 mc	0
4.2 mc	6 db
4.5 mc	40 db

(C) Characteristics.

Fig. 7-21. A bandpass filter constructed from readily available parts. (Based on data originally supplied by Ampex.)

as the Hewlett-Packard Models 400D or 400H, the Balantine 314, or equivalent.

B. Adjust the Detector Balance control on the demodulator for maximum rejection of carrier 10-mc ripple, with the modulator carrier frequency set to 5.0 mc and deviation set at zero (Modulator Input Level control complete counterclockwise). Then raise Input Level control for Step C.

- C. With a standard window or stairstep signal applied to the input of the modulator, set the carrier frequency and deviation in accordance with the proposed SMPTE recommended practice, i.e., 5-mc carrier frequency corresponds to blanking level and 6.8 mc corresponds to peak white.
- D. Record a two-minute section of window or stairstep signal and rewind the tape to the beginning of the recorded section.
- E. Place the machine in the reproduce mode and adjust the video Output Level control on the demodulator for an output level of 0.7-volt peak-to-peak video, not including sync.
- F. Remove the video input-cable from the input to the modulator in order to disable clamping. Set the Carrier Frequency control for a carrier frequency of 6.0 mc corresponding to a medium shade of gray.
- G. Record a two-minute section of undeviated 6.0-mc carrier and rewind the tape to the beginning of this recording.
- H. Remove the video cable from the demodulator output and connect the special bandpass filter to the output of the demodulator. Connect the output of the filter to an rms-measuring VTVM.
- I. Place the machine in the reproduce mode; set the scope-selector switch on the left-hand control panel to the Switcher Output position, and adjust the Tracking control for maximum amplitude of the scope presentation.
- J. Read the value of rms noise on the VTVM and compare this figure to the 0.7 volts (p-p) level. Remember to take into account the measured insertion loss of the filter (approximately 5 db for the filter shown in Fig. 7-21). Twenty times the log of this ratio is defined as the video signal-to-noise ratio of the television recorder.

## 7-9. CONTROL-TRACK LEVELS AND PHASE

Review Fig. 5-3 (phasing of control track with video track), and Fig. 6-10 (phasing of control track with edit pulse).

The vertical-sync pulse is recorded at a time when the referenced video head is in the approximate center of the tape. Actual spacing is between 1.05 and 1.25 inches from the control-track edge of the tape.

The amplitude of the frame-pulse current should be greater than 150% of the peak-to-peak value of the Tracking control signal-current in the control-track head during recording.

The polarity of the frame pulse with respect to the Tracking control signal should be as shown in Fig. 6-10.

The frame pulse should be positioned so that the centerline of the pulse intersects within 0.5 mil at the guided edge of the tape and the extended centerline of the area between the second and third video tracks after the track containing vertical sync (Fig. 5-3). Frame pulse width should be between 60 and 80 microseconds.

The value of the recording-tracking control-signal current (which should be essentially sinusoidal in shape) should be such that the tape is driven to saturation; however, it should not be so high as to cause an asymmetrical signal about the zero axis to be presented on playback.

The reader will recognize those characteristics which are physically measurable on developed tape; however, the width of the edit pulse (at the 50% amplitude point) will vary with the recording level and properties of developing solution.

## 7-10. CHECKING SERVO STABILITY

The mark of a good clean servo system is immediate stabilization of the picture as the vacuum guide engages the tape with the rotating heads. Momentary instability immediately following this action is often caused by the velocity loop in the head servo because this loop must function rapidly to obtain control tight enough for the phase loop to take over. Aside from "touchy" tubes (which usually can be located by light tapping with a pencil), the following points all have a bearing on general servo stability:

1. Check all tape transport-tension adjustments, cleanliness of the head-wheel and capstan, and control-track head.
2. Check condition of the tape, and number of splices; the latter is particularly important if the video heads have been worn to 1 mil or less of tip projection.
3. Check centering of adjustments; always be certain that frequency controls are placed in the center of the rotation where frequency is lost. It is also good practice from a preventive maintenance standpoint to ascertain the minimum and maximum pulse width obtainable from multivibrators so that the time when proper pulse widths or a square wave cannot be obtained is anticipated before trouble occurs.

NOTE: In setting the free-running frequency of 240- or 60-cycle oscillators of the triggered type, use the power line trig-

- gers on the scope and adjust the oscillator for slight left-to-right drift on the scope trace. This sets the oscillator free-running frequency slightly lower than the trigger frequency so that trigger control is stable. If the free-running oscillator frequency is higher than trigger frequency, unstable operation may result.
4. Become thoroughly familiar with the normal flow path of all control pulses so that the inputs and outputs of the various individual chassis or circuitry can be quickly traced.
  5. Check power supplies and power-supply regulation on a regular basis. Observe all gaseous voltage-regulators for possible "blinking" or actual extinguishment under operation.
  6. A closed-loop servo system has two major functions, loop gain (cannot exceed unity) and phase gain (cannot go to  $180^\circ$ ). If either is exceeded, oscillation occurs. The load on the headwheel or drum can be set on the heavy side by increasing tip penetration and then on the light side by decreasing tip penetration to point of loss of tape contact, ignoring jogs in the picture. If a tip penetration is found where worst possible stability occurs, set servo loop gains and phase gains for optimum stability at this point. Return tip penetration to standard. Stable operation should result throughout the life of this headwheel assembly, barring other troubles.
  7. Other units may affect servo stability. Check demodulator (detector) balance, processing amplifier stability (AFC circuits), and stability of reference pulse relative to a source of known stability such as the local synchronizing generator.

## 7-11. PROGRAM AND CUE-TRACK AUDIO

The program audio signal should be checked at periodic intervals (such as every three months) as a part of preventive maintenance to avoid deterioration to the point of audible discernment. The normal frequency response for video-tape audio track is within  $\pm 3$  db from 50 to 10,000 cps. The aural-cue track is normally limited to about 300-6,000 cps within 3 db. The program audio signal-to-noise ratio should be about 50 db measured overall between a recorded level corresponding to 3% total rms distortion at 1,000 cps and the noise present with the tape moving at 15 ips but no signal recorded.

The Proposed American Standard (VTR 16.5) for "Characteristics of the Audio Records for 2-In Video Magnetic Tape Recordings" follows. NOTE: This proposal (dated Oct. 19, 1960) has been

approved by the SMPTE Video Tape Recording and Standards Committees, and will be submitted to the American Standards Association, Inc., for approval.

1. *Scope*

This standard pertains to the audio records for 2-in video magnetic-tape recordings.

2. *Mechanical Characteristics*

The tape-path distance between video and audio recording heads shall be  $9.250 \pm 0.100$  in, with the audio record on the tape preceding the corresponding picture record. The distance between the two heads shall be taken as that between the point of intersection of transverse and longitudinal center lines of each magnetic gap, with the video head positioned at the angle of rotation which places it at the center of the audio track.

3. *Electrical Characteristics*

Reproducing characteristics shall correspond to Section 2.80, "Standard Reproducing Characteristic, of the National Association of Broadcasters Recording and Reproducing Standards for Mechanical, Magnetic, and Optical Recording and Reproducing" This section reads:

"It shall be standard that a Standard Reproducing System is one having an 'ideal' reproducing head,<sup>1</sup> the emf of which is amplified in an amplifier with a response curve having the following characteristic:

"At a tape speed of 15 inches per second: the response curve shall be that which results from the superposition of three curves, one that falls with increase of frequency at the rate of 6 db per octave. This curve is

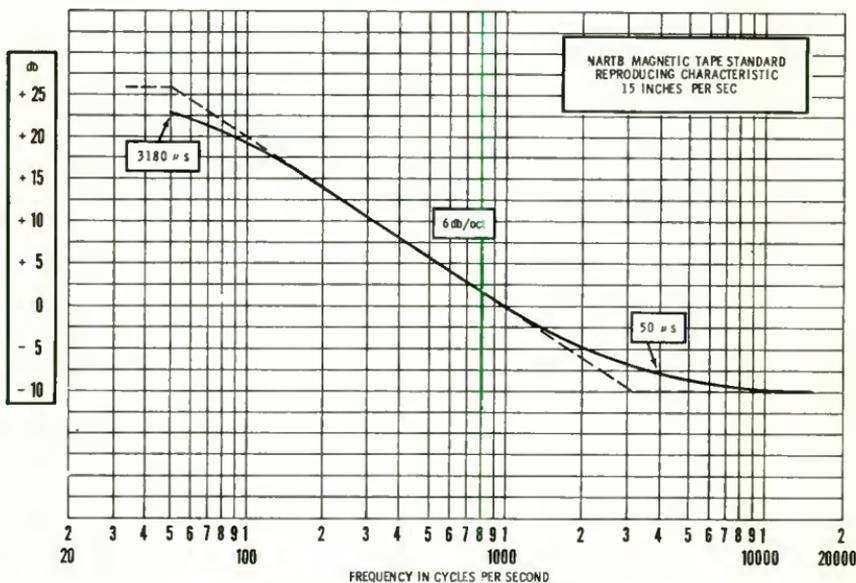


Fig. 7-22. NARTB reproducing characteristics.

to be modified at low audio frequencies by a curve that falls with decrease of frequency in conformity with the admittance of a series combination of a capacity and a resistance having a time constant of 3,180 microseconds; and this same curve to be modified at high audio frequencies by a curve that rises with increase of frequency in conformity with the admittance of a parallel combination of a capacitance and a resistance having a time constant of 50 microseconds. The combined curve is shown in Fig. 7-22."

<sup>1</sup> An "ideal" reproducing head is defined as a reproducing head the losses of which are negligible. With a normal ferromagnetic head this means that the gap is short and the arc of contact with the tape is long compared to the relevant wavelengths, and the losses in the material of the head are small. With the reproducing heads used in practice, an equalization to compensate for the head losses must be added to the replay amplifier."

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# TELEVISION TAPE FUNDAMENTALS

by Harold E. Ennes

Magnetic video tape has advanced the opportunities for more sophisticated television programming. Its advent changed the course of television development, and now it is considered as a fact and taken completely for granted. The how's and why's of television tape and its applications are a basic part of the studies of anyone interested in television technology.

This practical handbook covers all aspects of video tape from A to Z. Rotating-head theory, time-space errors, modulation and demodulation processes, video-signal processing, servo systems, setup procedures, head optimization, recording procedures, tape editing, maintenance procedures, and many other subjects are included in this volume.

Numerous easy-to-follow diagrams, line drawings, and actual photos enhance the author's practical explanations. The book is designed to serve the need for a ready reference for broadcast station personnel, as well as a basic text for homestudy or classroom use. Every broadcast engineer, technician, or student, and everyone engaged in manufacturing and other activities which require a knowledge of broadcast video recordings should have this volume.

## ABOUT THE AUTHOR



Harold Ennes has been associated with various phases of radio engineering since 1930. He entered the broadcast field in 1936 as a staff engineer with station WIRE, Indianapolis. Later he installed the first FM broadcast station in Indianapolis—noncommercial WAJC for Jordan College of Butler University—and was the station's chief engineer for 4 years. In addition he taught radio and TV at Butler University for 5 years. Since 1958 Mr. Ennes has been maintenance supervisor for Television City, Inc. (WTAE-TV Pittsburgh). He has written numerous articles and books on the various aspects of radio and television broadcasting. Other SAMS broadcast references by Mr. Ennes include: *AM-FM Broadcast Operations*, *AM-FM Broadcast Maintenance*, and *Television Systems Maintenance*.



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