An invaluable reference book for the electronic technician, containing hundreds of simplified, time-saving shortcuts for troubleshooting electronic equipment.

Electronic Technician's Handbook of Time-Savers and Shortcuts

by Carl G. Grolle

This complete, fact-filled book readily provides solutions to problems in every major area of electronics. Containing hundreds of tips and ideas, accompanied by over 140 diagrams and illustrations, this book gives the repairman quick, successful methods of troubleshooting that will save him hours of time and trouble.

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This book is dedicated to my wife Jan, whose encouragement and help have made it possible.

How This Book Will Help You Solve Electronic Problems -Quickly....

All of us who work as electronics technicians are constantly searching for ways to save time and increase our effectiveness. The ideas in this book are based on years of experience and they add up to a broad range of useful, money-making tips, techniques and tested ideas. Emphasis is placed on practical, common-sense approaches.

In a sense, having a book like this that provides realistic advice and time-saving shortcuts is like having a master technician right at your side. Jobs that would take days will be reduced to hours, jobs that could take hours can be reduced to minutes. For example, have you ever wanted to check a capacitor under actual working voltages—and couldn't because you didn't have specialized test equipment handy? This book explains how to do this, using only a VTVM. (See Chapter 2-6.) What about that sinking sensation when after working for hours to repair a particular piece of electronic equipment, you're no further ahead than you were when you started? This book offers a practical, simple step-by-step plan for troubleshooting any electronic device, even those that present especially tough problems. (See Chapter 13-1.)

While some fundamentals are inescapable, the book will keep electronics theory to a minimum. Readers should have a knowledge of fundamental electronics and a basic awareness of troubleshooting techniques. All phases of electronics will be covered—from resister shortcuts to checking solid-state devices, to designing and trouble-shooting printed circuits.

Electronics is exciting and challenging. Especially so when it is *profitable*. We will concentrate on procedures and simplified techniques that offer practical value to the working electronics man. Every chapter in this book is jampacked with a large variety of time-saving techniques and proven ideas that have been used successfully on the job. Here are just a few of the many practical questions this book will answer:

- How can a tube be identified if the numbers are missing, or how can a tube's elements be identified without the aid of tube manuals? (See Chapter 4-1.)
- How can a television set be repaired using an inexpensive probe? (See Chapter 2-7.)
- What's the first, most important step in designing a printed circuit board from a schematic drawing? (See Chapter 8-1.)
- Can you check transistors, rectifiers, SCR's, triacs, unijunctions without elaborate test equipment? (See Chapter 5.)

Answers to these questions and hundreds more are included.

Every chapter provides simplified, practical ways to deal with electronic components and various important areas of electronics. You can read the book from front to back or very quickly locate a specific answer to a key question by checking the table of contents. Here is a broad range of dynamic ideas and practical time-saving methods for all those who want to accelerate their progress in the challenging field of practical electronics.

Carl Grolle

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1

Practical Shortcuts for Working with Resistance

Resistors are the most common components used in electronics. They come in all sizes, shapes and colors. Technicians must select, identify, install, check, and remove resistors. Resistors and resistor circuits are generally one of the easiest phases of electronics to understand.

This chapter deals with some of the common hang-ups technicians have with resistors. Many time and work-saving ideas using resistors are discussed.

1-1. AN EASY WAY TO REMEMBER THE COLOR CODE

The resistor color code presents untold problems to technicians time after time. The author has seen electronics men in the business for twenty or more years still having problems with the code. The color code is not hard. The fact is that many technicians just have not bothered to really learn it.

Black, brown, red, orange, yellow, green, blue, violet, gray, white—this is the order of colors all technicians should know as automatically as they do their names. There is a sentence that will help you remember the color code, in which each word starts with the first letter of the colors, in order. You can't forget the sentence. Match it up with the color code and you can't forget the code either! Here's the sentence:

> Bad Boys Rape Our Young Girls, But Violet Gives Willingly.

The following column shows the common abbreviations for the various colors:

K —Black	—0
N —Brown	—1
R —Red	—2
O —Orange	—3
Y —Yellow	—4
G —Green	—5
B —Blue	—6
V —Violet	—7
A —Gray	—8
W—White	—9

Remember that all the abbreviations are the first letter of the color except in three cases. Black can't be abbreviated as *B* because it would get mixed up with blue, so the last letter, *K*, is used. The same logic holds true for brown. The only other variation is gray. *G* can't be used for gray because it would get confused with green. Just remember there's a lot of *A* in gray.

Have you ever made a mistake on a resistor's color band? Chances are you have. Make a mistake reading the first two significant colors and it might not be too serious. But make a mistake on that third band and you are in trouble. If you make an error on the third band, the value is at least ten times too high or too low. Keep in mind the following important points of the third band when selecting resistors from a parts drawer:

When the third band is . . .

1. Black, the resister must be less than a hundred ohms.
2. Red, the resistor must be in hundreds or .K ohms.
3. Orange, the resister must be in thousands (K) ohms.
4. Yellow, the resister must be in hundred thousand or .meg ohms.

5. Green, the resistor must be in meg ohms.
6. Blue, the resister must be ten megs or more.

Notice that red, orange and yellow are the common colors in the third band for the majority of resistors. Black, green and blue are relatively uncommon values for a third band color. This boils down to the fact that the three most important colors in the resistor color code are red, orange, and yellow used as the third band. Keep these points in mind when selecting resistors and a lot of trouble can be avoided.

Most technicians don't have problems with the tolerance bands. *No* fourth band means the resistor has a 20% tolerance, *silver* fourth band is 10% tolerance, and *gold* fourth band is 5% tolerance. In rare cases the third band is silver on a resistor. Multiply the first two bands by .01. If the third band is gold, multiply the first two bands by .1.

Resistors which conform to military specifications have five color bands. The fifth band indicates reliability level per 1,000 hours, as shown:

Fifth band color	*Level*
Brown	1%
Red.................	.1%
Orange.............	.01%
Yellow.............	.001%

As an example, suppose the fifth band of a military resistor is color-coded orange. This means that for every 1,000 hours of operation the chance for failure would not exceed .01%. Another example: a hypothetical military computer that has 10,000 orange fifth band resistors would have no more than one resistor failure after 1,000 hours of operation. That's reliability!

1-2. PRACTICAL METHODS FOR RESISTOR SUBSTITUTION

Frequently the technician must substitute or replace a resistor and finds that the exact part is not available. Naturally, if the exact replacement resistor is located easily, that's the best solution. On the other hand the exact resistor value is often not critical because of the tolerance designed into the circuit. Very often a piece of electronic equipment can be satisfactorily repaired in minimum time using a substitution resistor.

Suppose the technician must replace a 22K ohm 10% resistor which has increased in ohmic value. Notice, the resistor *increased* in value, not decreased. This is one of the most common ways resistors become defective. Very, very seldom does a resistor decrease in value. If the 22K ohm resistor's exact replacement is not available, the technician has several options at his disposal. One method would be to use an ohmmeter to find resistors close enough to the correct value to fall in the tolerance area of the defective resistor. For instance, a 20K ohm 5% resistor which measured 20K ohm with an ohmmeter would be a satisfactory replacement because it falls in the lower tolerance limit of the 22K 10% resistor.

Another technique would be to series-connect two resistors to make the correct value. In this case a 5.6K ohm resistor in series with a 15K ohm resistor would make a good replacement. Or two 10K ohm resistors in series would also be a good substitution. Always use a ohmmeter to confirm the series resistance total. Keep in mind the wattage rating of the replacement resistors. They should match or be greater than the original resistor.

Two resistors could be paralleled to form a replacement 22K ohm resistor. The easiest combination would be two parallel 47K ohm resistors. Many other parallel combinations could make the correct value. Figure 1-2A shows a parallel resistance calculator slide rule. The equivalent resistance of any two parallel resistors can be found in a jiffy with this calculator. Remember, for resistors in parallel the total resistance is always smaller than the smallest resistor. Keeping this fact in mind with a little bit of practice you can become very proficient in estimating the value of two parallel resistors. Don't forget to confirm the total value with an ohmmeter. All sorts of parallel and series combinations could be arranged to achieve the wanted value. For practical purposes, most often the desired resistance can be made using just two resistors in a series or parallel combination.

Another resistor problem which is a constant thorn in the side of the technician is the defective power resistor. Power resistors go bad more often than any other type of resistor because of heat deterioration. Generally these resistors are fairly easy to find because they are powering whole stages or many stages. The common trouble is the power resistor will open. DC voltage checks with a VTVM will usually locate the defective resistor quickly. A fast method for giving a power resistor a rough check is to feel it with your finger. Be careful not to burn yourself since most of these babies run quite hot. When you touch a physically large resistor and it's not hot you have to suspect an open part.

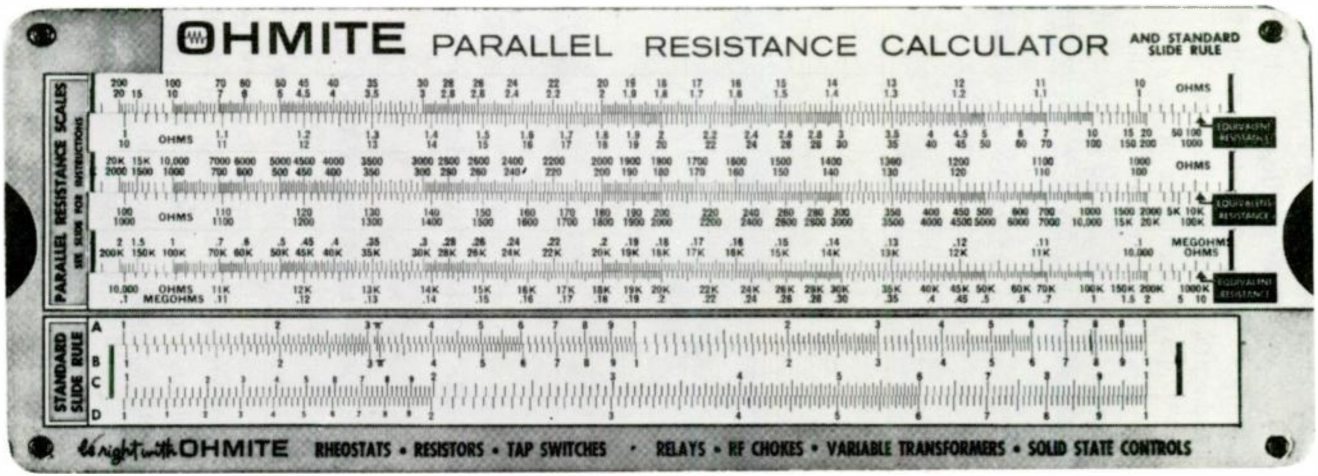


Figure 1-2A: Parallel resistance calculator
(Ohmite Manufacturing Co.)

Once you have found the open power resistor, the next problem is to find a satisfactory substitute. Suppose a 5K-7 watt power resistor opens in the power supply of an oscilloscope. If you have a good selection of power resistors, just pick out the correct value and wattage resistor you need and replace it. Many times you may have to substitute. You can always safely substitute a larger wattage resistor for a smaller wattage, providing the resistance value is the same and there is enough space. Figure 1-2B shows some of the combinations which could be used to substitute the 5K-7 W power resistor if space permitted.

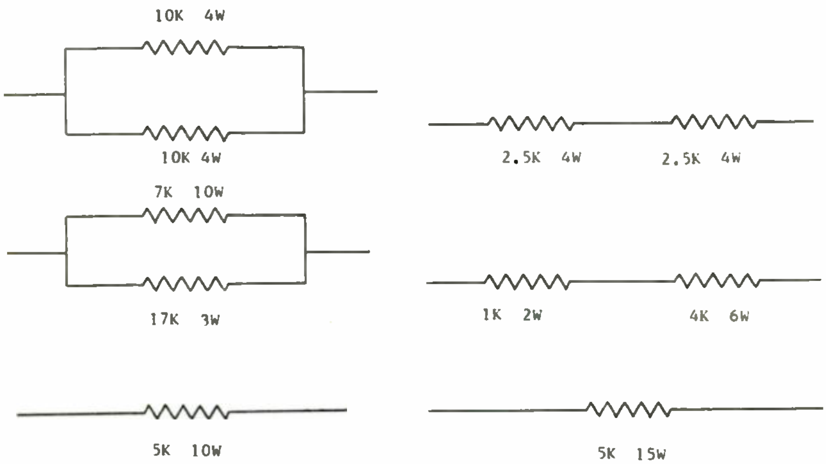


Figure 1-2B: 5K ohm—7W resistor substitutes

1-3. HOW TO WORK WITH VARIABLE RESISTORS

Remember the last time you wanted a certain value resistor to use in an experiment or to substitute in a repair job and you couldn't find the correct value? Not everybody can afford to stock all of the common ohmic value and various wattage resistors. Yet it certainly would be nice to be able to get your hands on the right resistance when you need it. Variable resistors could be the answer to the problem.

One of the handiest resistors to have available is a 100 ohm, 50 W adjustable resistor (Figure 1-3A). You can slide the center connection on the resistor from one end to the other, obtaining just about any resistance between 1 and 100 ohms. Fifty watts is generally enough wattage, so you don't have to worry about burning the resistor up when using it as a substitution resistor. Low ohmic value resistors are usually hard to find for substitution, and they burn out more often than others because of the heavy currents they often carry.

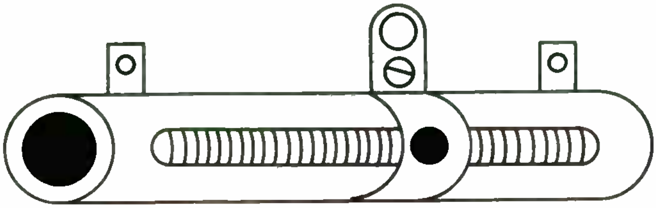


Figure 1-3A: Adjustable resistor

It may often happen that you will find a defective low ohmic value resistor when you don't have a replacement on hand. You would like to test the equipment to check it out and see if anything else is wrong. The adjustable resistor is the solution. Move the slider to the correct resistance and substitute for the bad resistor. Apply power and check the operation. If the operation appears normal you know the problem has been found, and you can then purchase the exact replacement. If the operation is still not normal you know that there are other troubles besides the defective resistor. Quite possibly the other trouble has been the cause for the original resistor defect. The adjustable resistor allows you to continue troubleshooting under dynamic conditions until the other bad part or parts are located.

Potentiometers are also great for substituting resistances. If you are designing or modifying a circuit, use potentiometers for the fixed value resistors. Then when you want to change a value, just turn the shaft and you've got it. Maybe you are designing a circuit and you aren't quite sure what value resistor will work best. No problem with pots; change the resistance while observing circuit action. When you get the best results you have found the correct resistance. Remove the pot or pots and measure their resistances and you know the resistor values to use.

Figure 1-3B shows the circuit for a resistance substitution box using three linear taper potentiometers. Use 5-watt potentiometers for the 10K and the 100K, and a 2-watt for the meg pot. Theoretically any resistance from 0 ohms to 1,110,000 ohms can be obtained. The top of each pot and the arm of the last pot can be connected to a banana jack marked as shown in the schematic. Make a couple of test leads with banana plugs on one end and alligator clips on the other. Calibrate the pots with an ohmmeter, marking various resistance points around each shaft. Slip a knob on each shaft and the box is ready to go.

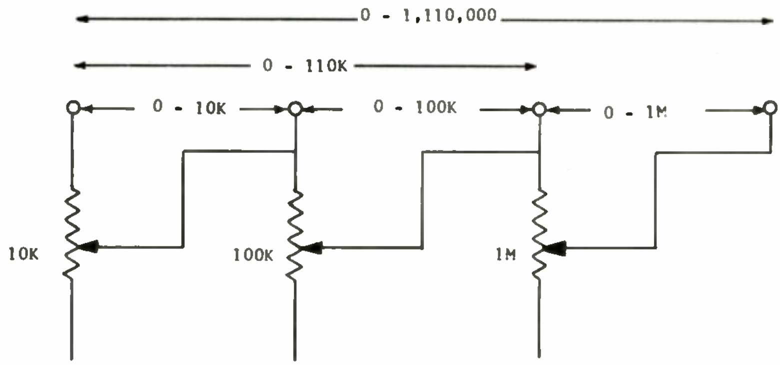


Figure 1-3B: Potentiometer resistance substitution box

If you want a 5K ohm resistance, insert the banana plugs in the 0 to 10K jacks. Rotate the 10K pot until the knob pointer lines up with the 5K calibration mark. Suppose you need a resistance of 110K ohms. Turn the 10K and 100K pot fully clockwise. Connect one banana plug in the first jack and the other in the third jack (0 to 100K jacks). Calibrate the pots accurately; use all combinations of jacks and the box will substitute for just about any resistance you want.

1-4. USING RESISTOR SUBSTITUTION AND DECADE BOXES

A resistor substitution box has a selection of the most common EIA resistor values ± 10% tolerance. The wanted resistor is usually selected by a rotary switch and brought out to a couple of five-way binding posts on the front panel.

The resistor decade box is a precision instrument using 1% or better resistors. A number of rotary switches connect the resistors in series and bring the resistance to the front panel on two five-way binding posts. Any resistance from one ohm to the maximum decade resistance can be switched in one-ohm increments. One advantage of the decade box is that any resistance can be obtained while the substitution box can only substitute for the fifty or so common resistor values.

The resistor substitution box is probably the most valuable device in electronics service work (Figure 1-4A). A technician is troubleshooting a public address amplifier and finds a charred resistor. The logical thing would be to find the resistor value on the schematic and replace it in the amplifier, and then take resistance measurements, trying to locate any shorts which may have caused the resistor to burn. However, as all service technicians know, schematics are not always available. The technician can guess what the value of the charred resistor might be, but he's not sure. After repairing the short that caused the resistor to burn, or convincing himself that the resistor had deteriorated by itself, the technician clips the resistor substitution box in place of the defective resistor. He applies power to the amplifier and tests for normal operation while switching the substitution box through various resistances. The resistance value which causes the best amplifier operation is probably very close to the original resistor's value.

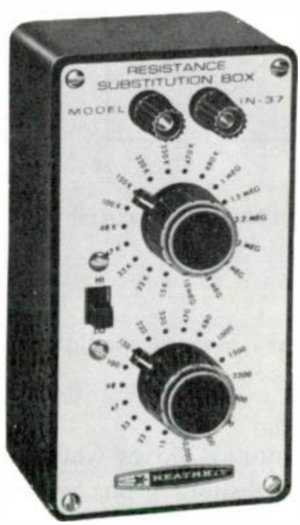


Figure 1-4A: Resistor substitution box (Heath Co.)

Another example where a resistor substitution box would be helpful is in the repair of older electronic equipment where time and use have changed the values of many parts. Often vertical and horizontal oscillator circuits in television receivers drift off frequency. Vertical and horizontal hold controls are made to correct this condition, but eventually they can't compensate enough for all the deterioration. The resistor substitution box is really helpful in this situation. Just bypass one of the main frequency determining resistors (usually a resistor in series with the vertical or horizontal hold control) with the substitution box (Figure 1-4B). Set the hold control for mid range. Then switch the substitution box until the oscillator locks in on the correct frequency, producing a stable picture. Replace the substitution box with a fixed resistor of equal value.

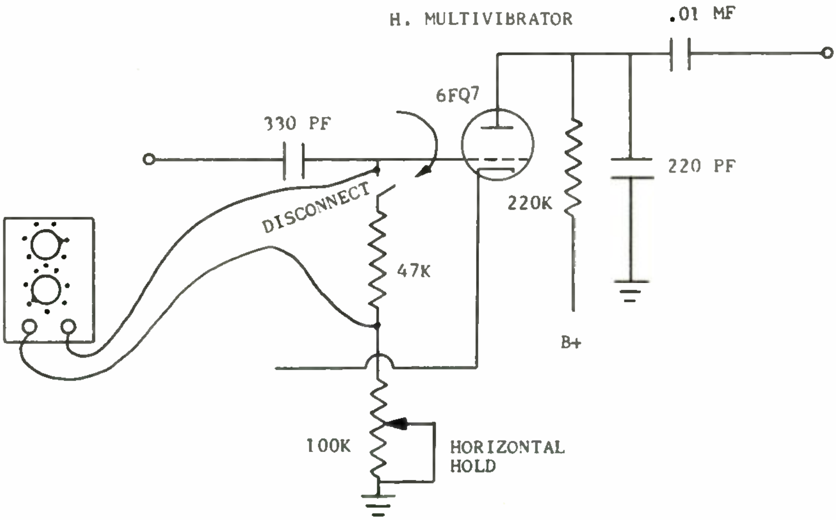


Figure 1-4B: Correcting the horizontal oscillator frequency with a resistor substitution box

Use resistance substitution boxes when you modify or develop circuits. More than one substitution box is certainly helpful because you can substitute each fixed resistor with a substitution box (Figure 1-4C). Usually when you change the value of one resistor a corresponding change is required in other resistors. With substitution boxes the entire setup can be quickly modified just by turning switches.

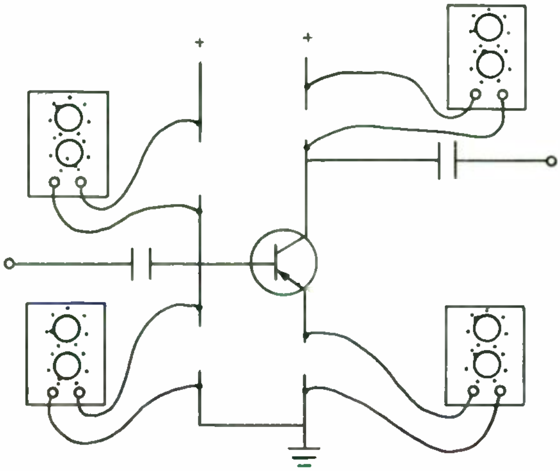


Figure 1-4C: Using resistance substitution boxes for circuit development

Resistance decade boxes can generally be used as resistor substitution boxes. However, decade boxes cost three or four times as much as resistance boxes and are larger in size. Whenever an accurate resistance value is needed, decade resistance boxes are invaluable (Figure 1-4D).

Figure 1-4D: Resistor decade box (Heath Co.)

A convenient use for a resistance decade box is to check the accuracy of ohmmeter ranges. Every technician sooner or later measures resistance in a live circuit. The ohmmeter may or may not be damaged. A quick check through the ranges with a decade box will confirm any troubles.

You want to extend the range of a voltmeter and you don't know what series resistance to use? Reach for the resistance decade box and your problem is solved. Connect the decade box in series with the meter as shown in Figure 1-4E. Monitor the power supply voltage with a VTVM or DVM. Set the decade box for a high resistance and the power supply for the maximum voltage you want the meter to read. Then decrease the decade resistance until the meter reads full scale. Replace the decade box with a fixed resistor of equal value and the voltmeter is all set for its new range.

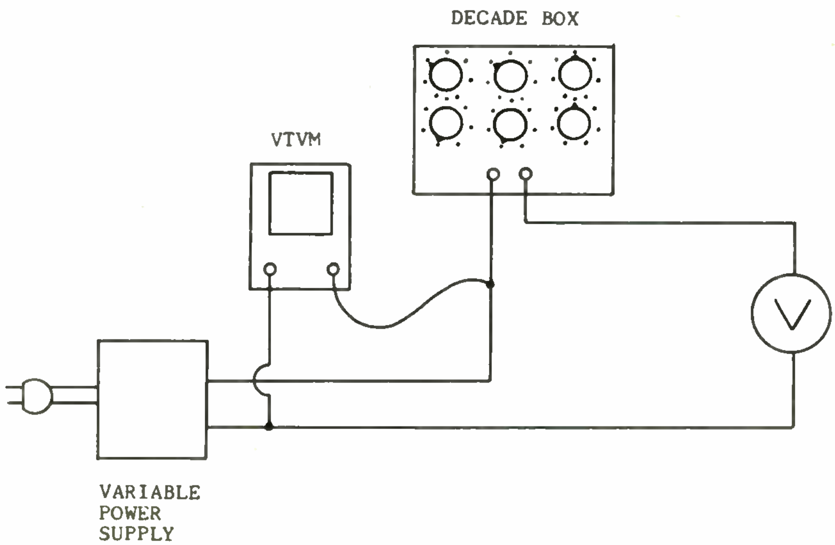


Figure 1-4E: Extending a voltmeter range with a decade resistance box

Figure 1-4F shows the setup to use to extend the range of a current meter using the decade box. Monitor the voltage across the series resistor with a VTVM. Start the decade box at zero resistance. Increase the power supply voltage until full-scale current is reached.

Compute the current by dividing the VTVM voltage by the resistance (R). Then increase the decade resistance from zero resistance to one ohm, watching the ammeter. If the ammeter reads more than full scale, the decade box isn't sensitive enough to determine the shunt resistance. However, if the ammeter reads less than full scale, keep on increasing the decade resistance in one-ohm steps until full scale is reached. Read the decade resistance and you know the shunt resistor value. CAUTION: *Don't exceed the maximum allowable current specified for the decade box.*

You can use the decade box for an arm in DC and AC bridge circuits. It can be used to calibrate test instruments. The more you use resistance substitution and decade boxes, the more uses you can find for them. They are real time savers!

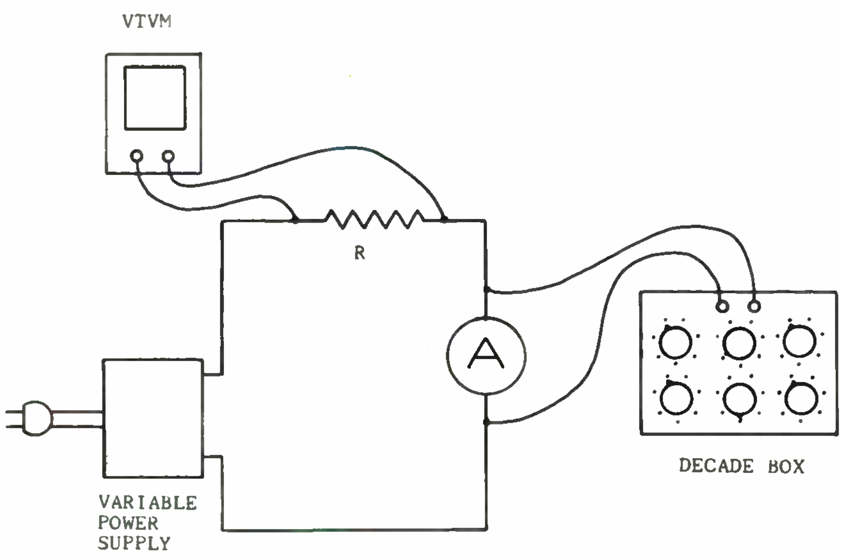


Figure 1-4F: Extending an ammeter range with a decade resistance box

1-5. TROUBLESHOOTING RESISTIVE CIRCUITS

Often when a resistor fails it will give a clear indication that it is defective. Many times a resistor will become hot enough to smoke and give off a burning odor. When a piece of electronic equipment breaks down and smoke rolls out, people tend to get very worried and upset. Many troubleshooting technicians feel the opposite when they see smoke. Smoke acts like a neon direction sign pointing to the problem area. Once the burning resistor or part has been located, the real cause of the trouble is much easier to locate. Keep in mind that a burning or overheated resistor is probably not the original defect. The chances are the resistor is overheated from another defective component in the circuit.

Shorted or leaky capacitors are notoriously bad for overloading resistors. Internal shorts in tubes and transistors also cause excessive current to be drawn through the associated resistor. Occasionally a resistor will go bad all by itself, especially power resistors which normally run hot. Invariably a defective resistor will increase in ohmic value.

Frequently you can spot a bad resistor by looking at it carefully. Naturally if it is smoking it is easy to find. Sometimes a resistor has been smoking, but by the time the technician starts to troubleshoot the resistor cracks open. The resistor crack often is small and hard to spot. An easy way to locate this type of defect is to probe the suspected resistors with an orange stick. You can buy orange sticks in most drugstores. They are great for probing because they are wood and are just about the right size (Figure 1-5A). As soon as you probe the

Figure 1-5A: Orange stick used for probing

cracked resistor the defect will be evident. Another type of defect occurs when the resistor turns to powder, generally in the middle of the resistor. This also occurs from overheating. If you suspect this type of problem, probe the center of the resistor and it will pulverize under the pressure of the probe.

If you see a resistor with strange colors on the color bands, suspect an overheated resistor. When a resistor heats abnormally high the color bands generally will discolor. If enough heat is generated in the resistor the color bands will not only discolor but will bubble as well. Don't forget your finger as a troubleshooting aid. A finger is a very efficient heat sensitive device. If you suspect a resistor is running too hot, touch it carefully with your finger; this is a quick and efficient method to find overheated parts.

Voltage checks and ohmmeter measurements are the very heart of successful troubleshooting. The various suggestions for finding defective resistors should not be interpreted as a substitute for using troubleshooting instruments, but rather as a first-step practical approach used in conjunction with test instruments. Many technicians become so bound in theory that they overlook the practical common-sense aspects of troubleshooting. Remember—it takes only a few minutes to smell, listen, look and feel before professional troubleshooting instruments are used.

2

Time-Saving Techniques for Use with Capacitors

This chapter concentrates on time-saving techniques involving many types of capacitors. Capacitors are used in every kind of electronic equipment. The technician must identify capacitors by value and type. He must know how to determine if a capacitor is good or bad. He has to know when capacitors can be substituted.

Many capacitor problems "bug" technicians because some capacitors are hard to read and identify. When a capacitor goes bad it may become intermittent or leaky and hard to locate. Some capacitors go bad and then heal themselves, giving nightmares to the repairman.

Many capacitor problems that seem impossible really aren't, and by using the correct techniques the problems can often be solved quickly. In the following pages you will find many tips, techniques and ideas about capacitors and capacitor defects that will be most helpful in dealing with capacitance problems.

2-1. READING CAPACITOR VALUES MADE EASY

Many capacitors are marked directly on the case with their value and working voltage. Reading this kind of capacitor usually is simple and straightforward. If the identification is blurred, missing or hard to identify, compare that capacitor with another one in the equipment having the same size and physical appearance. If you can read the values on the second capacitor, chances are the first capacitor has the same specifications. Sometimes wax covered paper capacitors become dirty and discolored and the values are almost impossible to read. Carefully scrape the wax with your thumbnail from the area where the capacitor is marked. Generally the markings will appear like magic.

Some tubular capacitors are marked with color-coded rings much like resistors. Don't panic when you see one of these babies; they are no harder to read than resistors. Just keep in mind the following pointers. Refer to Figure 2-1A. At first glance, reading the tubular

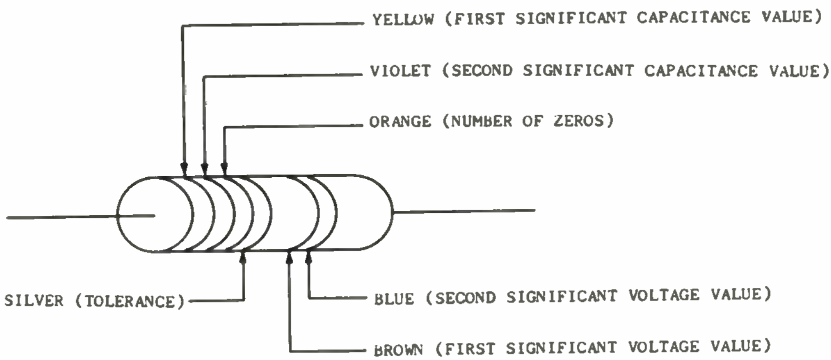


Figure 2-1A: Tubular paper capacitor color code

capacitor may look difficult. It isn't. Start at the end where the bands are the closest. The first number is 4 (color code yellow); the second number is 7 (color code violet). So the value is 47 plus the number of zeros which is 3 (color code orange). The value is 47,000 micromicrofarads or 47,000 picofarads. (For discussion of these terms see the following paragraphs.) Notice that the value is always in picofarads. The fourth band represents the 10% tolerance (color code silver). The last two bands are the voltage rating showing 1 and 6 (color code brown and blue). This is decoded as 1600 volts. When there are two voltage color bands, this indicates the voltage is over 900 volts and two zeros are added to the right of the numbers. For example, if the capacitor only had one voltage color band of yellow, then the voltage rating would be 400 volts. If the voltage color bands were brown and black, then the voltage would be 1,000 volts. Try your skill in finding the capacitor specifications for Figure 2-1B.

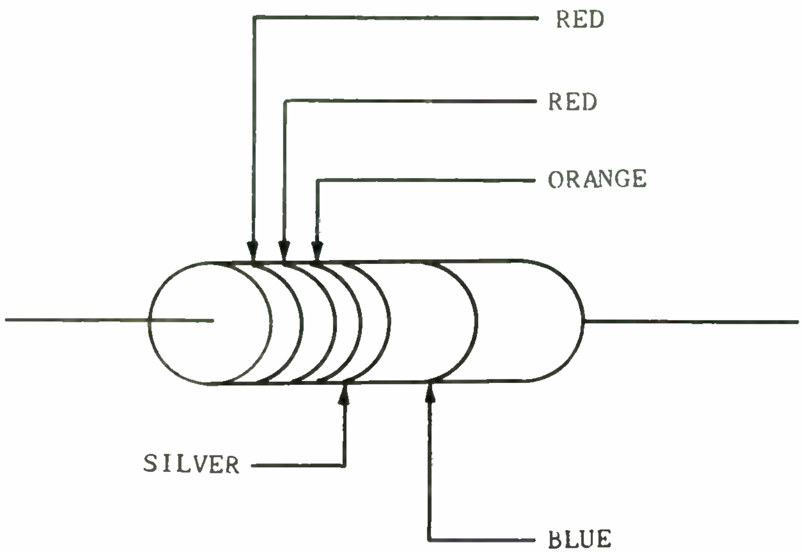


Figure 2-1B: Reading a molded tubular capacitor

The other popular type of capacitor technicians have trouble reading is the molded mica capacitor. Before discussing the mica capacitor let's make sure of the relationship between capacitance units. The main unit of capacitance is the farad. For practical purposes the farad is such a large unit it is seldom used to identify capacitors. So we can forget the farad for marking capacitors. One millionth of a farad is the microfarad, and this unit (MFD) is probably the most common unit for capacitor identification.

The other capacitance unit which is widely used is the micromicrofarad (one millionth of a microfarad). The thing about micromicrofarad capacitors which is sometimes confusing is that they are also known as picofarad capacitors and sometimes mickey-mike capacitors. Just remember that micromicrofarad equals picofarad equals mickey-mike.

Many times a technician has to find a capacitor marked in picofarads but the schematic has it listed in microfarads. Once the relationship between microfarads and picofarads is fixed in your mind the conversion between the two units is simple and done with ease. Just remember that a picofarad is one millionth (1/1,000,000) of a microfarad. A microfarad capacitor is generally large in size while a picofarad capacitor is generally small.

If you want to convert a picofarad capacitor to a microfarad capacitor simply move the decimal point six places to the left. For instance, a 47 PF capacitor would become a .000047 MFD capacitor. If you want to convert a microfarad capacitor to a picofarad capacitor simply move the decimal point six places to the right. For instance, a .001 MFD capacitor would become a 1,000 PF capacitor. Fix these relationships in your mind and you will never have problems in the conversion of capacitor units.

Here's how to read a molded mica capacitor. Refer to Figure 2-1C. Somewhere on the capacitor is marked an arrow. Position the

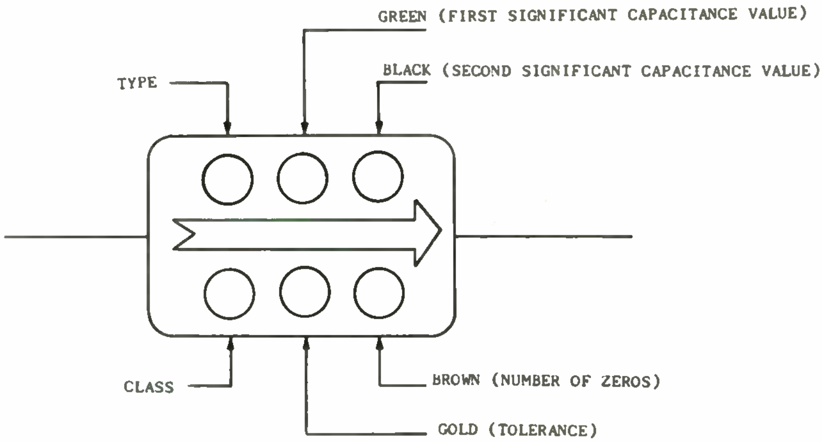


Figure 2-1C: Molded mica capacitor color code

capacitor so the arrow points to the right. Then read the first two significant values 50 (color code green and black). The value is 50 plus the number of zeros which is 1 (color code brown). This is a 500 picofarad capacitor. *Notice that the value is always in picofarads.* The tolerance is 5%. These four dots generally provide all information most technicians need to know. The class dot provides information on working voltage and the type dot shows whether the capacitor is a military or EIA type. Standard tables are available for specific information on the class and type dots.

If you identified the capacitor correctly in Figure 2-1B, the value is 22,000 PF 10% 600 V.

2-2. HOW TO FIND CAPACITANCE WITH A VTVM

How many times have you wanted to check the value of capacitors and couldn't because you didn't have a capacitance bridge instrument? Here's a method to check capacitance with a VTVM, a filament transformer and a resistor decade box. If you don't have a resistor decade box a selection of resistors from 50 to 10,000 ohms will be okay.

Figure 2-2A shows the circuit. The unknown capacitor is placed in series with the resistor decade box in the secondary circuit of a

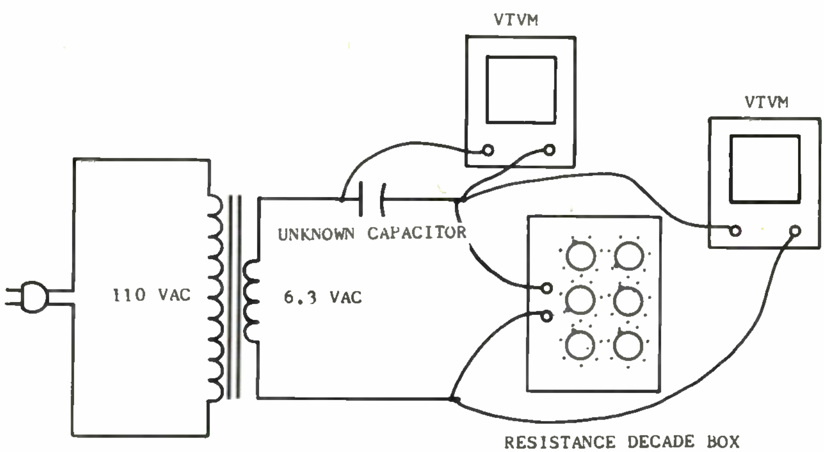


Figure 2-2A: Checking capacitance with a VTVM

110:6.3 VAC step-down transformer. Measure the voltage across the capacitor and compare the reading with the voltage across the resistor decade box. Change the resistance values until the two readings are identical.

Suppose the capacitor and resistor voltages are equal when the resistor decade box is set at 500 ohms. This means the AC resistance or capacitive reactance (Xc) of the capacitor must also be 500 ohms. Use the capacitance formula C = 159,000/f x Xc; plug in the values and compute.

$$C = \frac{159{,}000}{60 \times 500}$$

$$C = \frac{159{,}000}{30{,}000}$$

$$C = 5.3 \text{ MFD}$$

The answer always comes out in microfarads, so in this case the unknown capacitor is 5.3 MFD.

Let's try another capacitor. This time the voltages balance when the decade box is set at 6.5K ohms.

$$C = \frac{159{,}000}{60 \times 6{,}500}$$

$$C = \frac{159{,}000}{390{,}000}$$

$$C = .41 \text{ MFD (approx.)}$$

This simple method of determining capacitance results in a relatively high degree of accuracy. Next time you have some capacitors the values of which you would like to know, try this technique.

2-3. WAYS OF LOCATING OPEN AND SHORTED CAPACITORS

Often the easiest and fastest way to check a capacitor is to substitute it with another known good one. The suspected capacitor is removed and the good one is substituted. If the problem clears up, then the original capacitor must have been defective. This substituting of capacitors is a good method, but sometimes problems arise. For instance, an identical capacitor might not be immediately available, or it may be difficult or inconvenient to remove the capacitor.

Open capacitors are very easy to find by bridging the capacitor with a known good one. The capacitor doesn't have to be removed from the circuit for this bridging operation. A very common trouble in electronic equipment is the opening or drying up of electrolytic capacitors. Generally the values of electrolytic capacitors are not critical. If you don't have the exact capacity or voltage rating for the bridging capacitor, use a capacitor with a higher capacity and voltage rating. For instance, if you suspected an open 50 MFD - 150 volt electrolytic capacitor and didn't have the exact value handy, a 100 MFD - 400 volt capacitor would generally serve as a satisfactory bridging capacitor. Be sure to observe polarity markings of the capacitors when bridging.

Frequently two or more electrolytic capacitors are enclosed in the same can. Usually the plus side of each capacitor is connected to a terminal on the end of the can and the negative sides of all the capacitors are connected together with the case. Identifying one section of the multiple electrolytic from the other is usually quite easy. The terminal end of the capacitor is marked as shown in Figure 2-3A.

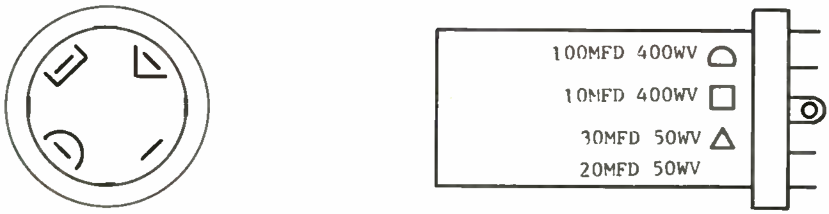


Figure 2-3A: Identification of a multiple unit electrolytic capacitor

The side of the capacitor is marked with the capacity, voltage rating and terminal symbol. The terminal marked with the triangular symbol must be the 30 MFD - 50 WV capacitor; the terminal marked with the half-circle symbol must be the 100 MFD - 400 WV capacitor, etc.

When you find one section of an electrolytic capacitor defective, it is wise to replace the whole can and not just parallel the bad section. The other sections of the capacitor may be okay, but chances are the trouble causing the first part to go bad will eventually cause the rest of the sections to malfunction.

Don't forget, when you have finished bridging a capacitor the substitute capacitor has been charged to the original capacitor voltage. It's always a wise move to discharge the two sides of the bridging capacitor with a clip lead. Large capacity and high voltage rated electrolytics can give nasty shocks even after they have been removed from the circuit for hours.

Shorted capacitors usually are easy to locate because they generally cause other parts to overheat or burn up. The best way to check for a shorted capacitor is with an ohmmeter. In most circuits an ohmmeter check will show a shorted capacitor without removing it from the circuit. Figure 2-3B shows a typical IF amplifier circuit. Suppose C_2,

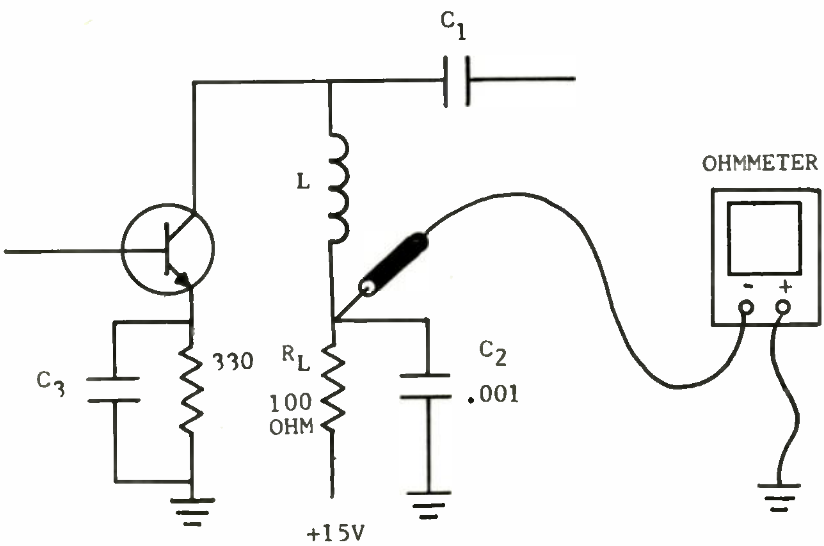


Figure 2-3B: Checking an IF amplifier stage with an ohmmeter

the bypass capacitor, shorted. This malfunction would burn out R_1 or cause it to run extremely hot. If R_1 were replaced it too would burn up because of the heavy current shunted to ground through the shorted C_2. Notice that bridging C_2 would prove absolutely worthless, as is the case when dealing with most shorted capacitors. R_1 could be located quickly by observing smoke; or if the resistor had burned out, the charred remains would be easy to spot. Once R_1 was identified, an ohmmeter check as shown in Figure 2-3B would pinpoint the shorted C_2. The ohmmeter would read close to zero ohms or the short resistance if the capacitor was partially shorted. If C_2 was normal, the in-circuit ohmmeter check would measure a fairly high resistance, measuring the power supply resistance in parallel with the reverse resistance of the transistor.

2-4. USING CAPACITOR SUBSTITUTION AND DECADE BOXES

A capacitor substitution box has a selection of the most common capacitor values with a ± 10% tolerance. The selected capacitor is picked by a rotary switch and brought out to the front on two five-way binding posts.

The capacitor decade box (Figure 2-4A) is a precision instrument using 1% or better capacitors. A number of rotary switches connect the capacitors to the binding posts on the front panel. Generally any capacitance from 100 PF to .1 or more MF in 100 PF steps can be

Figure 2-4A: Capacitance decade box (Heath Co.)

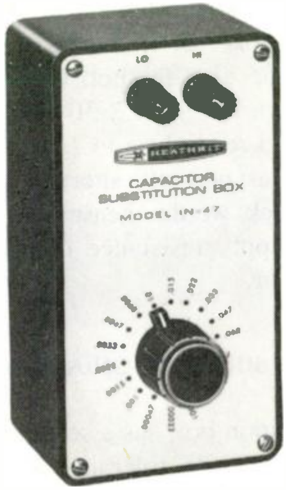


Figure 2-4B: Capacitor substitution box (Heath Co.)

selected by the switches. Capacitor decade boxes are much more expensive than substitution boxes.

The electronics service shop can find many uses for the capacitor substitution box (Figure 2-4B). Each bench technician should have a couple of them for capacitor substitution and bridging. They take up much less space and are more convenient to use than an assortment of individual capacitors. Changes in parts values can be easily compensated by switching the capacitor box through a range of capacitors until optimum operation is observed.

The experimenter will also find the capacitor substitution box great for breadboarding, modifying and designing circuits. Capacitance values can be found under dynamic conditions without the aid of involved calculations. Often capacitor substitution boxes can be used along with resistor substitution boxes to make circuit designing a breeze (see section 1-4 in Chapter 1).

Capacitor decade boxes are accurate laboratory instruments that provide precision capacitance values at the twist of a knob. They can be used to provide variable capacity when designing audio RC filters. Figure 2-4C shows the setup for testing a simple high pass RC filter. Various capacitances can be switched into the circuit until the best

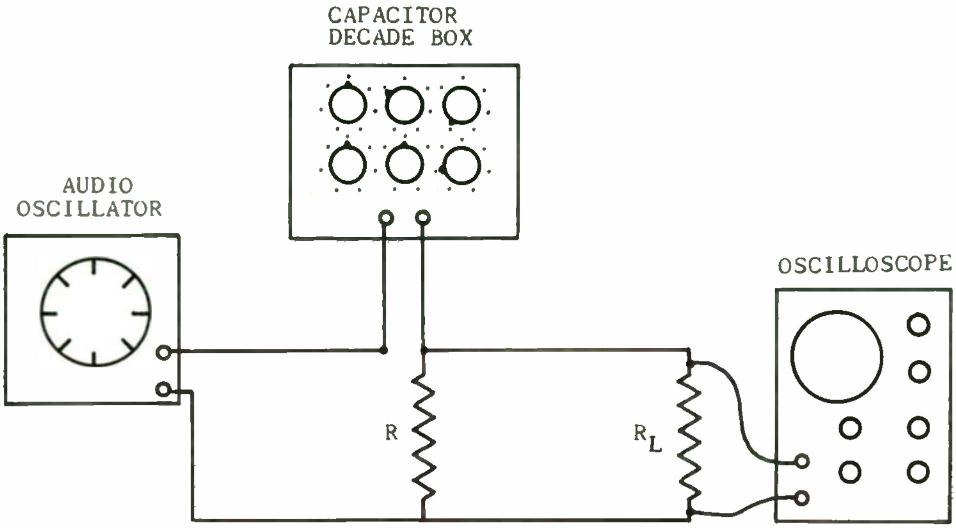


Figure 2-4C: Checking the frequency response of an experimental RC filter

response is indicated on the scope. You may want to use a resistance decade box in place of R so it too may be variable. R_L is the simulated load impedance with which the RC filter will operate. Plot a frequency response curve for each set of RC values at the test frequencies until the best combination is found.

The capacitance decade box can be used for the C when working with tuned circuits. It can be used for the variable capacity in bridge circuits. In high frequency circuits the stray capacitance of the decade box and the connecting leads can give erroneous capacity values. The best bet is to use the decade box to find the approximate capacitance and then use the actual capacitors for the final tests.

2-5. MAKING AND USING A CAPACITOR LEAKAGE TESTER

Here's a simple but effective test instrument for checking capacitors. Capacitors can be checked for leakage, shorts, opens, and approximate capacity. This tester is so sensitive that it will locate leakages greater than twenty million ohms.

The circuit is shown in Figure 2-5A. It is a basic voltage doubler circuit with a neon lamp indicator and an SPDT spring return test

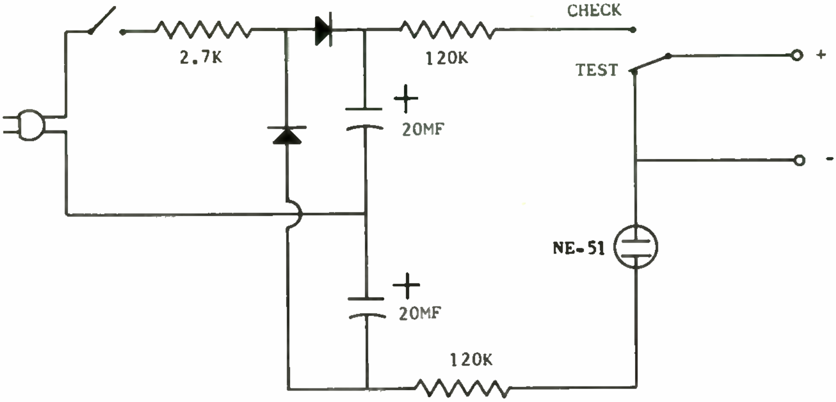


Figure 2-5A: Basic capacitor leakage tester

switch. The voltage at the output is approximately twice the peak line voltage. The output checking voltage of about 300 V is fine for testing capacitors under a high voltage. However, many capacitors which have a voltage rating of less than 300 V can not be checked with this tester.

Figure 2-5B shows a modification which can be used to lower the checking voltage so lower voltage capacitors can be tested. The pot

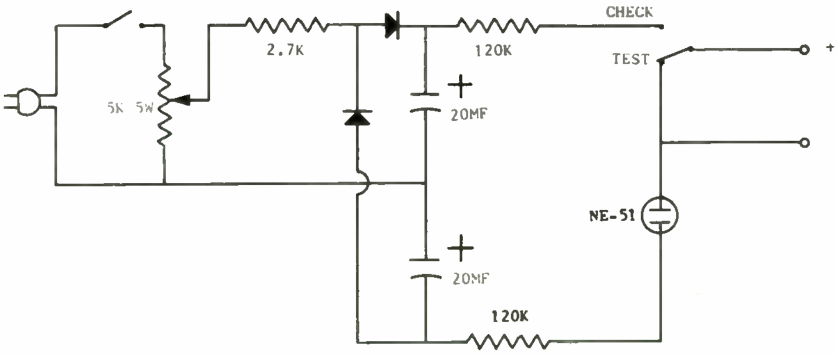


Figure 2-5B: Variable voltage capacitor leakage tester

can be calibrated and marked for the various output voltages needed.

A battery operated version of the leakage tester can also be made for portable operation. The circuit for this tester is shown in Figure

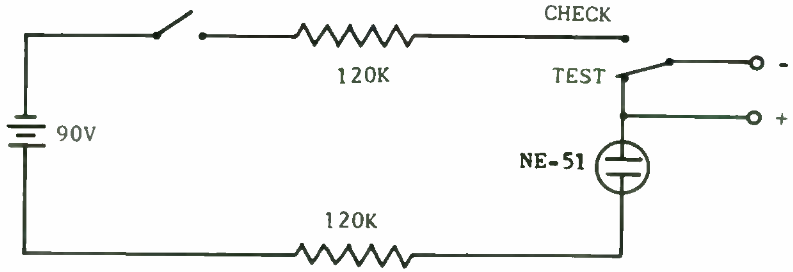


Figure 2-5C: Battery operated capacitor leakage tester

2-5C. A 90 V, or two 45 V photoflash batteries in series, can be used for the power source.

The operation of the leakage tester is quick and easy. The capacitor to be tested is connected between the + and - output terminals. The only precaution to be observed is not to exceed the voltage rating of the capacitor. *Note*—electrolytic capacitors can't be checked because they are inherently leaky. Apply power and push the output switch. If the capacitor is good, the neon lamp will blink once as the capacitor charges. If the capacitor is leaky, the neon lamp will blink continually, depending on the amount of leakage. A high rate of leakage will be indicated by a high blinking rate; a low rate of leakage by a low blinking rate. If the capacitor is open the lamp will not blink at all. Many technicians who have used this tester can even determine the approximate capacity of the capacitor by the brightness and length of the blink.

You don't have to worry about getting shocked by the capacitor after it has been checked because the spring-loaded SPDT switch automatically shorts the capacitor leads when released. By the way, the capacitor leakage tester also makes a great continuity checker. Just make sure, while checking continuity, that the circuit components can safely withstand the tester voltage.

2-6. TESTING CAPACITORS UNDER ACTUAL OPERATING VOLTAGES

Capacitors sometimes break down under voltage but check perfectly out of the circuit using an ohmmeter. One of the finest ways to check capacitors for leakage under dynamic working conditions is to use a VTVM and the following procedure: Refer to Figure 2-6A.

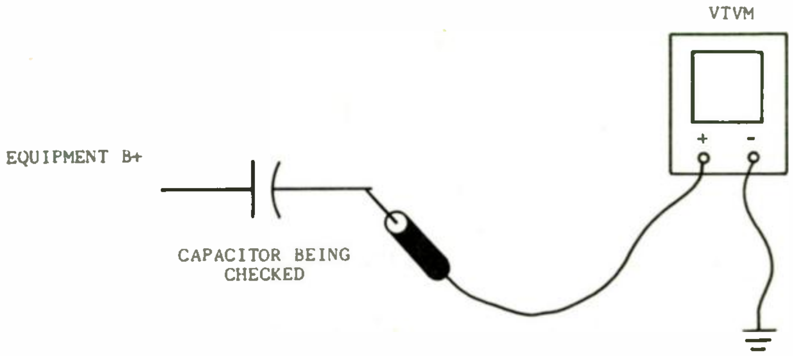


Figure 2-6A: Checking a capacitor under actual operating voltages using a VTVM

Disconnect the ground side of the capacitor being checked. The B + or voltage side of the capacitor should be left connected in the circuit. Set the VTVM for plus DC voltage at the correct voltage range. Clip the VTVM ground to the equipment ground. Touch the probe to the disconnected side of the capacitor. The setup is complete and you are now ready to apply power.

Apply power while monitoring the VTVM. A good capacitor will charge up to the equipment voltage through the VTVM. The VTVM is in series with the capacitor acting as a high impedance current meter. The VTVM pointer will slowly rise to the applied voltage as the capacitor charges. As the capacitor becomes charged, less charging current is required and the VTVM pointer will drop back towards zero voltage. When the capacitor is fully charged the VTVM will read zero volts. Remove power and the VTVM probe from the capacitor. The capacitor should be charged and should hold its charge. Wait a few minutes, then discharge the capacitor with a clip lead, looking for the discharge spark. The larger the voltage and the more the capacity, the greater will be the spark. If the capacitor functions according to this procedure, you know the capacitor is good and working under operating voltage.

If the capacitor is defective this procedure will pinpoint the exact defect in the capacitor. For instance, if the VTVM pointer reads continuous voltage, the pointer never dropping back to zero, then you know the capacitor is shorted. If the VTVM voltage drops some but never reaches zero, then you know the capacitor is leaky. An open capacitor will show no reading on the VTVM.

Most capacitors can be checked with this method. The exceptions are the small PF capacitors that require so little charging current that it's hard to see meter deflection on the VTVM. This method of capacitor checking can be used to check junkbox capacitors or any other capacitors whose condition is unknown. Just temporarily connect the capacitor to be checked at a B+ point in a radio or TV which is close to the voltage rating of the capacitor. Then proceed with the check. High voltage capacitors are especially good to check with this method. Even expensive capacitor checkers do not have provisions to duplicate the very high voltage that some capacitors must be able to withstand. The procedure for checking high voltage capacitors is exactly the same as any other capacitor. Just be sure that a high voltage probe is used and standard high voltage precautions are followed.

2-7. HOW TO MAKE AND USE A CAPACITOR PROBE

A capacitor probe is a simple but extremely effective troubleshooting device. A good technician armed with troubleshooting knowledge, a VTVM and a capacitor probe can locate and repair all types of electronic defects in minimum time. Very often he can do it much faster than can the average technician using conventional troubleshooting instruments.

The capacitor probe can be simple or elaborate. The basic parts are few. All that is required is a probe, a capacitor, a clip and some test lead wire. (See Figure 2-7A.) If the capacitor probe is going to be used

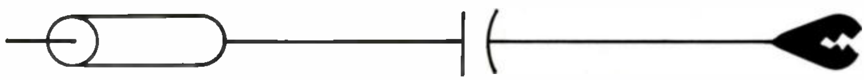


Figure 2-7A: Capacitor probe

mostly in high voltage, high impedance circuits (vacuum tubes), the capacitor should be rated at .02 MFD - 600 WV. If the probe is going to be used in low voltage, low impedance circuits (transistors), the capacitor should be rated at 2 MFD - 50 WV. Generally it's a good idea to have both types of probes.

The easiest way to make the probe consists of connecting a test probe to the capacitor with test lead wire, then connecting the other side of the capacitor to a clip lead with test lead wire. Some technicians have used an extra large insulator on the clip lead enclosing the capacitor. Probably the most professional way to make the capacitor probe is to make or locate a probe large enough in diameter to house the capacitor.

Here are some of the ways the capacitor probe can be used. In defective audio equipment the probe can be used to bridge coupling capacitors. Open coupling capacitors can be found very quickly with this method. Suppose the audio amplifier in Figure 2-7B will not pass a signal. The probe can be used to bypass an entire stage of amplification. For example, the clip can be fastened to the output of a preamplifier and the probe end connected to the input of the power amplifier. If the audio returns at the speaker, then the trouble must be in the

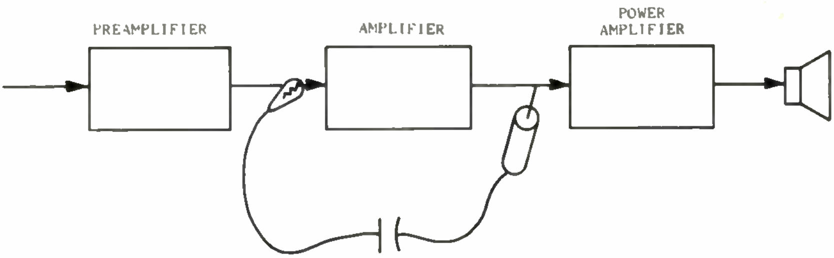


Figure 2-7B: Bypassing a stage of audio amplification with a capacitor probe

amplifier. Naturally the audio will not be as loud as normal, but the defective stage has been localized.

Another technique which is good for localizing a dead amplifier stage can be used in stereo equipment. Generally when something fails in a stereo system (except for the power supply), it upsets just one channel. The other channel continues to work normally. In Figure 2-7C the clip of the capacitor probe has been connected to the output of the working channel's power amplifier and couples a signal into the speaker of the defective channel. If sound is heard in the defective channel's speaker, then that speaker must be okay. Then move the clip to the input of the good power amplifier and the probe to the input of the defective power amplifier. If sound returns in the defective channel, its power amplifier and speaker are okay. Follow this procedure, working back towards the input as shown in Figure 2-7C, until the defective stage is located.

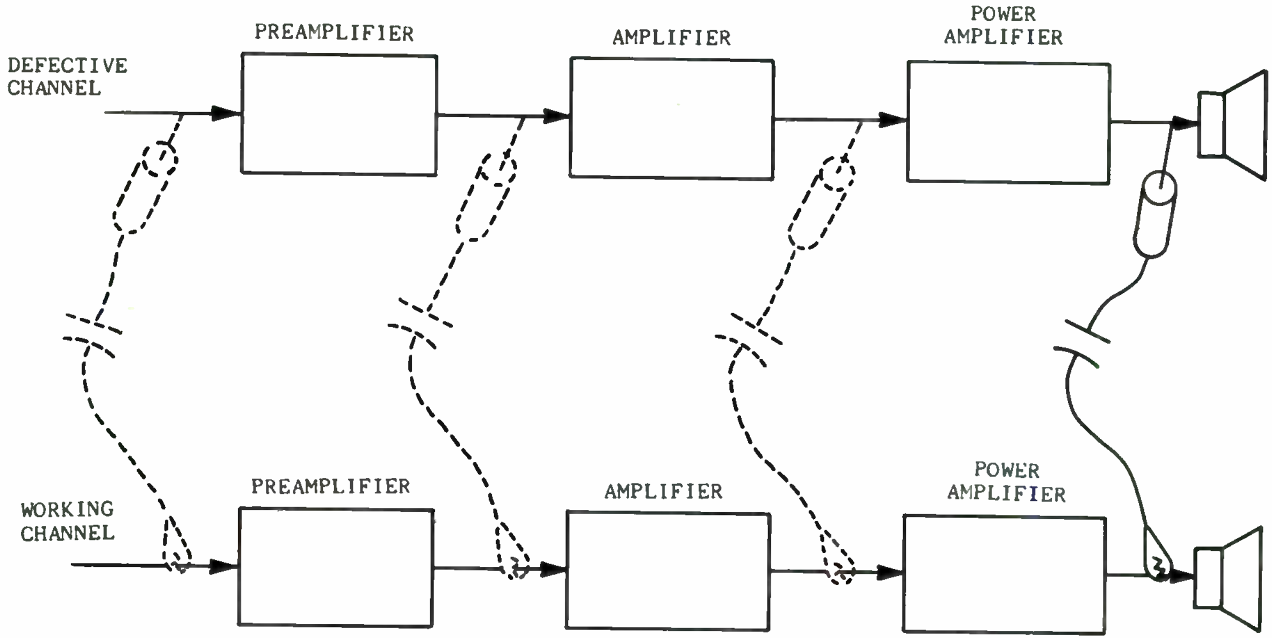


Figure 2-7C: Troubleshooting a stereo amplifier with a capacitor probe

The capacitor probe can also be used as a signal injector. Connect the clip on a source of 60 HZ. This can be a low filament voltage, a low secondary voltage of a power supply transformer, or any convenient source of low 60 HZ voltage. Then touch the probe to the input to the speaker; if a low 60 HZ buzz is heard the speaker is okay. Work back from the speaker, injecting the 60 HZ signal in the input of each amplifier. Each amplifier that is working properly will pass and amplify the 60 HZ signal. As you work back to the input of the amplifier, the signal should become louder and louder. When the 60 HZ buzz is not heard in the speaker, you have found the defective stage.

Radio frequency and intermediate frequency circuits operate at a much higher frequency, so many of the capacitor probe techniques will not work. However, many times the capacitor probe will be useful in bypassing suspected dead stages. For instance, in radio or television where an RF amplifier stage precedes a mixer-oscillator circuit, the clip can be fastened to the antenna terminals and the probe connected to the input of the mixer, bypassing the entire RF stage. If the sound and/or picture returns, the RF stage or stages probably is defective. Naturally the sound and picture will not be as good as normal. This technique sometimes is effective in locating bad IF stages. A method used in Figure 2-7D connects the mixer output to the input of the second IF, bypassing the first IF stage. If a weak picture and/or sound returns, the first IF is probably defective. Using the same method, the second IF and third IF stages can be bypassed with the probe.

When servicing a television set the capacitor probe can be very handy. Besides using the probe for checking coupling capacitors, audio stages, RF and IF stages, it can be used in other sections of the TV. Here's how to check for the presence or absence of sync pulses with the probe: Use the TV audio amplifier as a signal tracer. Turn the volume control to minimum, then connect the clip lead to the input of the audio amplifier. Probe the inputs and outputs of the sync stages. If sync is present, 60 HZ buzz will be heard in the speaker. Hearing the buzz confirms the presence of vertical sync. You can not hear the higher frequency horizontal sync, but you can assume it is there with the vertical sync pulses. This same method can be used to probe the video circuits. When video is present, 60 HZ buzz can be heard in the speaker. You will hear the vertical sync and vertical blanking signals which are with the video signal.

Keeping the clip of the probe on the input of the audio amplifier, the vertical sweep section can be checked. Probe the output of the

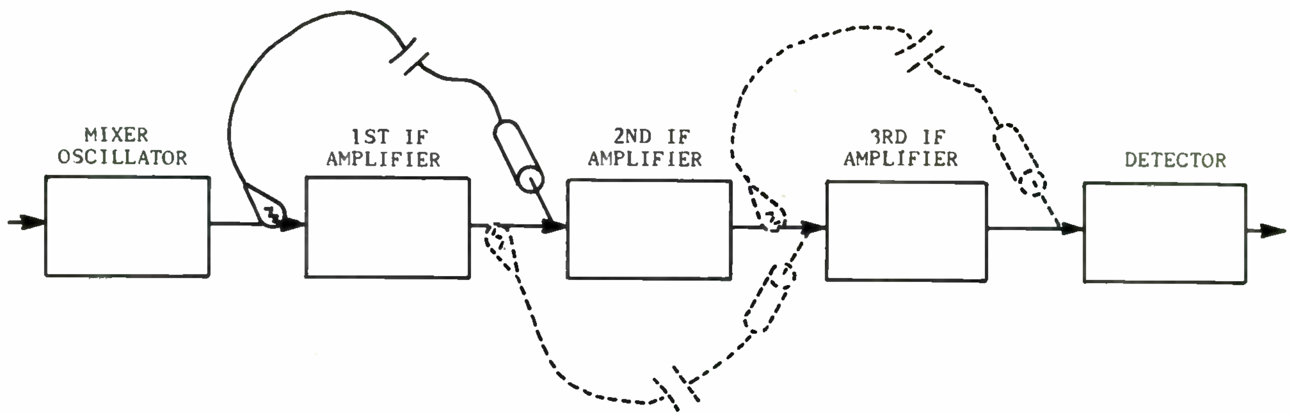


Figure 2-7D: Bypassing IF amplifier circuits with a capacitor probe

vertical oscillator. If it's working, you will hear the 60 HZ buzz in the speaker. Turn the vertical hold control back and forth. If you hear a slight change in the tone of the buzz, you know the vertical hold is controlling the oscillator frequency. Probe the input to the vertical output stage. If you hear the buzz, the signal is coming from the oscillator. Probe the output of the vertical deflection amplifier, listening for the buzz. CAUTION: *The signal at this point may be large enough to damage the audio amplifier stage*. If you are working on solid state equipment skip this step. Probe the top of the vertical deflection yoke. If the signal is present the vertical section is working up to the yoke. Keep in mind that the probe can only confirm the presence of a 60 HZ signal and can not differentiate between proper and improper waveshapes.

Suppose you are repairing a TV receiver with no vertical deflection. The sound is normal. The picture tube raster has collapsed verti-

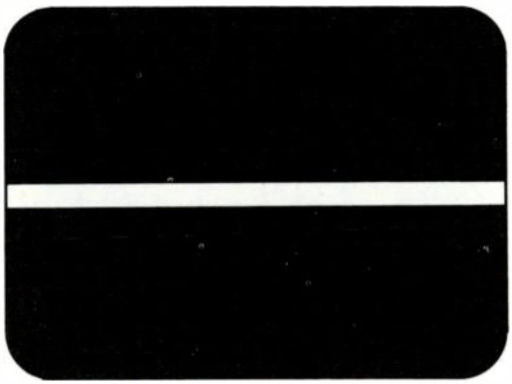


Figure 2-7E: TV raster showing no vertical deflection

cally and all you see is a thin white horizontal line (Figure 2-7E). Use your probe and check for 60 HZ buzz at the output of the vertical oscillator. You don't hear anything at the speaker, which indicates that the oscillator is dead. As a double check, try this technique: Remove your capacitor probe clip from the audio amplifier. Connect the clip to a source of 60 HZ (filament voltage, step-down secondary voltage, etc.) and probe the vertical amplifier input. If the raster returns, although somewhat misshapen, you know without a shadow of a doubt the trouble must be in the vertical oscillator. You have just confirmed that the vertical amplifier and vertical yoke are working when they receive some type of 60 HZ signal.

By now you can see how valuable the capacitor probe can be as a troubleshooting aid in all sorts of electronic equipment. One area of a TV set which we have not mentioned is the horizontal section. How can we use the capacitor probe here when the horizontal oscillator signal is normally 15,750 HZ, too high for most human beings to hear? The capacitor probe can be used in this section also. Use the same technique as in the vertical section—except when probing, rotate the horizontal hold control back and forth rapidly. This should lower the frequency of the horizontal oscillator so that you can hear it in the speaker as a high-pitched tone. Use caution when probing around the horizontal deflection amplifier stage. The output of the horizontal deflection amplifier and high voltage circuits should not be probed.

3

How to Use Practical Techniques When Working with Inductors

Inductors are used in all kinds of electronic apparatus. Chokes, coils, inductors, transformers are all part of the same inductor family. They present problems to technicians because of many factors. Many times inductors are poorly marked and it's hard to identify connections and leads. Transformers are often hard to test accurately without special equipment. Finding inductance of unmarked coils often is a problem. Inductors with shorted turns are very difficult to pinpoint with ohmmeter measurements. Many inductors are expensive and aren't readily available for substitution. However, there are some practical techniques to help the technicians minimize these inductor problems.

3-1. HOW TO IDENTIFY TRANSFORMER LEADS

It would be nice if all electronic component manufacturers would color code their transformer leads uniformly. They don't! However, there is a standard EIA color code for transformer leads that many manufacturers do follow. The standard color code for IF transformers and audio transformers is shown in Figure 3-1A. If you are not certain that an IF or audio transformer follows these color codes, an ohmmeter check will quickly verify it.

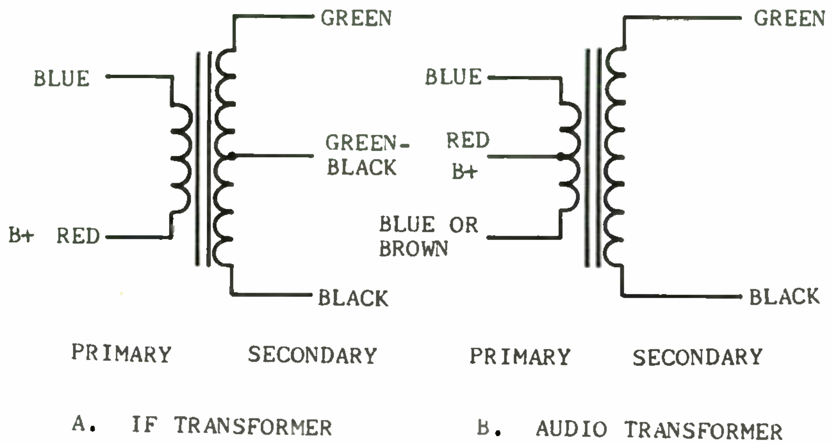


Figure 3-1A: Transformer color codes (a. IF transformer — b. Audio transformer)

Figure 3-1B shows the standard color code for power transformers. Most power transformers follow this code. If in doubt, check it with an ohmmeter. Suppose you want to check a power transformer's voltages. Find the primary leads, which are generally black. They usually have a resistance from five to forty ohms. Separate all the leads so none are shorting each other. Apply line voltage to the primary.

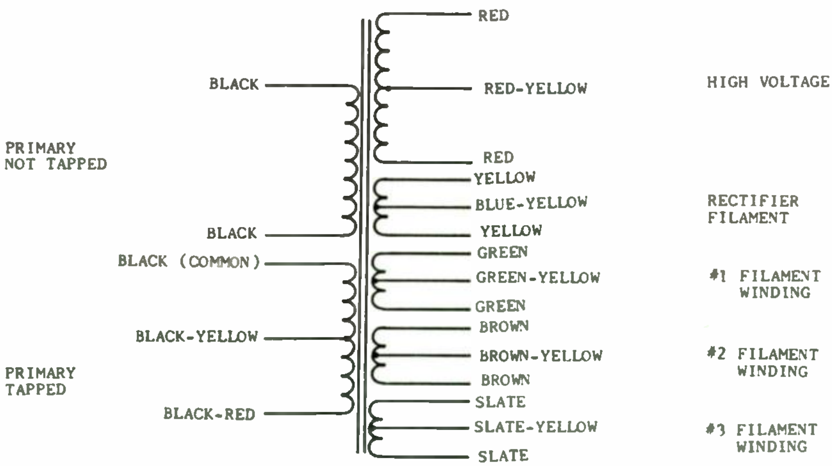


Figure 3-1B: Power transformer color code

Check the voltages on the rest of the transformer leads with an AC voltmeter. Be careful not to be shocked since many power transformers have very high step-up voltages on their secondary windings.

The color-coding of filament or step-down transformers is usually very similar to that of power transformers (see Figure 3-1B). The primary leads are generally black or black-yellow. Both secondary leads' colors are usually brown, or red, or yellow, or green. If there is a center-tap it is usually the same color as the secondary lead's except for a yellow tracer. Voltage checks can be made to find the exact secondary voltages.

When you have service information available for a particular transformer it becomes quite easy to identify leads. Many schematics list the color of transformer leads. Some transformer leads terminate on an insulating board marked with identity letters. Most service information lists the resistance of all windings of a transformer. An ohmmeter check will usually identify the windings.

3-2. TECHNIQUES FOR TESTING TRANSFORMERS

Most transformer problems can be detected with the senses or with a VTVM or DVM. Many times when transformers become defective they will overheat, causing smoke or a burning odor. Generally when this occurs the transformer is finished, even if another defect had caused the transformer to overload. An overheated transformer causes the varnish insulation on the internal wires to burn, causing the smoke and odor. Once the varnish has deteriorated the windings can short to each other or to the core and cause additional problems.

Most service information gives the resistance of transformer windings. When you make an in-circuit ohmmeter measurement on a transformer, make certain there is no parallel path for the ohmmeter current to follow. If you are in doubt, disconnect one of the transformer leads to isolate it from the circuit. Figure 3-2A shows an example of a misleading resistance measurement in a dead audio output stage because of a parallel path. Ohmmeter A reads 36 ohms which appears to be normal. Ohmmeter B measures infinite resistance which also appears normal, and ohmmeter C measures exactly 1.1 ohms. There's no significant lower resistance path around the primary winding, so ohmmeter A's measurement is accurate. Ohmmeter B shows no leakage resistance between the primary and secondary windings. Ohmmeter C is measuring what appears to be a normal reading. Not

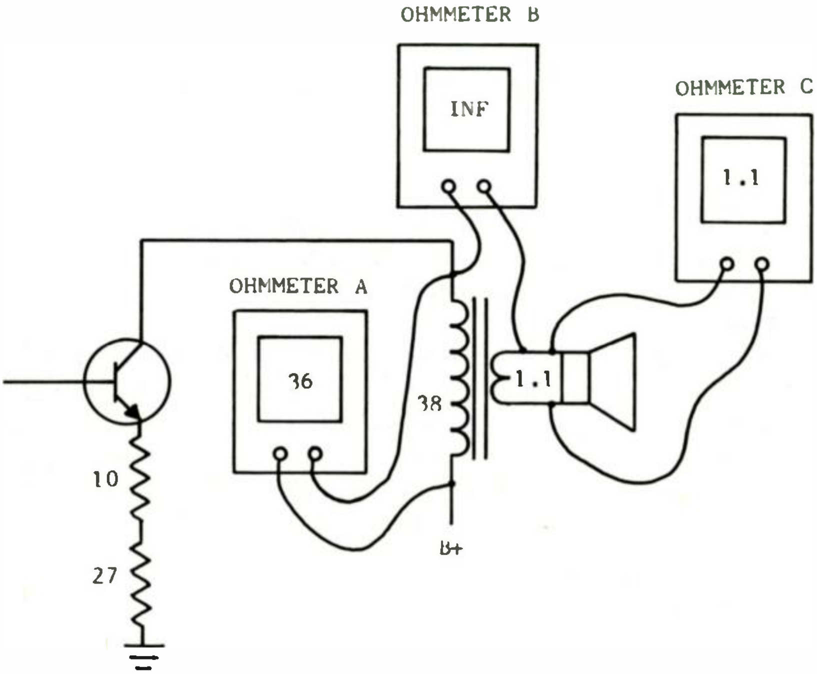


Figure 3-2A: Resistance measurements of an audio output transformer

so, because ohmmeter C is really measuring two windings in parallel: the secondary of the audio transformer and the voice coil of the speaker. In this case the transformer secondary is okay, but the voice coil is open. If the voice coil were normal, ohmmeter C would have measured less than the schematic resistance because of the parallel path.

Whenever you make any resistance measurements on transformers that are connected with plugs and sockets, always remove the plug or unfasten the connection. Many yokes, convergence assemblies and speakers in television sets are wired with removable connectors. Just pull the plug and make the resistance measurements on the pins of the plug. The pins are easy to identify and you will eliminate any parallel resistance paths.

One resistance measurement that is often overlooked when checking iron core transformers is the resistance from a winding to the core. A winding may easily have the specified resistance and be shorted to the core. Unless you measure from one of the leads to the core, you will never spot it. In multiple winding transformers such as power transformers, occasionally a winding will short to another winding. Each winding measures perfectly when ohmmetered by itself. The short resistance will show up only when the resistance measurement is made from one winding to the other.

One of the most common failures in small step-down transformers used for powering transistorized equipment is an open winding. Often the failure results from a mechanical rather than an electrical defect. These transformers have very fine wires which are often soldered to their terminals without any provision for strain relief. Any flexing of the case, bumping, dropping, or other mechanical strain can snap these connections. Many times this type of defect can be repaired. Carefully peel back the insulation tape around the windings until the transformer terminals are exposed. The chances are the wire will break where it is fastened to the terminal. When you see the break, remove the varnish insulation from the remaining wire with fine sandpaper, being very careful not to break any more of the wire. If the wire breaks again just as it comes out of the winding you won't be able to repair it. Splice another wire on the broken lead, leave a loop for strain relief (Figure 3-2B), and resolder it on the terminal. Retape, test, and the transformer probably will be better than new!

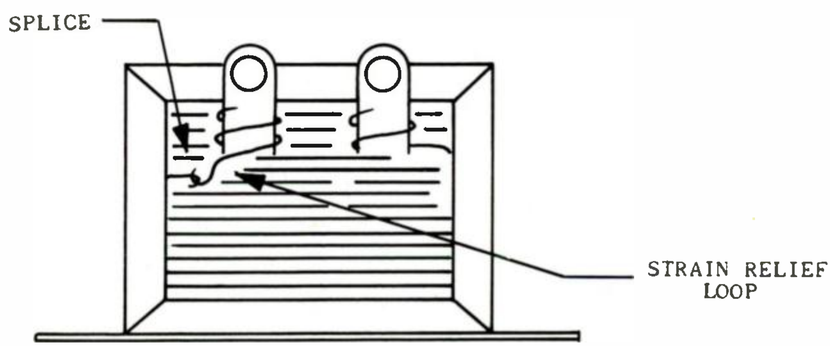


Figure 3-2B: Repairing an open transformer winding

If a power transformer is running hot and you measure a lower-than-normal AC voltage on the secondary windings, you can't assume the transformer is at fault. There's a good probability the transformer is being loaded excessively by a defect in the circuit. Remove the transformer secondary leads from the circuit and recheck the voltages. If the voltages return to normal and the transformer temperature drops, you can be fairly certain the transformer is okay and the trouble is in the load.

3-3. HOW TO FIND INDUCTANCE WITH A VTVM

Have you ever wanted to know the inductance value of a choke? Values are seldom marked on chokes. Did you ever want to use a winding of an extra transformer for a choke but couldn't because you didn't know the inductance? Here's a method to check inductance using only a VTVM, a filament transformer, and a bunch of resistors from 50 to 10,000 ohms. If a resistor decade box is available, use it instead of the resistors.

Figure 3-3A shows the circuit. The unknown choke is connected in series with the resistor decade box. They are connected to the secondary winding of a 6.3 VAC filament transformer. Measure the voltage across the choke and the voltage across the decade box. Compare the readings, changing the resistance values until the two voltages are the same.

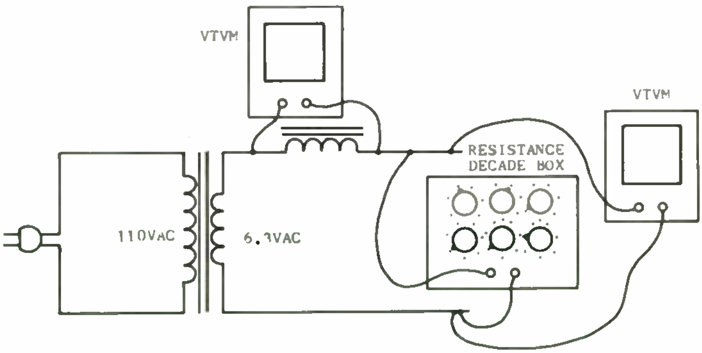


Figure 3-3A: Finding inductance with a VTVM

Suppose the inductor and resistor voltages are equal when the resistance is 5,000 ohms. This means the AC resistance or inductive reactance (X_L) of the choke must also be 5,000 ohms. Use the inductance formula $L = X_L / 6.28 \times f$. Plug in the values and compute.

$$L = \frac{5{,}000}{6.28 \times 60}$$

$$L = \frac{5{,}000}{376.8}$$

$$L = 13.2 \text{ h}$$

The unknown choke is 13.2 henries.

Here's another example. The voltages across the choke and resistance are equal when the resistance is 1,200 ohms.

$$L = \frac{1{,}200}{6.28 \times 60}$$

$$L = \frac{1{,}200}{376.8}$$

$$L = 3.2 \text{ h}$$

This method of determining inductance is fast and accurate. Try this technique on unknown values of chokes and transformer windings.

3-4. CHECKING INDUCTORS FOR SHORTED TURNS

Shorted turns in coils, chokes and transformers sometimes occur. This defect is very hard to detect with conventional test instruments. Ohmmeters are not sensitive enough to detect the small resistance difference between an inductor with shorted turns and a normal inductor.

A simple method to find shorted turns involves the use of an oscilloscope. Any good service oscilloscope can be used. When a quick change in voltage or a pulse is applied across an inductor, the inductor will tend to ring. The ringing will continue until the energy is completely absorbed. The resultant waveform viewed on an oscilloscope takes the form of a damped sine wave much like the one shown in Figure 3-4A. A good inductor will always ring in this manner. The

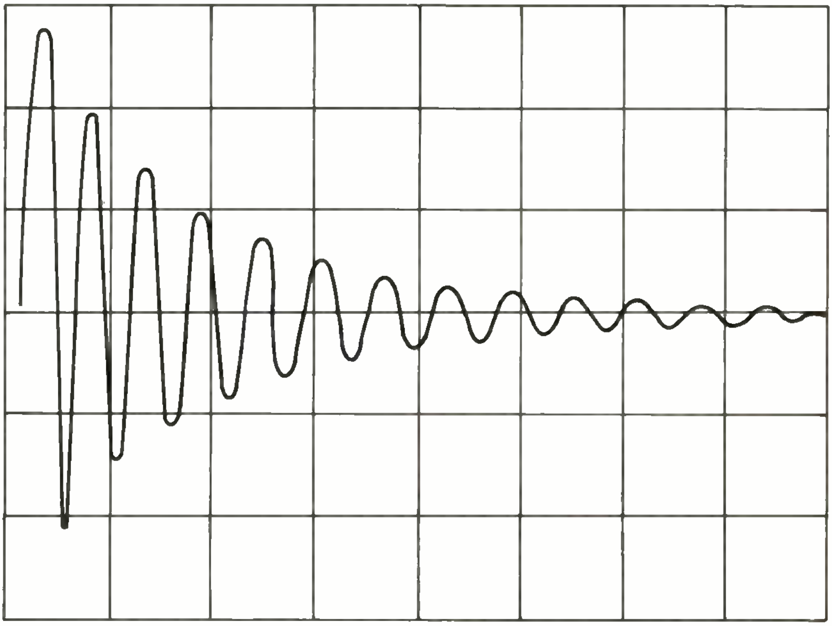


Figure 3-4A: A damped oscilloscope waveform produced by a good inductor

beginning oscillations are the largest in amplitude, and gradually they will become smaller and smaller until they disappear. However, if an inductor with a shorted turn or turns is put to this test the waveform will be significantly different. The inductor will not ring and will not produce a smooth damped wave, but will dissipate the energy in a few quick damped oscillations (Figure 3-4B).

The scope must be modified slightly to perform this test. A pulse source is needed to ring the inductor. The sweep generator in the scope can be used as the pulse source. This is a convenient source because the generator is readily available and the frequency can be changed with the scope's sweep controls. Open up the scope and locate the sweep generator. Then capacitively couple a signal from the top (ungrounded side) of the sweep generator's cathode or emitter resistor to a

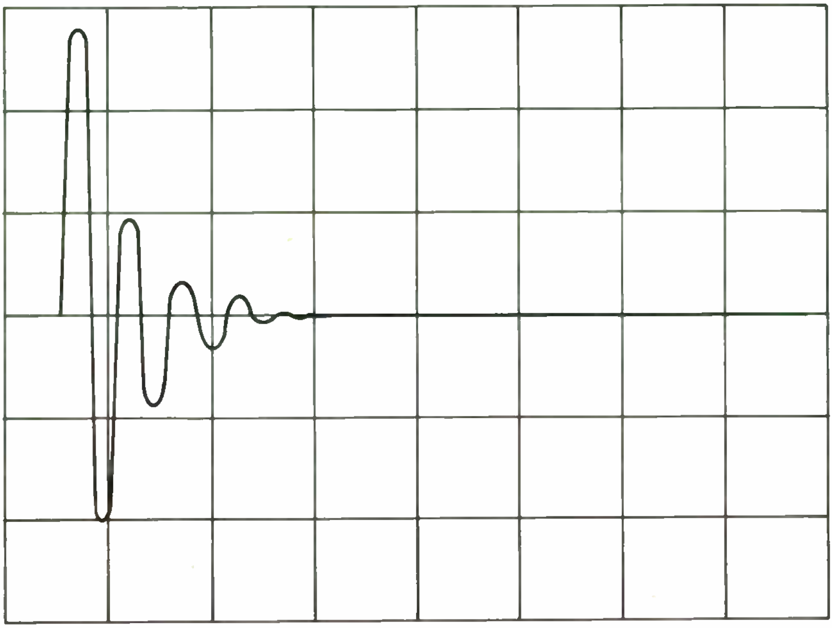


Figure 3-4B: A damped oscilloscope waveform produced by an inductor with shorted turns

jack on the front panel (Figure 3-4C). The jack can be mounted anywhere convenient on the scope's front panel. Use shielded cable from the sweep generator to the test jack.

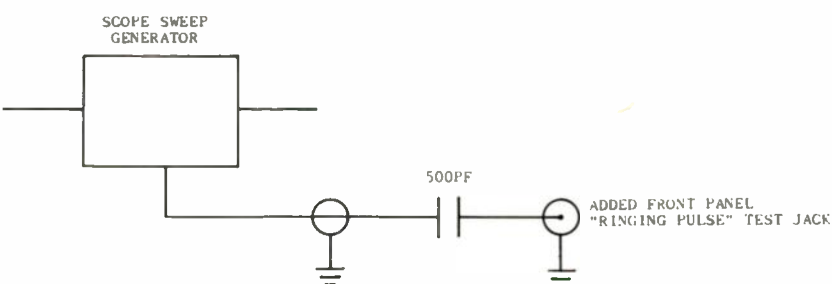


Figure 3-4C: Ringing pulse test jack circuit

After you have the scope modified you are ready to check the inductor for shorted turns. Connect the inductor between the vertical input jack and ground. Connect a clip lead from the ringing pulse test jack to the ungrounded side of the inductor (Figure 3-4D). Change the

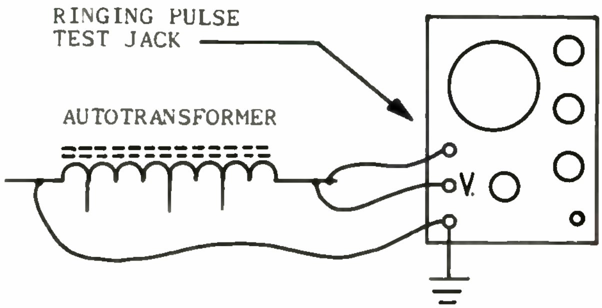


Figure 3-4D: Scope connection to test for shorted turns

horizontal sweep controls on the scope until a waveform is observed. If the waveform appears as in Figure 3-4A, the inductor has no shorted turns. If the inductor appears as in Figure 3-4B, the inductor has one or more shorted turns. The correct setting of the sweep controls can be determined experimentally. Keep in mind that large inductances will require lower sweep frequencies and small inductances higher sweep frequencies.

Next time you suspect some shorted turns in a yoke or flyback transformer, try this technique. When there are shorted turns in an inductor you can quickly confirm your suspicions with this testing method.

4

Time and Work-Saving Methods to Use With Vacuum Tubes

This chapter deals with tips and shortcuts involving vacuum tubes. Many vacuum tube problems can be diagnosed and solved with the use of practical work-saving ideas.

The technician is often overwhelmed with the thousands of types of tubes. Much time is spent trying to find simple service information. Too often you can't check a tube on a tube checker because the data isn't available. Or, if you do check a tube, can you really trust the reliability of the tube checker?

Every serviceman and troubleshooter runs into these problems. They can't be eliminated but certainly they can be minimized if practical common-sense techniques are followed.

4-1. HOW TO VISUALLY DETERMINE ELEMENT NUMBERS

How many times have you wanted to find the pin numbers of filaments, cathodes, grids and plates in vacuum tubes without digging the information out of a tube manual? You can determine this information from most tubes by carefully looking at them. Remember, most tubes are glass and you can see their internal construction.

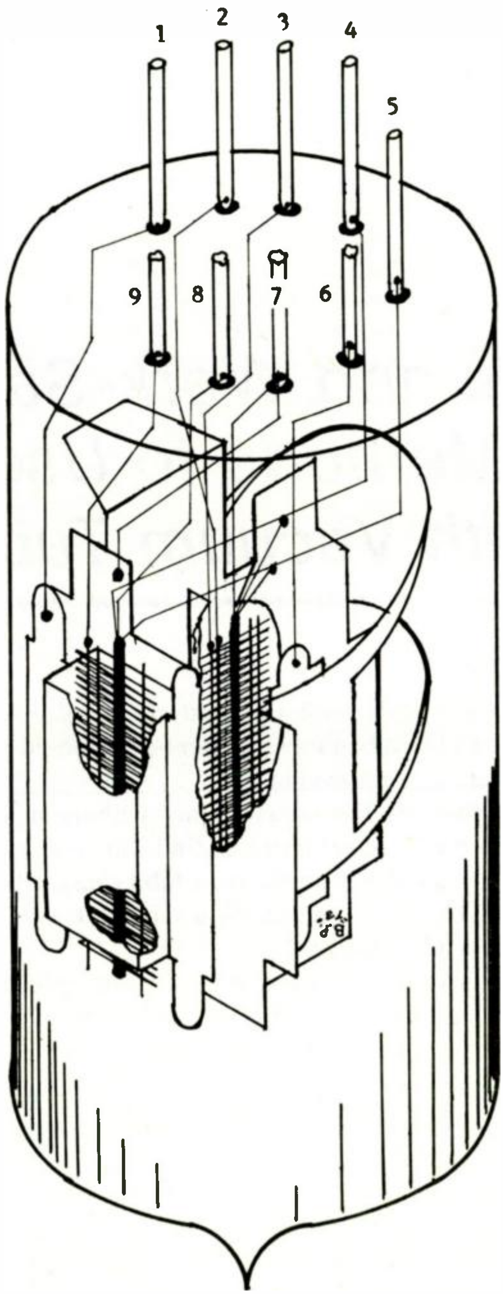


Figure 4-1A: Cutaway view of a 6GH8A tube

Suppose you wanted to find visually the pin connections of a 6GH8A tube, a workhorse in many color television sets (Figure 4-1A). Look inside the tube at the lower section and you can immediately see that this is a dual tube since there are two sets of heaters and the metal separator. The heaters are easy to find because they are located in the center areas of the tube inside the cathode cylinder. Following the heaters down shows they are welded to pins 4 and 5.

Remember, when you are looking at the base of a tube or tube socket, you always count the pins *clockwise* from the keyway or opening. When you are probing a tube socket from the top, you always count the pins *counterclockwise*. Keep these simple rules straight in your mind and you will save yourself a lot of meaningless work. The cylinder around the smallest section's heater, the cathode, is fastened to pin 8. Continuing in that same section, moving towards the outside of the tube, the next welded pin connection is the control grid, pin 9. Finally, the last connection is to the plate, pin 1. You now know that one-half the tube is a triode, and you know the numbers of all the connections.

Now look at the other section of the 6GH8A. The cathode sleeve is connected to pin 7. Always start at the center of the tube elements and move towards the outside envelope when determining pin numbers. The next connection is the control grid to pin 2. The screen grid must be the next connection, pin 3. And finally the outside cylinder, the plate, is welded to pin 6. Now you have the main pin connections for the other section of the 6GH8A.

Next time you don't have service information at your finger tips, try this technique and save yourself some time and frustrations.

4-2. PRACTICAL WAYS TO CHECK TUBES WITHOUT INSTRUMENTS

A common trouble is gaseous vacuum tubes. This condition is caused by a crack in the glass envelope permitting air to leak into the vacuum tube. After enough air leakage, the trouble is visually observable as a white misty appearance on the inside of the envelope. Usually the heater has burned out because of the presence of oxygen. Just a glance at the tubes is all that is needed to spot this defect. Be careful that you don't get cut when you pull the tube out. Sometimes the envelope will completely break apart as pullout force is applied. If the tube is only slightly gassy, a tube checker is needed to detect this condition.

Check for the presence of a gassy tube before applying power. If none of the vacuum tubes appear gaseous, apply power and check to see if all the tube heaters and filaments light. Determine if the equipment is wired for series or parallel heaters. Parallel heaters always require a power transformer which is easy to locate. Also, the equipment will probably be heavier. The majority of tubes in parallel heater strings will start with numbers 6 or 12.

When one of the heaters opens in a parallel string, the rest of the tubes will remain lit. Just look for a tube that is not lighting around the heaters. You may have to darken the surrounding area to see some of the tubes. Sometimes it is normally hard to see the heater glow in certain tubes. If you are in doubt, touch the tube to see if it is becoming warm. A warm tube means good heaters.

In a series heater string, all the tubes will be off if any one heater opens. The best way to locate the defective tube is with an inexpensive filament-continuity checker. Simply plug the tubes in the checker, one at a time, until the defective one is located. Start with the large high power tubes because the odds are they will fail first. Tube substitution, voltmeter and ohmmeter checks can also be used to locate the bad tube. Generally these methods are more time consuming than the filament-continuity checker.

Some other defects which can be observed in vacuum tubes are arcing and flashing between the elements. Generally, tapping the tube will cause this type of problem to become worse. Occasionally, tapping the tube will remove the cause of the arcing and the tube will appear normal. However, any time arcing or flashing is observed, the tube should be replaced. Some power tubes that are becoming gassy will glow violet down in between their elements and should be replaced. Don't confuse this symptom with the purple glow on the inside of some tube envelopes, which is a normal condition.

Another technique used to find a bad tube, especially an intermittent problem, is tapping the envelope with a pencil or probe. Many times the trouble will recur or become worse when the tube is tapped. Try lightly tapping the tubes from a couple of different angles.

Power tubes whose load increases or drive decreases will often run excessively hot. Frequently the experienced technician can detect this problem by carefully feeling the envelopes of the suspected tubes. It takes some experience to differentiate between a normally hot tube and a super hot one. Occasionally, power tubes will run so hot that the plates (the largest metal area inside the tube) will become cherry red.

This symptom is very easy to spot if you recognize what you are seeing. If the plates are running red hot, remove power immediately or the tube will destroy itself.

All tubes are marked with their number on the sides or the top of the envelope. Sometimes one of the most frustrating experiences is trying to find that number. The number has disappeared over the years, but the chances are it is there somewhere. One technique for finding the number is to breathe a mist on the envelope, which often will make the number visible again. Another trick is to rub the tube through your hair. Often the hair oil will show up the number. If you look carefully the chances are you'll find the missing tube's number. As a last resort, when it is impossible to locate the number compare the size and internal construction of the tube with other tubes until you find an identical comparison. This is time consuming but it may be the only way to identify the tube.

4-3. TIME-SAVING TECHNIQUES FOR TUBE SUBSTITUTION

It's faster and better to substitute a tube than to check a tube. Many, many professional technicians believe and adhere to this statement. No one can argue with the fact that substituting a suspected bad tube with a known good one is a quick procedure. All the time necessary to substitute is the time needed to remove the old tube, select and remove the new tube from the box, and insert it into the socket. Substitution is not only faster, but is also a better method for checking tubes than is the use of a tube checker. Number one, you can seldom fully trust a tube checker. Number two, all the operating conditions of the circuit can't possibly be duplicated with a checker. Number three, tube checkers are time consuming to set up and require constant updating. This is not to say that tube checkers should be thrown out. Practically speaking, it's impossible to stock substitutes for all tubes. Also, for preventive maintenance tube checkers can provide valuable information as to tube condition and probable lifespan.

Generally a suspected bad tube should be substituted with an identical known good tube. Notice that the substitute should be a *known good tube* and not just an identical new tube. New tubes are sometimes defective. Many technicians have torn their hair out because they have replaced a bad tube with a new but defective replacement. Then they have spent hours on a wild goose chase before the error was discovered.

Sometimes manufacturers will slightly improve the design or change the style of a tube. The newer version tube will keep the same number as the older version except for an additional letter or letters at the end of its number. For instance, the 5U4G rectifier has been changed to the 5U4GA and then to the 5U4GB. The newest version can be substituted for any of the previous versions.

There are times when the identical tube isn't available and a different number tube can be substituted. Care must be taken when interchanging tubes because they may not work in all circuits. Also there are some series circuit tubes which require a controlled warm-up time. Industrial tubes can often be interchanged for their receiver tube counterpart to obtain more reliability. Foreign and American tubes are frequently interchangeable. The best bet is to follow an up-to-date tube substitution manual and follow its recommendations.

4-4. ARC-CHECKING HIGH VOLTAGE TUBES

Drawing arcs from high voltage tubes is a fast and efficient way to troubleshoot and localize trouble. High voltage sections are often hard to service in the conventional manner because test equipment can be damaged. Arc-checking in the high voltage sections of television receivers is a good example of this type of troubleshooting. CAUTION: *Follow good safety rules when making these checks*. Be certain that no part of your body is near a grounded area. Use only one hand (put your other hand in your pocket). Make certain the screwdriver handle can insulate your hand from the maximum voltage of the check point.

Arcs can be drawn from high AC or DC voltages (Figure 4-4A). AC arcs will jump to an ungrounded object. DC arcs will jump to a grounded object. Suppose a technician is working on a television receiver with no raster but with good sound symptoms. This is a classic case of a probable high voltage defect. Arc-checking can be used to localize the problem quickly.

A good place to begin is the horizontal output section. Touch the plate of the horizontal output tube with the blade of an ungrounded screwdriver. Make sure the handle is well insulated. Normally the voltage at this point is about 5KVAC. If this section is working, you can draw a small arc—about an eighth to a quarter-inch. The presence of the arc will confirm the proper functioning of the horizontal oscillator and horizontal output amplifier.

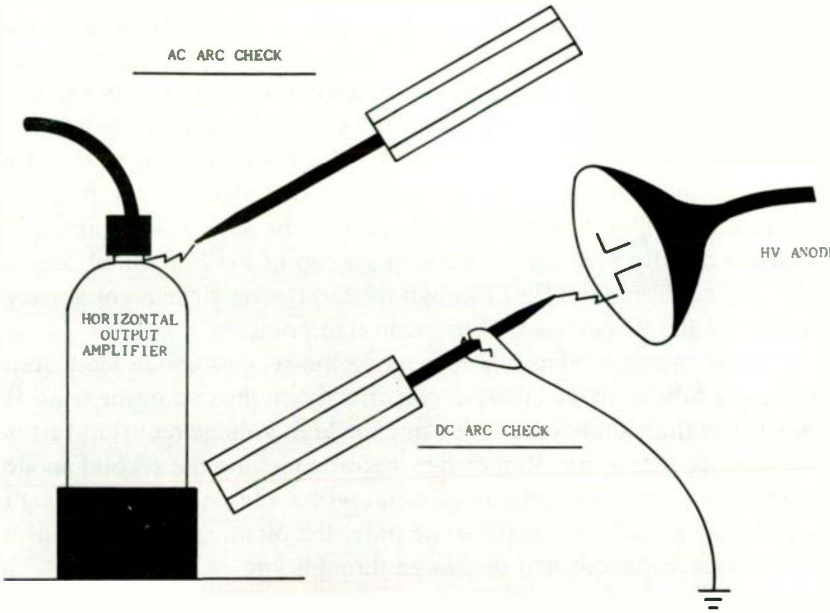


Figure 4-4A: Arc checking high AC and DC voltages

Next, check the plate of the high voltage rectifier tube, which is generally in the high voltage cage. Use an ungrounded screwdriver to draw an arc from a half-inch to an inch. An arc at this point confirms the proper functioning of the horizontal oscillator, horizontal output amplifier, damper and flyback transformer.

If the arc at the plate of the high voltage rectifier seems okay, check the DC arc at the second anode of the picture tube. Ground the screwdriver blade with a clip-lead to the high voltage chassis. Carefully bring the end of the screwdriver blade close to the second anode. An arc at this point should be three-quarters to one-and-one-quarter-inches long. If an arc is present here, all the high voltage circuits must be working. The only trouble spot left that could be producing the no-raster symptoms would have to be the picture tube circuits or the picture tube itself.

Generally with this type of symptom, one of the previously mentioned checks will be faulty. The defective area will be localized and the repair is much easier. Arc checks can also give you an estimate of the approximate voltage magnitude. As a rule of thumb, 20,000 volts will jump one inch through dry air. If you pull a three-quarter-inch arc from the second anode lead, the voltage is about 15,000 volts. Needless to say, when making arc checks be sure to observe safety precautions. Don't be like the TV repairman who was showing his helper the dangerous points in the television. The repairman had a metal solder aid in his hand and was pointing out the various places in the receiver not to touch. "Don't ever touch this point," he said as he pointed to and inadvertently touched the metal plate cap of the horizontal output tube. The soldering aid flew through the air; the repairman got a nasty shock, and the helper learned to avoid that point.

Sometimes it's advisable to remove the second anode lead from the picture tube to make an arc check directly on the end of the lead. If you suspect the picture tube of loading the high voltage rectifier, this is a good procedure to try. Remember, before touching the second anode of the picture tube, to ground that point with a clip lead. Even though the TV may have been off for some time, the picture tube can act as a high voltage capacitor and discharge through you.

4-5. HOW TO REJUVENATE PICTURE TUBES

When a picture tube goes bad in a TV receiver, it generally presents a dilemma to the owner. Many times the choice is buying a new set or replacing the picture tube. There's a third choice. Some picture tube problems can be corrected without replacing the tube. Low emission, heater-to-cathode leakage, opens and shorts are some of the problems that may be repairable.

There are tube testers on the market which are made specifically to check and repair picture tubes (Figure 4-5A). These testers will check emission from the cathode. Many can predict the probable useful life remaining in a CRT. Black and white picture tubes can be checked, as well as each gun in color tubes. They can check for shorts and opens, and can actually repair many of these problems. Low emission picture tubes can often be rejuvenated to a near normal condition.

Here's a typical example: A four-year-old black and white TV receiver has no observable raster; the sound appears normal. Put the TV in a dark room or area and closely observe the CRT screen while turning the brightness control full on (CW). If you see a faint raster and picture, there's a good chance that the picture tube is the trouble. Check the emission of the CRT with a tube tester. If it reads *low* or *no*

Figure 4-5A: CRT tester (B & K)

emission, try to rejuvenate it. CAUTION: In the process of rejuvenating the tube you may completely blow the heaters. In most cases it is worth the risk since the tube is worthless anyway.

Generally there are two or three rejuvenating positions on the checker. They are labeled low, medium and high—or something to that effect. Try the lower position first. Many times the rejuvenation will occur on the first try. Some tubes will rejuvenate like a miracle. One minute the raster is completely black and the next minute (after rejuvenation) it is almost perfect. Some rejuvenations will last for years, others for minutes!

Color picture tubes are just as easy to rejuvenate. Generally just one gun will need rejuvenation. The red gun will often decrease emission before the others. When you satisfactorily rejuvenate a color tube, you have saved a bundle of money.

Picture tube brighteners are also great for extending the useful life of picture tubes (Figure 4-5B). The brightener is a device that plugs between the CRT socket and the picture tube base. There are brighteners for black and white, color, series and parallel heaters, and with all types of basing arrangements. Some brighteners have provisions to act

Figure 4-5B: CRT brighteners (Perma Power)

as a 1:1 isolation transformer. They provide no boost voltage on the heaters, but provide isolation between the heater and cathode when there is heater-to-cathode leakage. Most brighteners provide isolation between the heater and cathode as well as stepping up the heater voltage.

Occasionally a picture tube can be repaired by tapping it. Shorts in the electron gun can sometimes be removed with sharp taps around the circumference of the CRT neck. Sometimes the internal electrode wires in older picture tubes break loose from the external base pins, causing intermittent conditions. This type of trouble can be repaired by resoldering or crimping the base pins.

Once in a while, picture tube trouble turns out to be just a dirty screen. Smoke and grease particles are attracted to the face of the CRT by the high voltage. In older picture tubes that require a separate safety shield, dirt on the safety glass and the CRT face is a common problem. A good cleaning with a non-abrasive cleanser can do wonders for the brightness. If there is a lot of cigar smoking and food frying in a house, you can bet the picture tube needs cleaning.

Remember, when you're working around or with picture tubes you are dealing with a potentially dangerous device. Once the air has been removed from a CRT there is a tremendous amount of atmospheric pressure exerted on the glass envelope. To withstand this pressure the glass is quite thick, one-half inch or more, on the face areas of large picture tubes. A sharp blow to a CRT may cause the tube to implode violently. The pieces of the glass envelope will collapse inward, striking each other and causing the fragments to change direction and fly outward. If you happen to be in the path of the flying glass, very serious injury can occur.

Many times old or worn-out picture tubes have to be discarded. Before they are thrown out they should be deactivated to remove the vacuum and render them harmless. Figure 4-5C shows a good method to use when deactivating CRT's. Insert the picture tube in a strong

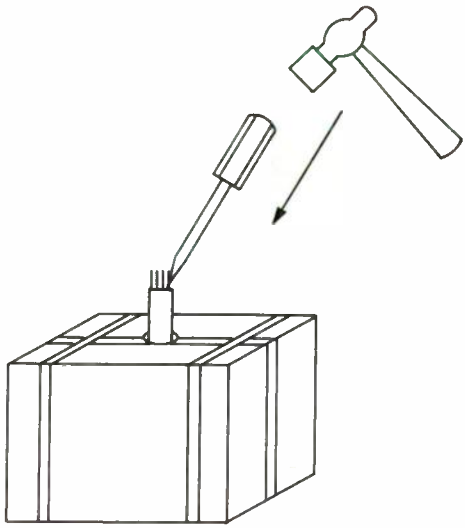


Figure 4-5C: Removing the vacuum from a picture tube

cardboard box, leaving only the base of the neck exposed. Tape or tie the box securely so the picture tube is completely surrounded by the cardboard. Wear a safety shield on your face and heavy gloves on your hands, and put on a long-sleeved jacket. Then take a metal scribe or ice-pick type of device and hammer it cautiously through the end of the CRT base and into the glass envelope. When the envelope is broken, you will hear a hissing sound as the air rushes into the vacuum. As soon as the hissing sound stops, the CRT is no longer a potential bomb.

5

How to Use Practical Techniques When Working with Solid-State Devices

The following chapter discusses and explains practical time-saving techniques for testing all kinds of solid-state devices. A common problem among many electronics men is determining the condition of diodes, transistors, silicon controlled rectifiers, triacs, integrated circuits and other types of solid-state components. Many of these parts can be checked easily and reliably with conventional test equipment.

Many times technicians hesitate to remove, for testing, suspected bad transistors or other solid-state parts from printed circuit boards for fear of damaging the board or the electronic component. This chapter shows simple, effective ways to make in-circuit checks on many solid-state devices.

Solid-state troubleshooting and repair is certainly a major part of many technicians' responsibility, and it will continue to increase each year in the foreseeable future. A practical common-sense approach when working with solid-state equipment is mandatory for the successful electronics technician.

5-1. HOW TO TEST DIODES AND RECTIFIERS

Diodes and rectifiers are the easiest parts of the solid-state family to test. There are many commercial testers on the market for this job, but the majority of diodes and rectifiers can be checked satisfactorily with an ordinary ohmmeter.

When preparing to check a diode or a rectifier, first determine which end is the cathode. The cathode is almost always marked one way or another. See Figure 5-1A for various common methods used to identify the cathode end. Remember when checking a diode or rectifier that electron flow will travel from the cathode to the anode. When

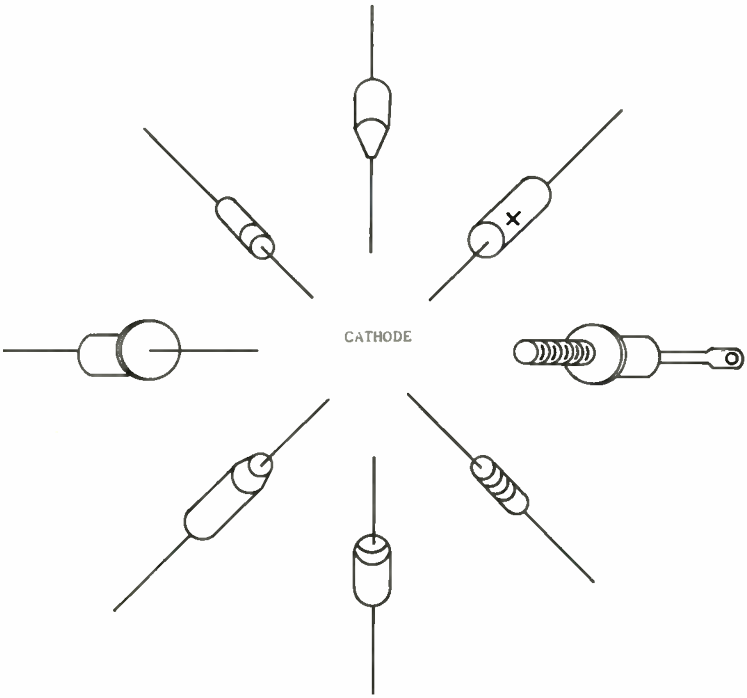


Figure 5-1A: Cathode identification for diodes and rectifiers

using an ohmmeter to test a diode, make certain you are absolutely sure of the polarity of the ohmmeter leads. It is a good idea to measure the ohmmeter leads with a voltmeter to determine polarity. Then mark the polarity of the ohmmeter leads directly on the leads or the ohmmeter case with a felt marking pen. This is especially helpful when using more than one ohmmeter since ohmmeter leads can be either polarity.

Connect the negative ohmmeter lead to the cathode and the positive lead to the anode. This hookup forward biases the rectifier, and the ohmmeter reading should be low for a good rectifier (Figure 5-1B). Connecting the positive ohmmeter lead to the cathode and the negative lead to the anode reverse biases the rectifier giving a high resistance reading.

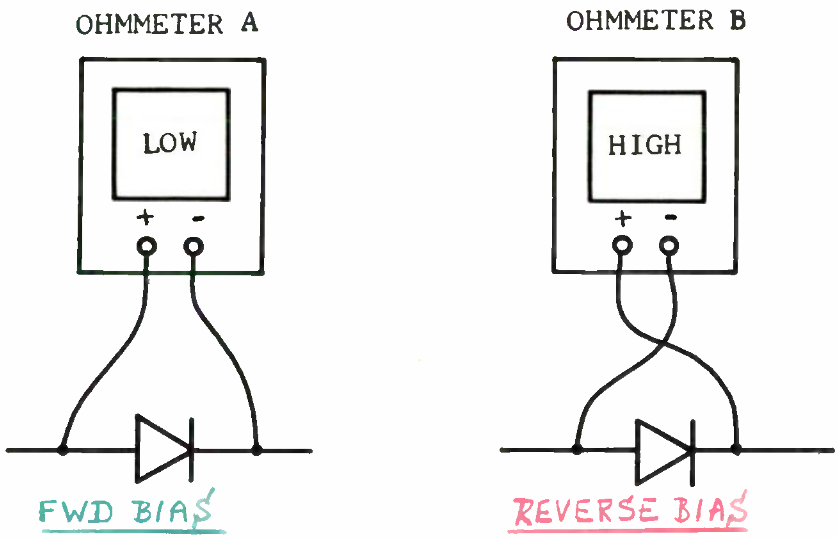


Figure 5-1B: Checking a rectifier or diode with an ohmmeter.
A. Checking in the forward direction gives a low resistance reading.
B. Checking in the reverse direction gives a high resistance reading.

It's important to check the resistance in the forward direction on the R x 1 scale of the ohmmeter. Other scales will sometimes give erroneous readings because the ohmmeter is not forward biasing the diode enough to cause full conduction. Inversely, when checking the reverse direction, use a high enough resistance scale to determine the reverse resistance.

The ratio between reverse and forward resistance should be at least 10 to 1. Most rectifiers and diodes will have more than a 100-to-1

back-to-front ratio. A typical silicon rectifier will measure about 20 ohms forward resistance and over 1000,000 ohms back resistance.

You can also determine whether the diode is a germanium or a silicon type when checking the forward resistance. A germanium diode will start conduction when about .25 V is placed across it. A silicon diode needs more voltage, about .6 V, to cause it to conduct. Just measure the voltage drop across the diode with a voltmeter while checking the forward resistance with an ohmmeter (Figure 5-1C).

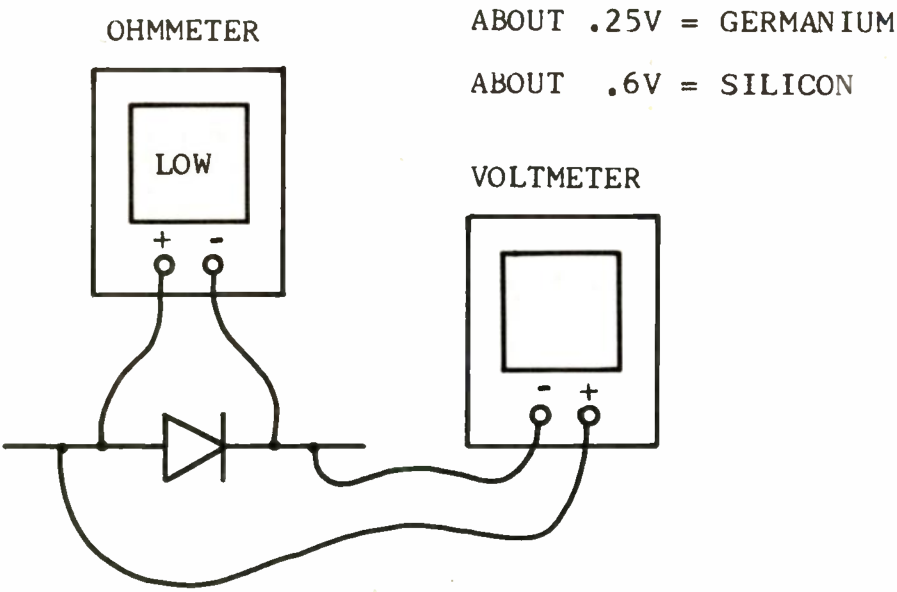


Figure 5-1C: How to determine if a diode or rectifier is germanium or silicon

Diodes and rectifiers are so simple and yet they cause much confusion to many electronics men. Probably the primary reason for the confusion is the fact that the cathode of a rectifier is always marked the positive side even though the anode has to be more positive for the rectifier to conduct. The cathode side of a rectifier is marked positive because that side is the most positive side in a circuit. The anode side, although more positive when the rectifier conducts, is only that way one-half of the AC alternation. The average polarity of the anode side is zero. The polarity of the cathode side is positive at least one-half of the time (with filter capacitors all of the time), and hence becomes the most positive point in the circuit. Remember that the cathode is always marked positive and you won't be confused.

5-2. WORKING WITH ZENER DIODES

An ohmmeter can check zener diodes in the forward and back direction, but can't check the zener breakdown point. Zeners will check exactly the same as a conventional diode using an ohmmeter: low resistance in the forward direction and high resistance in the reverse direction. If the zener doesn't check correctly in this manner you know it's bad. However, if it does check correctly, you still don't know if it will break down at the correct zener point.

Figure 5-2A shows a simple but effective circuit for checking zener diodes. The zener is reverse biased to its zener point by the

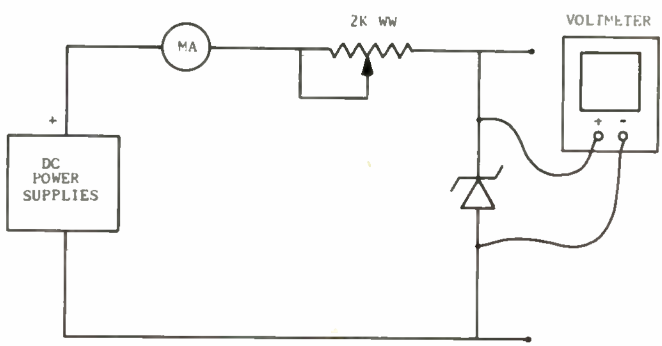


Figure 5-2A: Test setup to check a zener diode

current flowing through the 2K pot. At the zener's specific current level, the diode will break down, causing the voltmeter voltage to remain constant throughout the wattage range of the zener. For example, suppose the zener is rated for 10 V, 400 MW. When the zener point is reached in the test circuit, the diode will conduct for any voltage above 10 V, keeping a constant 10 V across itself and measured by the voltmeter. The voltage will remain 10 V as long as the current remains below 40 MA (400 MW). As a rule of thumb, remember zeners will not operate properly unless loaded to 20% of maximum load. In this case good zener action will begin when the zener current reaches around 8 MA.

Did you ever have to replace a defective zener, and find that you couldn't locate the exact replacement? Zeners can be connected in series (Figure 5-2B) to increase the breakdown point as long as you do not exceed the current rating and power dissipation of either zener. If

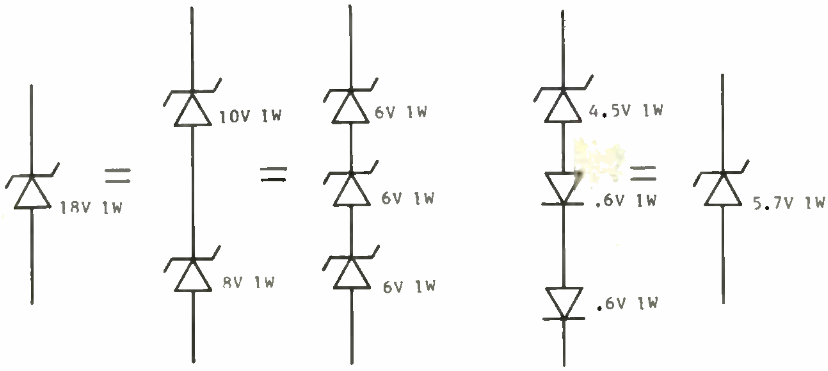


Figure 5-2B: Practical methods to change zener voltages

you need an 18 V zener and only have available an 8 V and a 10 V zener, just connect them in series. If their wattage rating is the same or higher than the original, they will work just as well. Three 6 V zeners in series would also be the electrical equivalent of an 18 V zener.

Another way to change a zener voltage is to connect germanium or silicon diodes in series with the zener. A germanium diode will increase the zener breakdown voltage about .25 V and a silicon diode about .6 V. Figure 5-2B shows a 4.5 V zener diode connected in series with two silicon diodes to produce an equivalent zener of 5.7 V.

It's possible to increase the effective wattage of a zener diode by using it with a silicon power transistor. A 1/2 W zener used with a 5 W power transistor can be used as the electrical equivalent of a 5 W zener. This type of combination is generally much less expensive than buying the high wattage zener. Figure 5-2C shows the hookup. The voltage from the emitter to the collector will be the zener voltage (12 V) plus the transistor base-emmiter voltage (.6 V). In most circuits the slight increase in equivalent zener voltage will not be a factor. Occa-

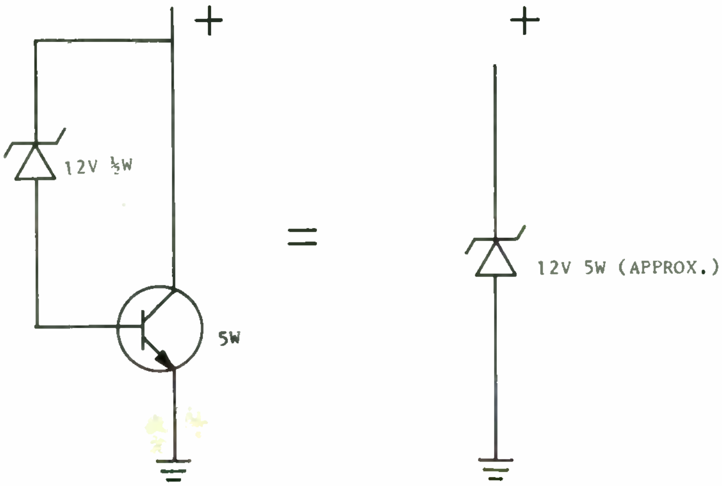


Figure 5-2C: Using a power transistor to change the effective wattage of a zener diode

sionally these zener-transistor circuits will tend to generate noise. If this occurs, just connect a 100 MFD electrolytic in parallel with the zener to stop the noise.

Figure 5-2D shows how an unregulated power supply is changed to a simple regulated supply, using the zener-transistor combination. Choose R to limit maximum zener current. Maximum zener current will occur when there's no load on the power supply.

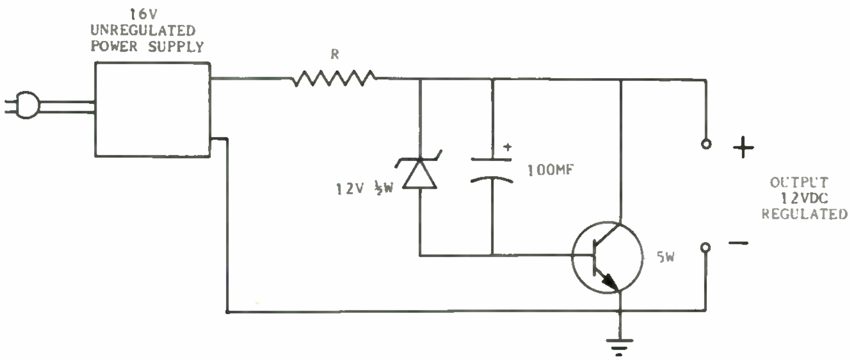


Figure 5-2D: Simple zener-transistor regulated power supply

5-3. RESISTANCE CHECKS FOR TRANSISTORS, UNIJUNCTIONS, AND FETS

In solid-state circuits, resistance measurements with conventional ohmmeters have always been tough. Generally there is some kind of solid-state device in parallel with the ohmmeter probes. The ohmmeter voltage turns on the transistor or diode, causing it to conduct and giving erroneous resistance measurements. Desoldering and pulling out the parallel solid-state devices is always time consuming and likely to cause damage.

Accurate ohmmeter measurements can be made in transistor, diode and other solid-state circuits using special low voltage ohmmeters. These ohmmeters operate on voltages less than .1 V in comparison with the usual ohmmeter voltage of 1.5 V. The voltage is not large enough to cause transistor and diode conduction. In-circuit resistance readings using this type of meter can be made with the same reliability as the conventional ohmmeter in vacuum tube circuits.

Let's take in-circuit resistance measurements in the transistor circuit (Figure 5-3A). Suppose you want to measure the resistance of the

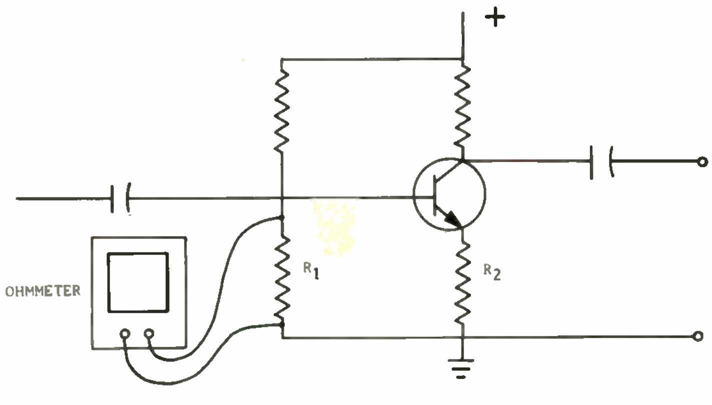


Figure 5-3A: Checking resistance in the circuit

bias resistor R_1. A conventional ohmmeter could indicate all kinds of resistance readings, depending on the polarity of the probes and the ohmmeter range. On the other hand, when using an ohmmeter with a low voltage feature, you don't have to be concerned with ohmmeter polarity or tracking between ranges. The transistor will never turn on and the base, emitter and collector elements can be considered open.

Most transistors can be checked out of the circuit with fairly good results with an ohmmeter. Each pair of transistor elements will act as a diode with a forward and back resistance.

Simply measure the forward and back resistance between each set of transistor elements as shown in Figure 5-3B. The base-emitter junction and the base-collector junction will both act as a conventional diode with low forward resistance and high reverse resistance. The emitter-collector junction will act as a high resistance diode in the forward direction and a higher resistance in the back direction. CAUTION: Transistors checked in the forward direction with an ohmmeter on the R x 1 scale may damage the transistor, although this seldom happens.

Another method to check transistors using two ohmmeters is shown in Figure 5-3C. The transistor is tested under DC conditions much as it operates in an actual circuit. Also, a relative indication of transistor gain can be observed on the emitter-collector ohmmeter.

First connect the emitter-collector ohmmeter with the lead polarity as shown in Figure 5-3C. The emitter-collector junction is back biased and should read a high resistance. Then connect the other ohmmeter to the base-emitter junction, using the correct ohmmeter polarity to forward bias it. This ohmmeter will show a low resistance and will turn on the emitter-collector junction, causing that ohmmeter to change from high to low resistance.

Unijunction transistors (UJTs) can also be checked using an ohmmeter. Figure 5-3D shows the symbol and resistance equivalent of the UJT. If you think of the UJT as a diode connected to the junction of two resistors, an ohmmeter check seems quite logical. The ohmmeter when connected between base 1 and base 2 will measure a fixed resistance regardless of the polarity of the ohmmeter leads. Connect the ohmmeter to the emitter and to each base as shown in Figure 5-3E.

Ohmmeter measurements can be made on field effect transistors (FETs) with some degree of success. Figure 5-3F shows the symbols of junction type field effect transistors (JFETs) and their equivalent internal resistances. A drain-to-source ohmmeter measurement will show a fixed resistance, about 100 to 10,000 ohms, regardless of the ohmmeter polarity. The gate to drain or source resistance is identical, depending on ohmmeter polarity as shown in Figure 5-3F. In the forward direction the gate will measure around 1,000 ohms to the drain

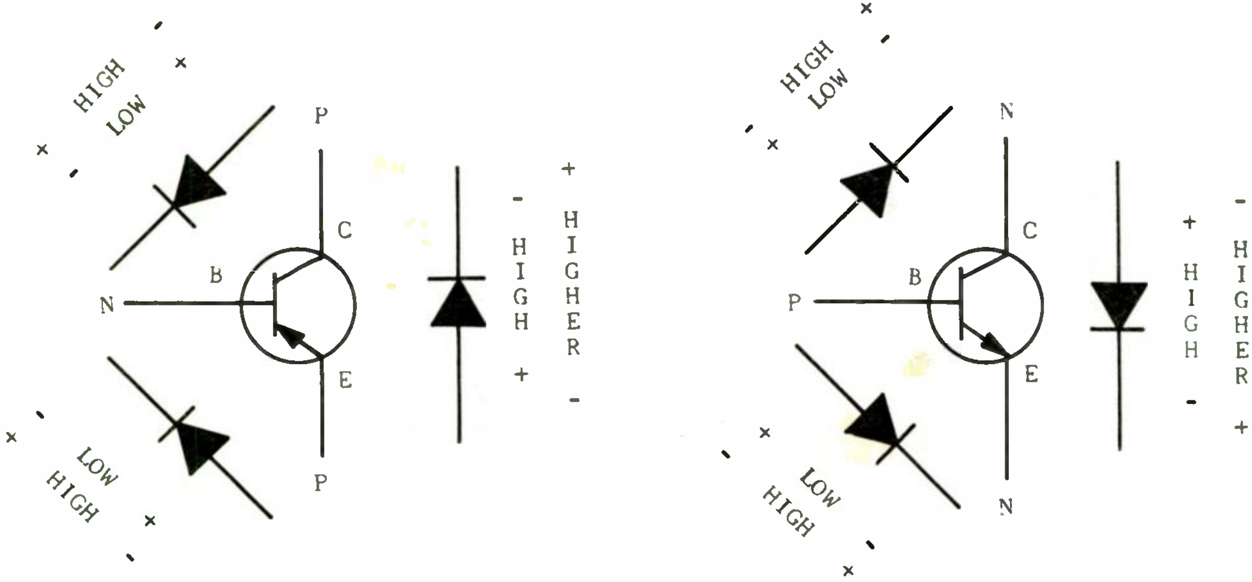


Figure 5-3B: Ohmmeter measurements of transistors

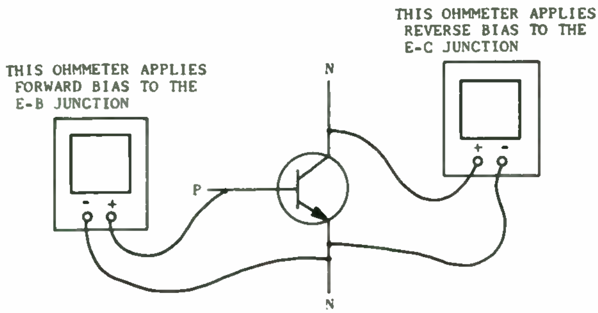


Figure 5-3C: Checking a transistor using two ohmmeters

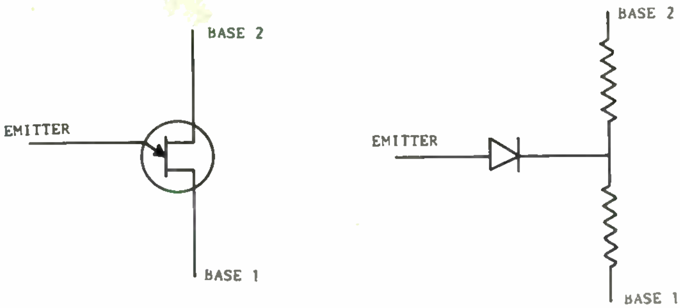


Figure 5-3D: The unijunction transistor

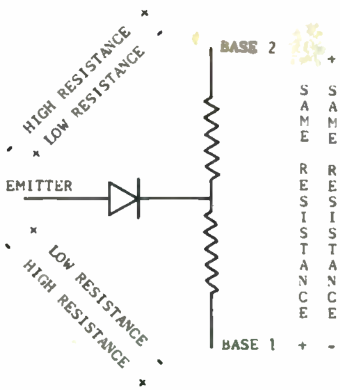


Figure 5-3E: Checking a UJT with an ohmmeter to check forward and back resistances

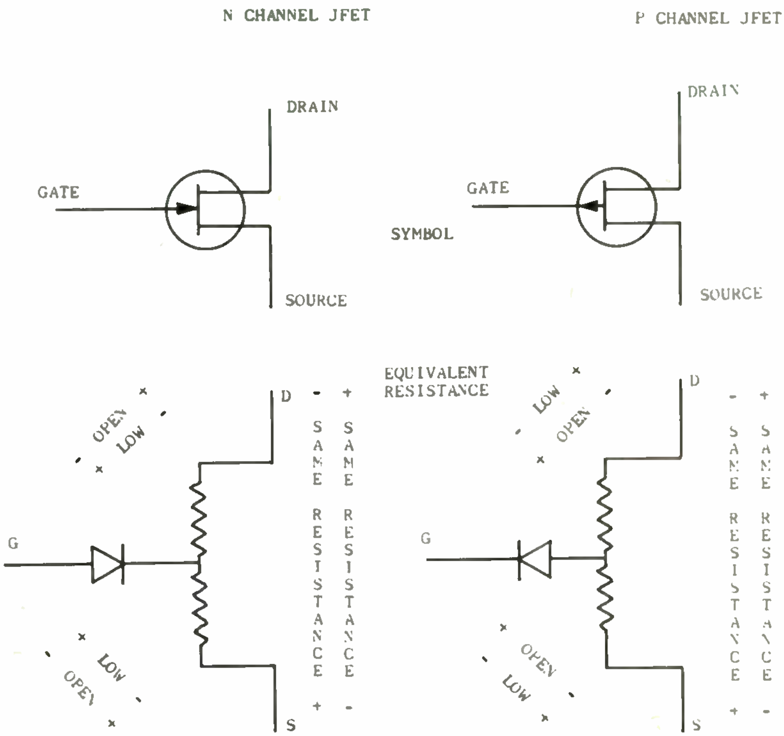
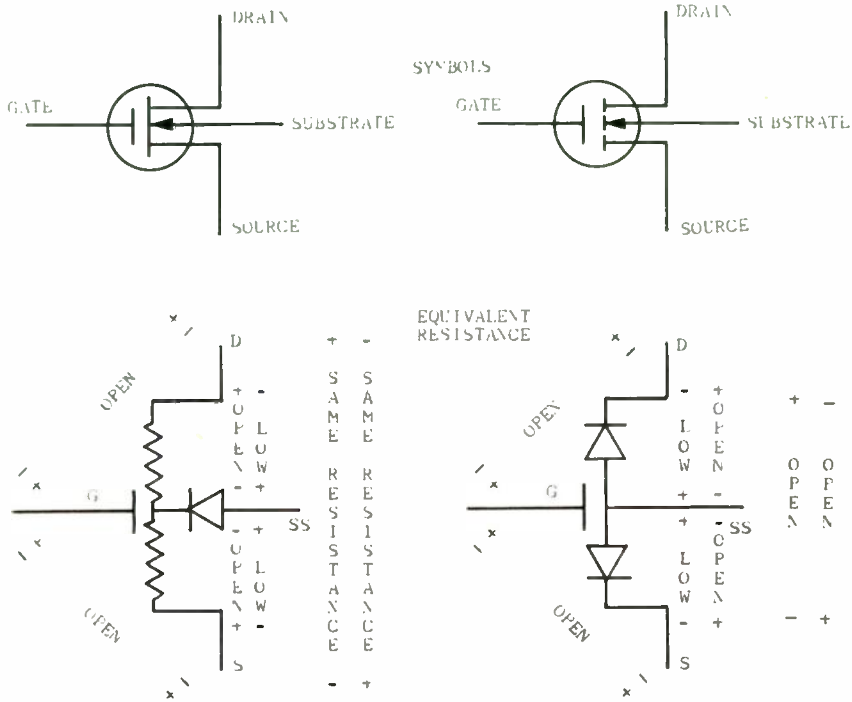


Figure 5-3F: Junction type field effect transistors

or source; in the reverse direction the gate will appear open because of its high impedance characteristics.

The metal oxide semiconductor field effect transistor (MOSFET) can also be checked with an ohmmeter. Care must be taken when handling MOSFETs because of the small gate-channel-capacitance. Any static voltage can easily puncture the thin insulation film between the gate and channel. It's a good practice to wrap tinfoil around the leads while the MOSFET is out of the circuit. You should work on a grounded metal plate, keeping your arms in contact with the surface. The soldering iron or gun element should also be kept grounded.

Figure 5-3G shows the common symbols for two types of MOSFETs and their equivalent resistances. The gate will always appear open regardless of ohmmeter polarity. The other possible ohmmeter readings are shown in Figure 5-3G. The internal diodes generally will



A. DEPLETION/ENHANCEMENT MOSFET

B. ENHANCEMENT MOSFET

Figure 5-3G: Metal oxide semiconductor field effect transistors

measure around 1,000 ohms in the forward direction and open in the reverse in both types of MOSFETs. The drain-to-source resistance in Figure 5-3GB should be between 100 and 10,000 ohms.

Remember, resistance testing of solid-state devices is not always a foolproof test. Resistance measuring very often will detect defective transistors and diodes, especially in go-no-go situations, or give the technician an indication of the trouble that he otherwise may not have known. When in doubt as to the quality of any solid-state device, the ultimate check is substitution with a known good component.

5-4. EASY-TO-MAKE VOLTMETER CHECKS OF TRANSISTORS

Voltage checks on the transistor elements are fast and easy to make and often lead the technician to a defective circuit or transistor.

Generally in transistor equipment, capacitors have the highest failure rate, with transistors second and diodes third. Nevertheless, the transistor is an excellent place to make voltage measurements since most troubles will show as a voltage change on the transistor elements.

Very often an obstacle confronting a technician in making transistor voltage checks is the lack of service information. Is it an NPN or a PNP? Which is the emitter, base, and collector? These are the questions which must be answered before making voltage checks. It would be nice if all manufacturers followed a standard basing policy, but they don't. There are all kinds of shapes, sizes and arrangements of transistor packaging. The best bet is to have up-to-date basing guides which are available from transistor manufacturers. Figure 5-4A shows the most common transistor basing arrangements. Generally the basing

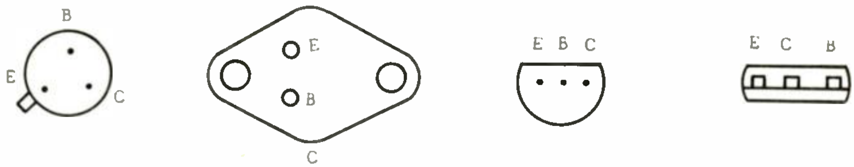


Figure 5-4A: Common transistor basing arrangements (bottom view)

arrangement follows an emitter-base-collector pattern. Power transistors usually have their case or heat sink connected to the collector. Confirm it with an ohmmeter check.

If you can't find the transistor type and the basing arrangement, you can usually determine this information with voltage measurements. The following ideas may help you to remember the correct voltage polarities needed on the transistor elements:

P.....Emitter.........needs a positive voltage.

N.....Base...........needs a negative voltage (less positive).

P.....Collector ......needs the most negative voltage (least positive).

N.....Emitter.........needs a negative voltage.

P .....Base...........needs a positive voltage (less negative).

N.....Collector ......needs the most positive voltage (least negative).

Notice that the emitter and base need the same voltage polarity as their material letter. The collector always needs the opposite voltage polarity of its material letter.

Suppose you measure + 5V on one transistor lead, + .5V on another element, and + 1.1 V on the remaining lead. By analyzing these three readings you can determine the basing arrangement and type. The first reading, + 5V, is the most positive voltage and could be the collector of an NPN transistor. The second reading, + .5V, is the least positive or most negative reading, indicating it is the NPN emitter. The last element must be the base and + 1.1 V confirms it. The base of an NPN transistor needs a positive voltage but not as positive as the collector. The transistor is an NPN type and the basing is identified.

The heart of transistor voltage measurements is the forward bias voltage needed between the base and emitter to turn on the transistor. A germanium transistor needs about .25 V between the base and emitter for forward bias. A silicon transistor needs about .6 V for forward bias. When the forward bias (base-emitter voltage) is missing or low, the transistor is turned off. A voltage check showing erroneous forward bias indicates a defective bias circuit or a bad transistor. The forward bias for the transistor described in the previous paragraph is .6 V, indicating the correct bias for a silicon transistor.

The elimination or addition of forward bias can be used as a troubleshooting aid when measuring transistor voltages. Here is an example of eliminating forward bias: The forward bias on a transistor is correct but the collector voltage seems high. Monitor the collector voltage while jumping a clip lead between the emitter and base. This immediately removes forward bias and turns off the transistor. If the transistor had been working, the collector voltage would increase close to the supply voltage. If the collector voltage shows no change, the collector-emitter circuit must be defective.

The opposite case is to add forward bias when it is missing. This may turn on the transistor and return the circuit to normal operation as if by magic. When a transistor has no or low forward bias try this technique: Connect a 10K resistor between the collector and the base. This will usually turn on the transistor. Monitor the collector voltage; it should drop as the transistor is forward biased. If this happens the trouble has to be in the bias circuit supply. The transistor is okay.

Transistor voltages can be measured in respect to a common or a ground point. They also can be measured from element to element. Either measuring technique is fine as long as the results are evaluated correctly. Both types of measurements will produce identical readings. Referring to Figure 5-4B, using the common ground method of

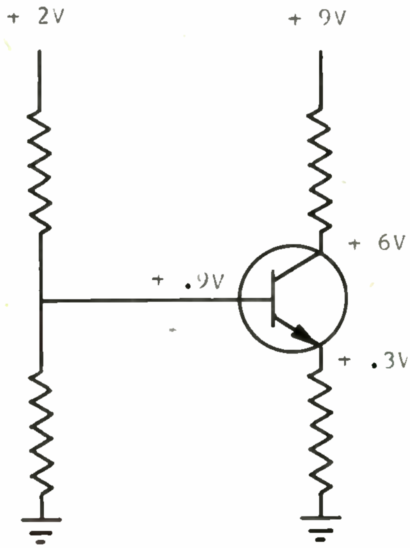


Figure 5-4B: Normal voltage measurements in an NPN circuit

measuring voltages, the base to ground would measure + .9 V; the emitter to ground would measure + .3 V. The difference between these two voltages is the forward bias, + .6 V. In the element-to-element method, the common voltmeter lead would be connected to the emitter and the positive voltmeter lead connected to the base. The forward bias would be measured directly, again + .6 V.

Measuring the collector voltage using the common ground method would show + 6 V. Using the element-to-element method, the measurement would be made from the emitter to the collector, + 5.7

V. Then measuring across the emitter resistor would read + .3 V. Adding these two voltages together gives the same collector voltage, + 6 V.

High impedance multimeters, VTVMs, or DVMs, are great for measuring transistor voltages. Almost all the latest voltmeter models have very low voltage ranges. A typical meter of this type will start with a full scale voltage range of 100 MV. With the use of these sensitive meters, small changes in bias voltages are easy to spot.

5-5. IN-CIRCUIT TRANSISTOR CHECKS WITH AN OSCILLOSCOPE

Many transistors can be checked in the circuit, using a simple curve tracer and service type oscilloscope. The curve tracer can be constructed inside the scope's case with appropriate jacks brought to the outside, or as a separate test instrument. The major parts needed for the tracer are a 6.3 VAC filament transformer, SPDT switch, a couple of resistors, two test prods and some test lead wire. Figure 5-5A shows the schematic for the curve tracer.

Operation of the curve tracer is simple and straightforward. The equipment power to the transistor circuits should be off. Connect the curve tracer to the oscilloscope as shown in Figure 5-5A. Then with the test prods touch the various transistor leads, comparing the scope waveforms with the waveforms shown in Figure 5-5B. The key area of the waveform is the knee of the curve. A sharp change in direction at the knee indicates a good junction. If the knee is rounded, the junction has leakage. If there is no change in direction on the waveform, the junction is shorted or open. Check each junction of the transistor: emitter-base, emitter-collector, base-collector. The majority of transistors can be checked reliably in the circuit, using this technique. The waveforms may be inverted or mirror images of those shown in Figure 5-5B. This is normal.

Occasionally a transistor will check *bad* in the circuit but *good* out of the circuit. It's a good policy to check suspected bad transistors out of the circuit before a replacement is made. The suspected bad transistor must be removed from the circuit anyway, so little time is lost. Many technicians make up their own set of junction waveforms for the transistors in the equipment they service. This simplifies determining good and bad junctions for the borderline cases and for those transistors which can't be satisfactorily checked in the circuit.

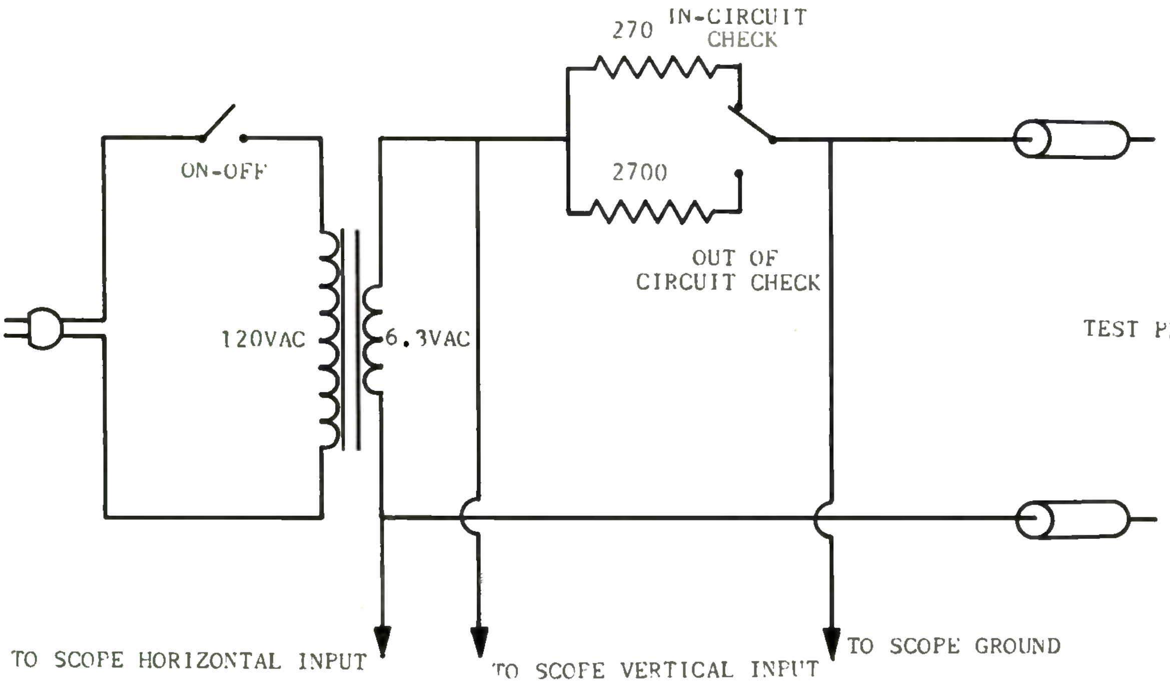


Figure 5-5A: Transistor curve tracer schematic

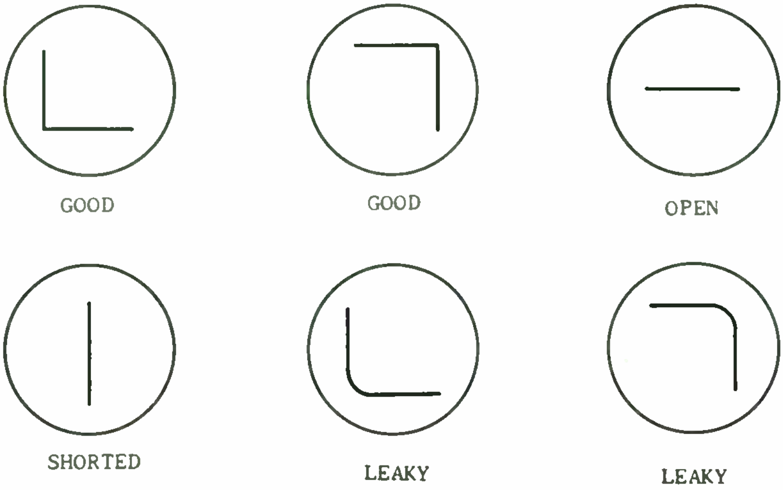


Figure 5-5B: Transistor junction waveforms

5-6. HOW TO TEST SILICON CONTROLLED RECTIFIERS AND TRIACS

Silicon controlled rectifiers (SCRs) and triacs are excellent solid-state devices to control power. They are used in all types of electronic equipment, and like all electronic components, they sometimes fail. Many SCRs can be checked with the use of an ohmmeter. SCRs come in all types of packages (Figure 5-6A), but always have three active elements: the cathode, anode, and gate.

An SCR is simply a solid-state rectifier whose forward resistance is controllable. With no gate signal, the SCR acts like a rectifier with a very high resistance, both in the forward and in the back direction. When the proper gate signal is applied, the SCR will conduct in the forward direction like a conventional rectifier. It will continue to conduct until the anode voltage is removed.

To check an SCR, connect an ohmmeter as shown in Figure 5-6B. The resistance between the anode and cathode should be very high regardless of the ohmmeter polarity. Then temporarily short the anode (connected to the positive ohmmeter lead) to the gate. The SCR should immediately turn on, showing a low resistance on the ohmmeter, and should continue conducting even after the gate lead has been removed from the anode. Once the anode-cathode circuit begins conduction, the gate has no control. Now removing either of the ohmmeter leads, even

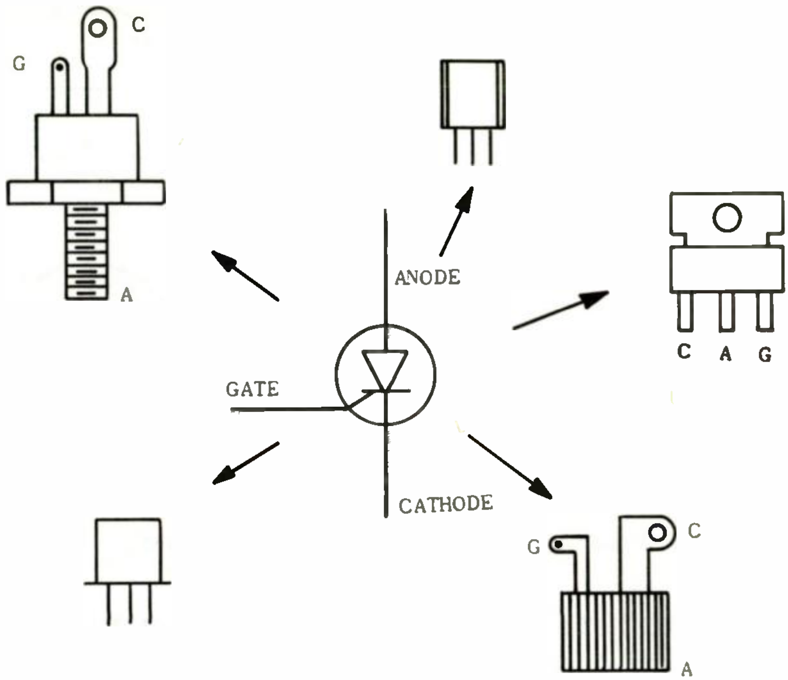


Figure 5-6A: Silicon controlled rectifiers

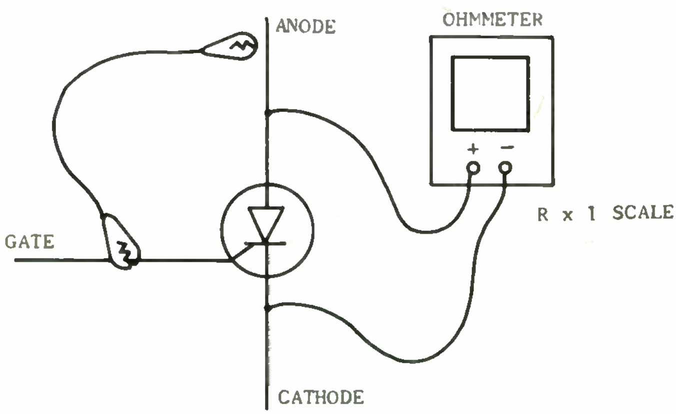


Figure 5-6B: Checking an SCR using an ohmmeter for an instant, will turn off the SCR and it will return to its high resistance original condition.

The triac is a thyristor which acts like two parallel SCRs (one inverted) with a common gate. The triac can be turned on exactly like the SCR as well as being turned on with the opposite polarities on the anodes and gate.

Figure 5-6C shows how to check a triac using an ohmmeter. Connect the positive ohmmeter lead to anode 2 and the negative lead to anode 1. The resistance reading should be very high. Then momentarily short a clip lead between anode 2 and the gate. The triac should turn on and stay on even with the gate lead removed. The ohmmeter will show low resistance. If the triac passes this test it is one-half checked. To check the other half of the triac, interchange the ohmmeter connections. Again the resistance reading should be high. Now momentarily short the gate to anode 2 and turn on the triac in the other direction. The ohmmeter will read low resistance and stay that way with the gate open until one of the ohmmeter leads is removed. This completes the triac check.

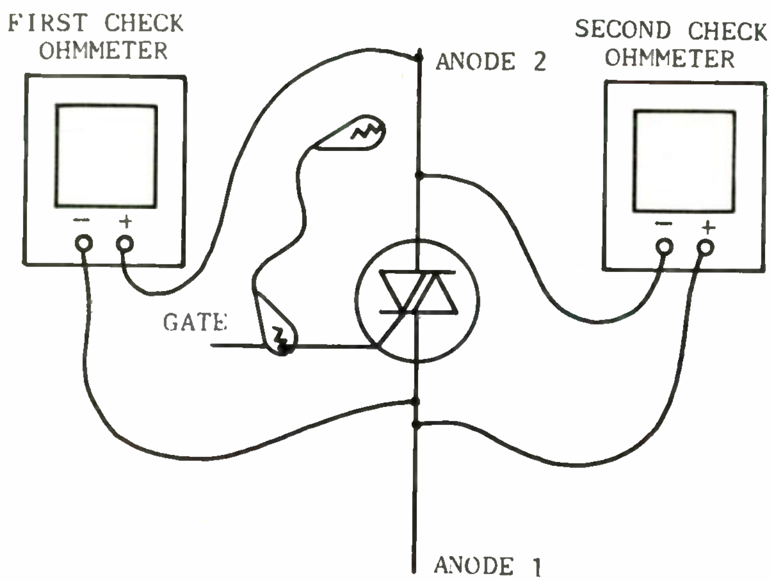


Figure 5-6C: Checking a triac using an ohmmeter

Occasionally you may find an SCR or triac which can't be turned on with an ohmmeter because of insufficient ohmmeter current. The R x 1 range generally provides enough gate current to fire the thyristor. On the other hand, the current from the R x 1 range may be too high and damage a sensitive gate SCR. Use higher resistance ranges for these kinds of devices.

5-7. TESTING INTEGRATED CIRCUITS

Integrated circuits (ICs) can be tested in circuit or out of circuit when troubleshooting. If it is at all feasible, in-circuit testing should be tried first, because of the time involved and possible damage caused by removing the IC for an out-of-circuit check. There are specialized troubleshooting aids, such as logic clips and probes, available for in circuit testing of some ICs. These aids are great for checking some digital ICs, but usually they are quite expensive and not always available to some technicians, The following discussion will deal with practical ways to check ICs using conventional test instruments.

When troubleshooting IC circuits, whether they are linear or digital, keep in mind some basic points. An IC is really just a small compact set of circuits operating within conventional circuits that use common electronic components and conductors. The technician can not be too concerned with what is happening inside the IC; you can not take measurements or replace parts on the inside of an IC.

The technician must concentrate on the external factors which are required to make the IC perform. Are power supply and other DC voltages correct and within specifications when measured on the pins of an IC? Is the proper AC or DC signal available at the input or inputs of the IC? If the proper input signal is there and the DC voltages are okay, is the IC output correct? These kinds of external measurements will give the best information to the technician so he can evaluate whether the trouble is in the external circuit or the IC.

Once the trouble has been localized to a particular IC and associated circuits, an ohmmeter (especially a low voltage ohmmeter as discussed in section 5-3 of Chapter 5) can very often be used to make meaningful checks. Many times when an IC does fail, it will be a catastrophic failure such as a dead short or complete open which can be detected easily with an ohmmeter on the IC pin connections. Suppose the technician is repairing equipment that has failed because of a defective flip-flop in the circuit shown in Figure 5-7A. The trou-

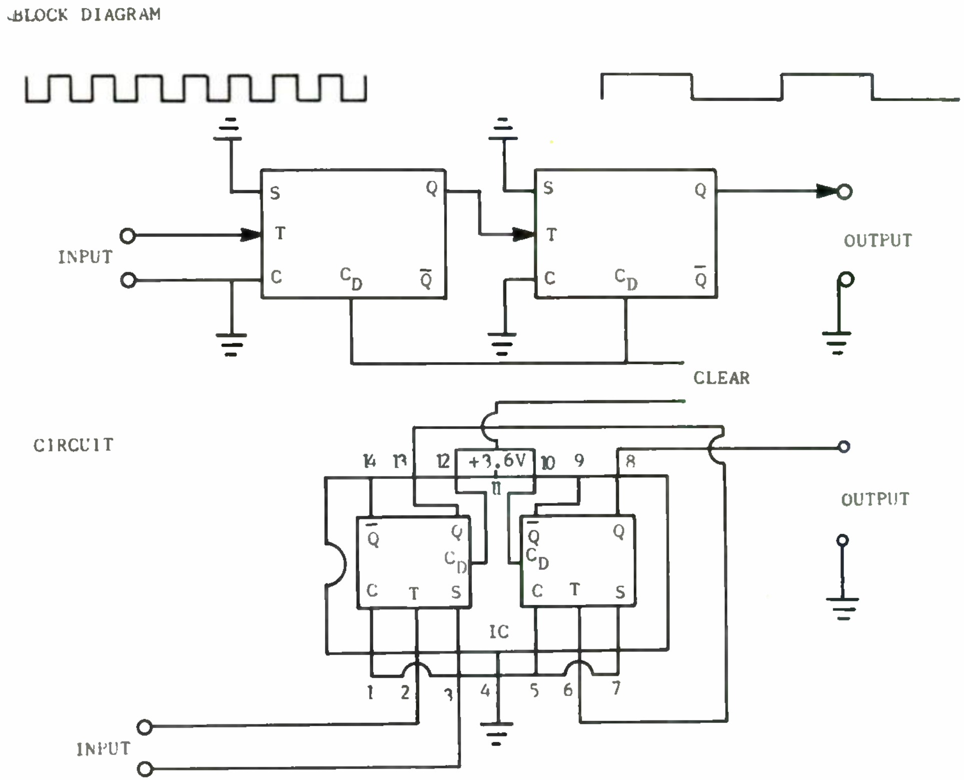


Figure 5-7A: IC divide-by-four block diagram and circuit bleshooter understands the operation of a divide-by-four circuit. He knows that eight input pulses are necessary to obtain two output pulses. Using an oscilloscope, the technician has traced the problem to the divide-by-four IC. All the input pulses are present and correct but the output, pin 8, stays at ground. The intermediate output, pin 13, also stays at ground. The technician makes a voltage check at pin 11 for + 3.6 V. That's okay. He then checks the voltage on the clear line, pins 10 and 12, to make sure it's not turning off the divide-by-four with a positive voltage. The clear line measures zero; it's okay. Next, he makes a resistance check and finds all the ground connections, pins 1, 3, 4, 5 and 7, are connected and have continuity. Pins 13 and 8, the outputs, are still grounded.

Now let's review what the technician knows:

1. The input signal is okay.
2. Power supply voltages are correct.
3. The clear line is not the trouble.
4. All grounds have continuity and are connected.
5. The outputs stay grounded (pins 13 and 8).

All the external signals, voltages, and resistances are normal; the IC must be bad. The divide-by-four IC is replaced and the circuit returns to normal. Notice the technician had no problem troubleshooting this circuit even though he may not have understood the internal circuitry of the IC.

Let's take a look at the other main type of IC—the linear integrated circuit. Figure 5-7B shows a general purpose four-transistor array IC used as an audio preamplifier. Troubleshooting this type of IC circuit is straightforward and much like any transistor amplifier. Scope the input to determine if the signal is getting to the IC. Then scope the output, which should be an amplified version of the input. Suppose the output waveform is missing. If the signal is at the input, then scope the signal as it passes through the amplifier until it disappears. The waveform at pin 9 should be almost identical to the input waveform. Then scope pin 2, which will show an amplified version of the signal. The output of the next transistor, pin 1, should be scoped. Again the signal should be an amplified version of the previous one. Then scope pin 7. Here's where it turns up missing.

The signal has passed through the IC until the last transistor. Looks like a bad IC. Don't pull out the IC yet. First check the power

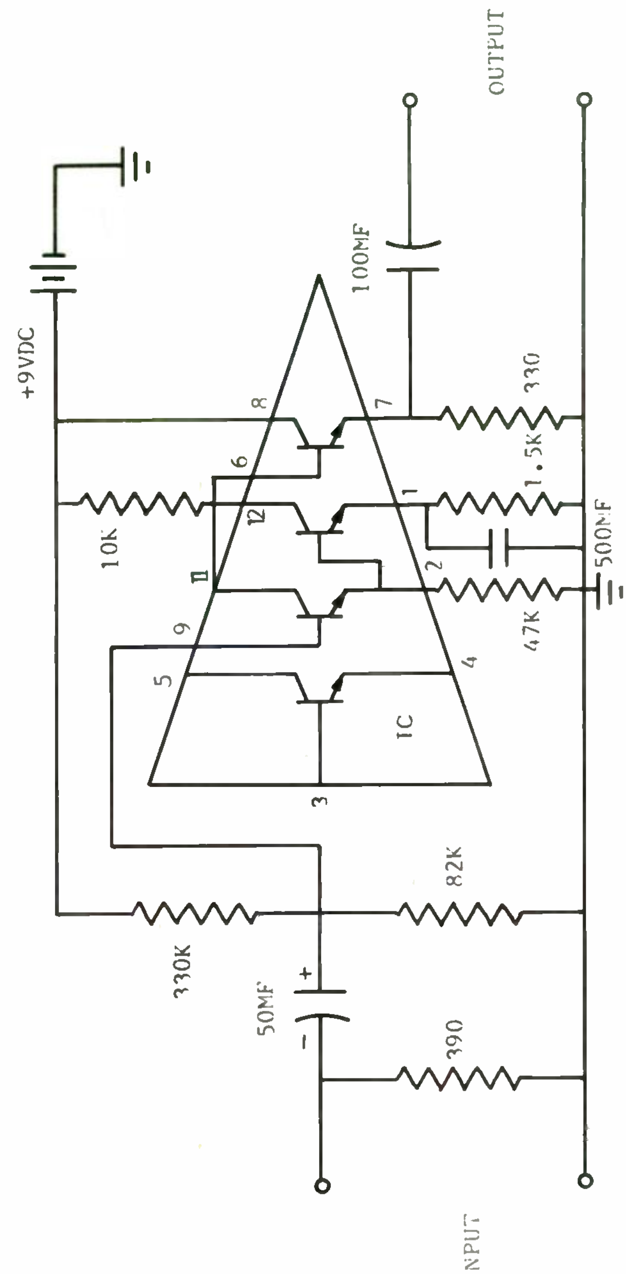


Figure 5-7B: IC audio preamplifier circuit

supply voltage. It measures + 9 VDC at the top of the 10K resistor and O V at pin 8. A careful examination of the connection between pin 8 and the circuit board reveals a cold solder joint. Reheat the joint to boil out the excessive flux; add a little more solder and the amplifier works like new.

Suppose you did measure the + 9 VDC at pin 8. The trouble still could possibly be external to the IC. The 100 MF output capacitor may be defective or there may be bad connections to the 330 ohm resistor. Check them out. Finally, if everything external to the IC is okay, then run an ohmmeter check on the final transistor (5-3, Chapter 5). Normally at this stage you would have to pull out the IC if the final transistor checked bad. However, in this IC you will find an extra transistor that you may be able to utilize with a little rewiring.

6

Key Steps to Soldering and Desoldering

Soldering is an art which can make or break any electronic repair or construction job. If the right tools and techniques are used, soldering is a breeze; when the wrong ones are used it becomes a nightmare. Electronic kit manufacturers claim that 90% of the completed kits returned for repair are due to bad connections and soldering. Troubleshooting equipment with cold solder joints is one of the toughest kinds of repair work for technicians.

Desoldering has also become a skilled and important part of the technician's duty. With printed circuits, integrated circuits and miniaturization in electronics, desoldering and removing parts can be really tough. Many printed circuit boards cost a fantastic amount of money; yet components with fourteen leads or more have to be removed and replaced without damage to the rest of the board.

The choice of tools and methods often determines the success of a soldering or desoldering operation. New and better tools are becoming available every day for specific applications. In this chapter, common-sense practical ways to solder and desolder are discussed. With a little ingenuity and practice you might be able to make a first-class desoldering and soldering job that originally seemed impossible.

6-1. HOW TO USE THE RIGHT SOLDERING TOOL

What should you use, a soldering iron or a soldering gun? It's simple; if you are only making a few solder joints, as in repair work, your best bet is the fast heating gun. On the other hand, if you are going to be soldering for hours or days as in construction work, then use the iron. Even the few seconds it takes for a gun to heat is too long to wait when you have a lot of soldering to do.

The perfect solder joint is smooth, with a uniform coating of shining solder. The rosin core flux has been boiled away, and all the connections on the joint can be seen but appear to be one. If you apply too much heat, the wire insulation will melt back or parts will be overheated; too little heat and you have a cold, crystalline, grainy solder job.

The wattage written on the gun or iron is the clue for proper selection. If you are trying to solder a ground terminal connected to five or six wires or parts, use a large wattage gun or iron. Two or three hundred watts may be necessary if the terminal is fastened directly to the chassis. The chassis acts like the heat sink, and unless you have enough heat it will absorb the heat as fast as you apply it. If there are parts tied to the terminal which could be damaged by excessive heat, clip a heat sink between the terminal and the part (an ordinary alligator clip makes a good heat sink).

Most wiring connections can be made with a 30 to 50 watt soldering iron. The secret for good results from any gun or iron is getting good heat transfer from the heating element to the soldering tip. Most soldering irons have tips which screw into the heating element. The tip threads will eventually oxidize and bond to the element unless periodic care is taken. Often an iron will not give maximum heat because of the thermal contact resistance between the tip and the element. Generally all that is needed to break this resistance is to loosen and tighten the tip a couple of times. Some soldering iron manufacturers recommend an antiseize compound which helps to prevent the tip from becoming fused to the element. Every twenty or thirty hours of iron use, remove the tip and reapply the antiseize compound to the threads. Soldering gun tips will often oxidize where they are fastened to the gun, causing loss of heat transfer. The gun body will heat instead of the tip. Loosening and tightening the connecting screws or nuts a couple of times will eliminate this problem.

Keeping the soldering tip clean and tinned is very important to good soldering. A damp sponge, rag, or paper towel makes a good wiper for soldering tips. Copper tips should be filed to shape when they become pitted. Before you file the tip, make sure you are not using an ironclad tip. This type of tip should never be filed because filing removes the thin iron cover.

Follow these soldering pointers for professional soldering results:

1. Make sure the connections to be soldered are physically tight and clean.
2. Tin the cleaned soldering tip with a small puddle of 60:40 tin-lead rosin core solder.
3. Position the soldering tip, if possible, at the bottom of the joint so gravity will help the solder flow.
4. Keep as much contact as possible between the soldering tip puddle and the connection surface for quickest and maximum heat transfer.
5. Apply solder to the top of the joint. The solder should melt almost immediately and flow downward and over the joint towards the soldering tip. Use just enough solder to thoroughly wet the connections.
6. Remove the tip and solder, making sure the joint does not move until the solder has hardened. If you want to speed up the solidifying time of the solder, touch the joint with a wet finger.

Small wattage irons, 20 to 30 W, and tiny tips are a must for printed circuits and integrated circuits. Many of these irons have interchangeable tips for various kinds of fine work. Tips 3/64-inch in diameter are common. The shape and the size of the tip are also factors to consider when soldering. There are straight tips and offset ones, chisel, pencil, pyramid, screwdriver, needle and spade tips.

Remember when buying a soldering iron that it should not only be the wattage and size you want, but it should also be easy to hold and well balanced. Even after the iron has been plugged in for hours, the handle should be cool enough to hold firmly and comfortably. Check to make certain that the element end of the handle has no metal fastened to it to burn your fingers.

6-2. TIPS FOR SOLDERING IN HAND-WIRED CIRCUITS

Although more and more electronic equipment is constructed with modules and printed circuits, there are still a lot of conventional hand-wired circuits around. Even equipment with printed circuits always has a certain number of components mounted off the board on the front panel or chassis.

One of the more difficult solder jobs some technicians have trouble with is the multiple connection with many wires or parts fastened to it. Keep in mind the following suggestions to make soldering this type of joint a lot easier: Start the first connection at the lowest point on the terminal strip or lug and fasten it securely with a mechanical connection. Connect the next wire or part directly above the first, again with a mechanical connection. Keep working up the terminal strip until all the connections are made mechanically. Then solder all of the connections at once with an adequate wattage iron. The finished joint will look as though it came out of a soldering factory!

Repairing older equipment often results in bad soldering. The primary reason is that all the connections and soldered joints have become oxidized and dirty. A thorough cleaning job is a must before new parts are soldered to old connections. Generally, a careful scraping of the old joint with a screwdriver blade or scratch awl is all that's necessary to clean it for resoldering. Occasionally you will have to use rosin paste flux if you just can't get the joint clean. Most manufacturers do not recommend the use of paste flux, but when soldering in old equipment sometimes it's necessary, especially when you are soldering old stranded wire or shielded cable where it's impossible to clean all the strands. Use as little paste flux as you can and heat the joint slightly longer than usual to boil most of the flux away.

You may have to make solder connections that are almost impossible. They are buried under wires or parts deep inside a chassis. Try to move the blocking wires and parts away from the area as much as you can without putting excessive strain on their leads. A soldering gun with a built-in light is really helpful for this kind of soldering. If you don't have enough room to heat the joint and apply solder at the same time, first tin the lug and then tin the part's lead. Wrap the lead around the lug with a longnose pliers; then heat the joint until the tinned solder melts on both parts and blends together.

6-3. GUIDELINES FOR SOLDERING PRINTED CIRCUITS

Soldering in printed circuits is several ways easier than hand-wired circuit soldering. First, the connections are all single; one lead fits in one printed circuit hole. Second, the parts are generally not in the way when soldering. The parts are usually on one side of the board and the circuitry on the other side. And finally, printed circuit connections are easier to clean for soldering. The flat ribbons of copper are easy to scrape clean with a screwdriver blade or small wire brush soldering aid. Steel wool does a good job of cleaning the copper strips, but also will short the printed circuit if not completely removed. If the printed circuit has other parts already soldered to it or is mounted in the equipment, it's not advisable to use steel wool for cleaning.

A 30 watt soldering iron is generally recommended for printed circuits. A higher wattage iron or gun may have enough heat to destroy the bond between the copper foil and the board. Position the soldering iron tip so that maximum surface contact is made between the tip, the foil, and the part lead. For fast and good soldering, it's important that the tinned soldering tip touch the foil and the part lead simultaneously. Add solder and the connection should be made almost instantly.

Fine or extra fine gauge solder will generally do the best job in printed circuits. Five-core solder with 60% tin and 40% lead, 20 gauge is the best all purpose solder. If you are going to solder a lot of IC connections, use smaller gauge solder. Solder as small as 34 gauge (.009 in.) is available.

Occasionally a printed circuit foil will crack from stress or be broken when removing a part. This can be repaired just by bridging the foil with some solder. However, the best method for repairing the break is to lay a small piece of hookup wire (22 gauge) along the broken foil so that each end of the wire extends about a half-inch beyond the break. Then solder the wire to the broken foil and the completed circuit will be stronger than the original one.

Often a part has to be replaced on a printed circuit and the part side of the board is tough to reach. Try this technique if there is a little space on the foil side of the board: Cut the bad part out and replace it on the foil side. Just position the part's leads along the correct foil strip and solder.

After you have completed a soldering job on a printed circuit, really "eyeball" the foil carefully. Look especially for solder bridges between closely spaced foils. A solder bridge as fine as a hair can waste a lot of time and do a lot of damage. A magnifying glass or a magnifying lamp can really be helpful for this kind of problem. If you are in doubt about a hair-like solder bridge, run a knife blade through the area where you think the bridge might be shorting. You won't hurt anything and if the bridge is there, the blade will remove it.

6-4. SUCCESSFUL WAYS TO REMOVE PARTS FROM PRINTED CIRCUITS

Removing parts from a printed circuit can be easy, or it can be hard, or it can be a disaster! Don't panic when you have to remove a fourteen-legged object from a circuit board. It's going to be tricky, but if you choose the right method it's going to be a lot simpler than you think. Read on for some tips, techniques and ideas on various methods to remove printed circuit components like a professional.

Let's start with the easy stuff first, like removing an object with only two leads (a resistor). Grab the resistor lead on the part side of the circuit board with the slotted end of a soldering aid (Figure 6-4A). Melt

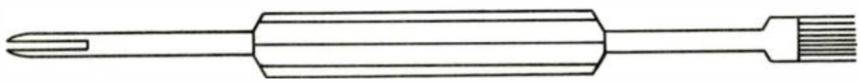


Figure 6-4A: Soldering aid

the connection on the foil side of the board while twisting and prying steadily with the soldering aid tool. Presto! In a few seconds the resistor lead will unsolder and can be pulled through the mounting hole to the part side of the board. Do the same with the other lead. Sometimes the leads are bent over on the foil before they are soldered. Don't try to pull the lead through its hole until you've straightened the bent end.

If you find it difficult to hold and pull on the part lead while heating the connection (you may not have room to work on both sides of the board at once), make the simple parts puller shown in Figure 6-4B. Just bend a strip of sheet metal into a U shape and drill a hole in the tip. Connect one end of a fairly stiff spring in the hole and slip the other end of the spring around the lead that you are going to remove. As soon as the connection is heated, the spring will pull the part lead free.

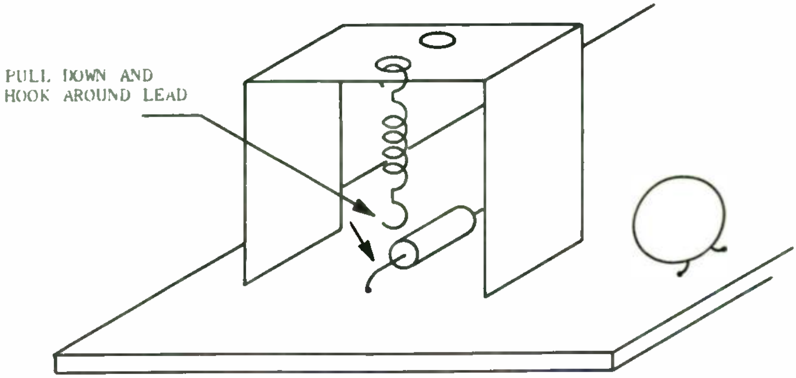


Figure 6-4B: Parts puller for printer circuits

Often a resistor or capacitor has to be replaced and the soldered side of the board is hard to reach without a big disassembly operation. Don't try to unsolder the part. Pulverize it with a longnose pliers leaving just the leads remaining. Hook the replacement part on the existing leads, solder, and the job is finished. It's a good idea to heat sink the pulverized part lead before soldering so the heat does not melt the connection on the printed side of the circuit (Figure 6-4C). If a component has completely opened, don't even bother to pulverize it. Just solder the new part in parallel with the open one and it's fixed.

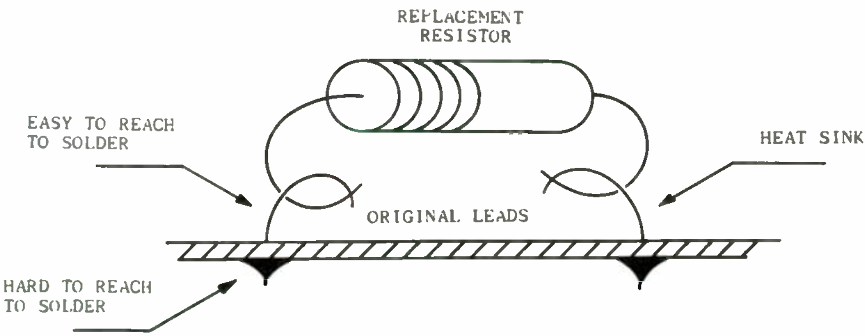


Figure 6-4C: Replacing a resistor on a printed circuit board using the original resistor's leads

Usually when a part is removed from a printed circuit, excess solder will flow over the part hole, blocking it for reinsertion of the new part. An easy way to find the hole is with a round tapered wooden toothpick. Push the toothpick through the mounting hole on the part side of the board and reheat the foil. As soon as the solder melts, the toothpick will push down easily through the hole, moving the solder away and leaving a clean hole.

One of the problems involved in desoldering printed circuits is locating the right foil path to melt. As soon as you look on the foil side, one conductor looks like another. X-ray vision would solve your problem. You can do the next best thing with a bright lamp or even a pen-light held close to the part side of the printed circuit. The light will make the board translucent and you can easily locate the right foil connection.

What do you do when you have to desolder a part with eight connections from a printed circuit? It's simple; just get eight technicians with eight soldering irons and the part will practically jump out! That's not the way to do it, but sometimes you do wish you had a few more hands. One method is to remove all the solder from each connection individually until all the leads are free. There are various ways to practice this technique. One method requires holding the printed circuit foil above the soldering iron so gravity will help the melted solder flow down from the connection to the iron. Another way is to suck the excess melted solder from each connection with a vacuum bulb. There are some soldering irons made with a built-in vacuum bulb especially for this operation (Figure 6-4D). Blowing through a soda straw will also move the solder away from the heated connection. Cover up the rest of the circuit so the solder doesn't short any other connections. Use braided shield wire for a solder sponge. Coat the shield wire with a light coating of paste flux and heat it along with the connection. The solder will flow from the connection into the braided wire, leaving the connection free from solder. You can brush excess solder away with a toothbrush or a soldering aid tool as shown in Figure 6-4A. All these desoldering methods work more or less. Just try to figure out which one would be the best for each particular application.

Another method that can be successful but that generally puts a lot of strain on the component and the board is the heat-and-lift technique. One or two connections are heated while a lifting force is applied to that section of the part. The heated connections will generally pull up slightly. Heat a couple more connections while applying force to that

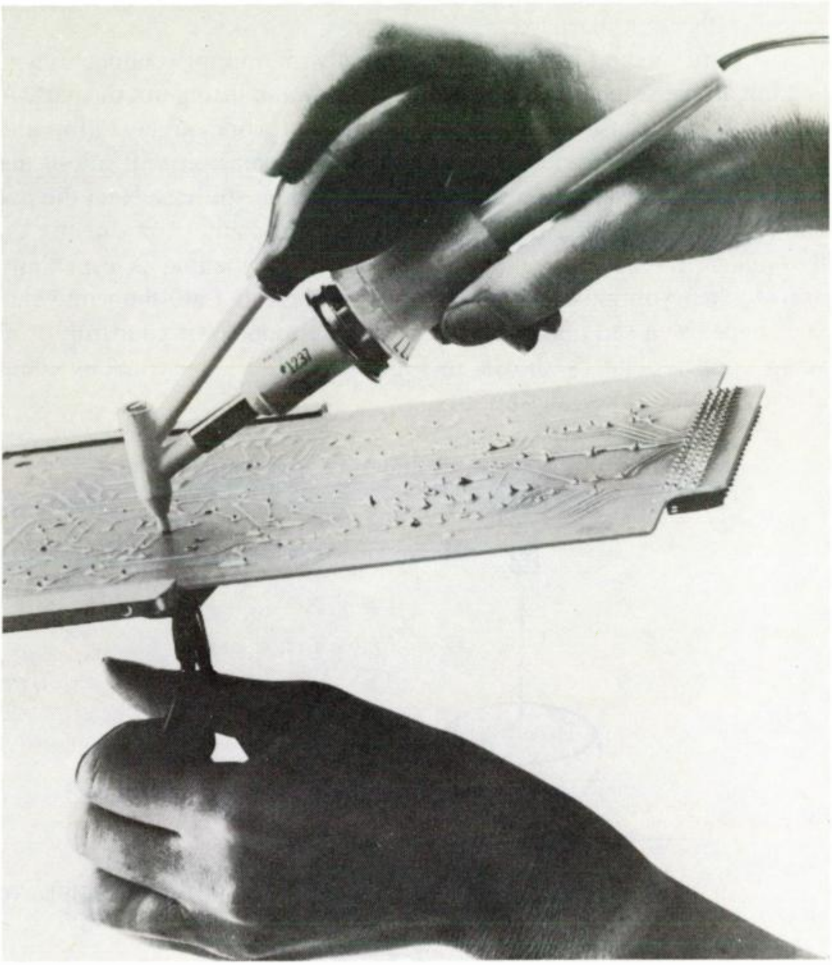


Figure 6-4D: Desoldering tool
(UNGAR, Division of Eldon Industries, Inc.)

section of the part. Keep on doing this around the perimeter of the part and eventually the leads will lift out of the printed circuit. This technique works best on components with four leads or less which are spaced rather far apart.

A third method used to remove parts with multiple connections is heating all the soldered joints simultaneously and lifting out the part. A small solder pot just the size of the component works great. Fill up the pot with as much solder as possible. Surface tension will allow the solder to mound above the rim of the pot without spilling. Heat the pot and when the solder is liquid, set the multiple connection directly on the solder mound and pull out the part. This method is especially useful when you have to remove a lot of parts that are the same size and shape. You can make various size solder pots to fit your iron from scrap copper plate as shown in Figure 6-4E, or you can buy them already made in desoldering kits.

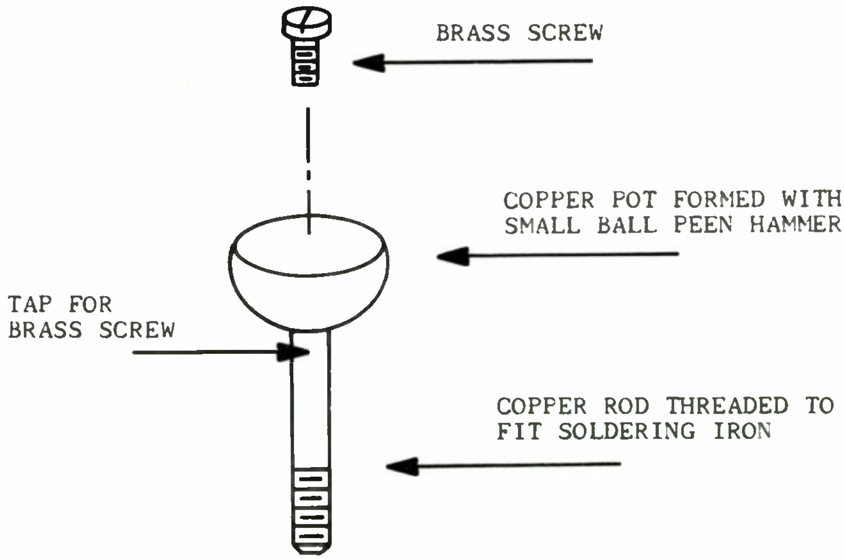


Figure 6-4E: Small copper solder pot

Another technique is to use specially made desoldering tips that have large and specially shaped heating surfaces. Some of the common ones are shown in Figure 6-4F. When you use these tips to remove parts, make sure that the component leads have not been bent over or crimped before soldering. If they have been, you will have to straighten each pin out individually before the desoldering tips will be successful. Before desoldering, make certain the tips have reached their operating temperature. Also tin the tip heavily so maximum surface contact between the tip and all the part leads can be made. If you make good initial contact with all the leads, it will take only a few seconds before the solder has melted and you can lift the part from the board.

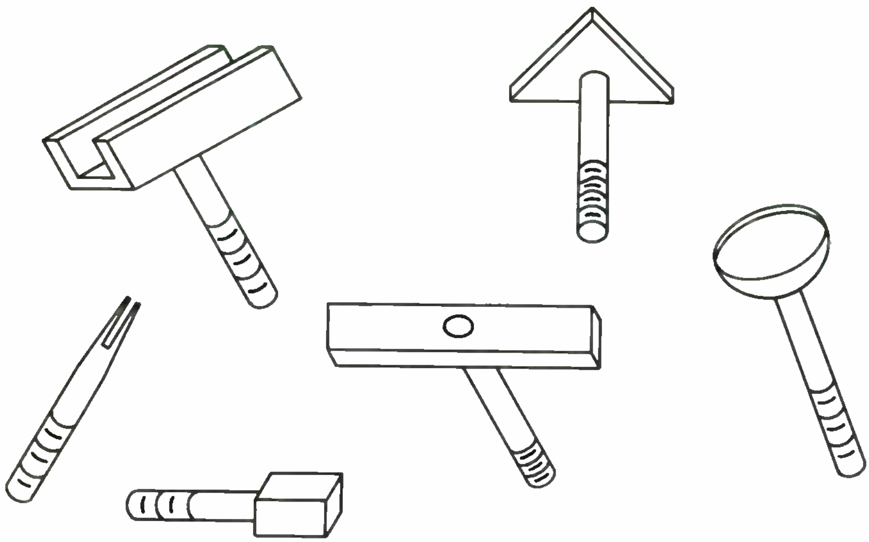


Figure 6-4F: Desoldering tips

Figure 6-4G shows a spring-loaded extracting tool made especially to remove in-line ICs. Lock the tool over the IC and heat the IC connections with a bar type desoldering tip. As soon as all the connections are melted the extractor will remove the IC.

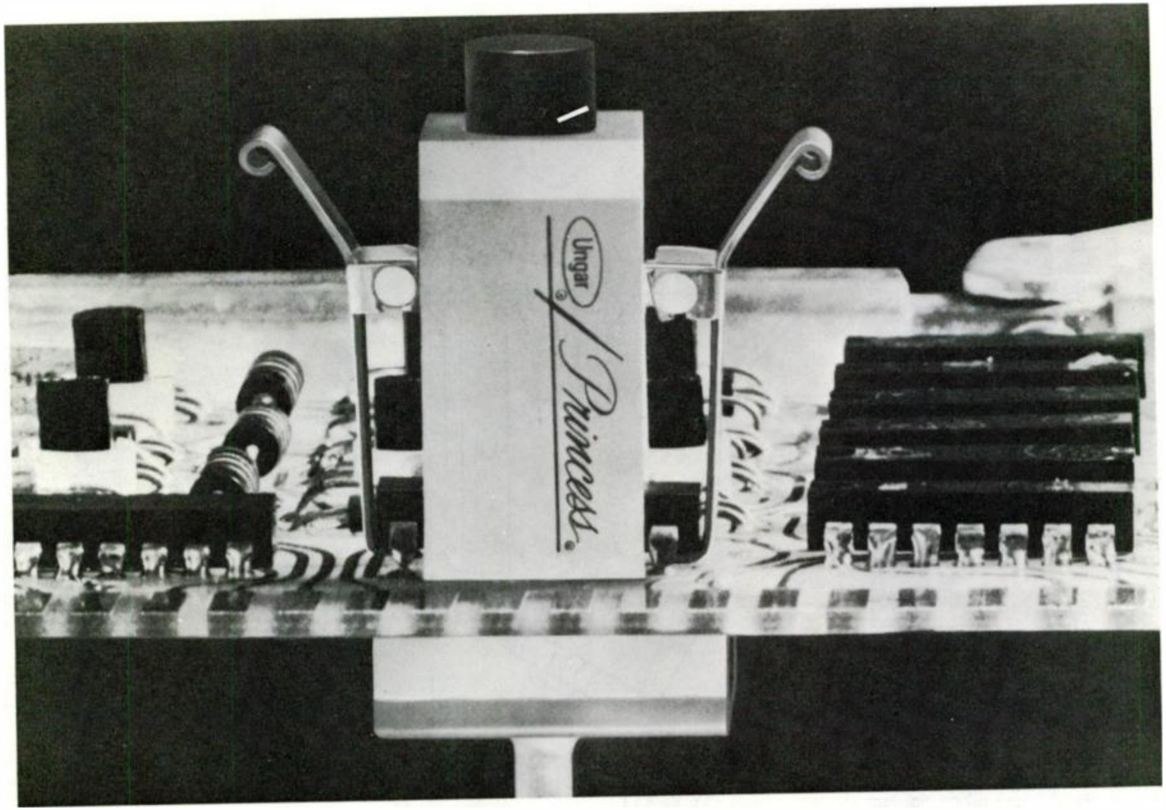


Figure 6-4G: Dual in-line IC extractor tool
(UNGAR, Division of Eldon Industries, Inc.)

7

Practical and Successful Wiring Methods

Did you ever look at the wiring of military electronics or high class industrial electronics equipment and marvel at the precision construction? They can be jampacked with components, wire and hardware, and yet everything seems to have its place. Service points are usually easily accessible even in the most compact chassis. There can be a hundred wires or more, but to the casual observer there appear to be only a few cables and harnesses here and there. This type of electronic construction has been well thought out and results from a team effort of engineers, technicians and construction workers.

It would be nearly impossible for a single technician to duplicate this type of construction while building an individual piece of equipment. However, in the following chapters there are certain techniques and suggestions that can be followed which will produce superior electronic construction projects.

7-1. HOW TO USE PROFESSIONAL WIRING TECHNIQUES

The following wiring techniques are recommended for electronic equipment construction which is not affected by stray wiring capacitance. Some of these wiring methods are not suitable in radio frequency circuits.

Before beginning to run wires between components, study the layout of the parts and terminal strips. Try to visualize a central path for all the wires to follow, branching off at various intervals to connect a series of components. Figure 7-1A shows a typical wiring layout

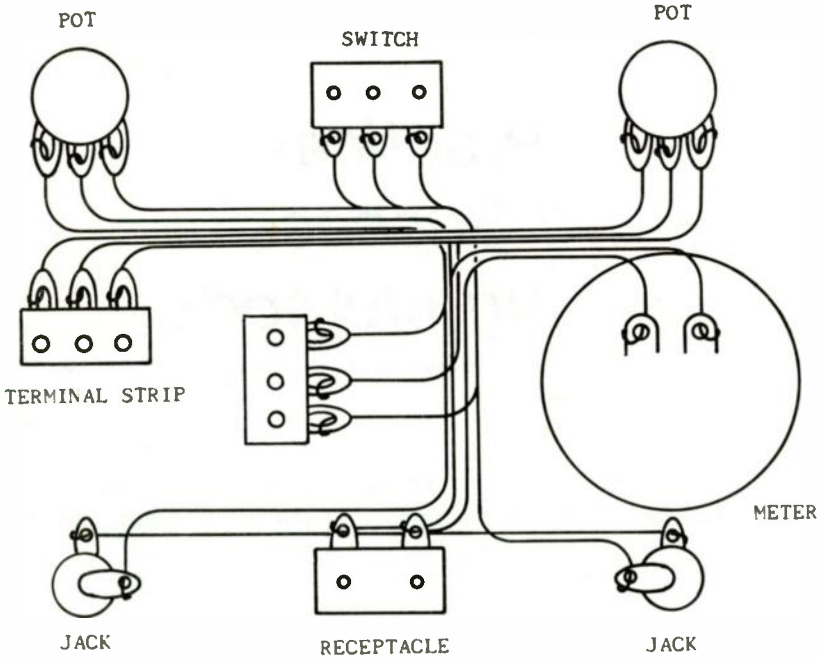


Figure 7-1A: Wiring layout

using this technique. Notice the main bundle developed in the center of the layout with branches leading horizontally to the various components. All single wires are run into groups and then into the main bundle. When it's not practical to have one main wiring bundle, use two or three.

The secret to a clean-looking wiring job is to make it appear as though there are very few wires connecting the parts. Keeping the wires in bundles is one way to create this illusion. Another method is to always keep the wires close to the chassis. Always dress the wire from a connection along the chassis and into a bundle (Figure 7-1B). Whenever you are running a wire by itself, there probably is a better way to reroute the wire so that it can be run with other wires. Keeping the wires close to the chassis and in bundles makes all the terminals and connections easily accessible for tests and troubleshooting.

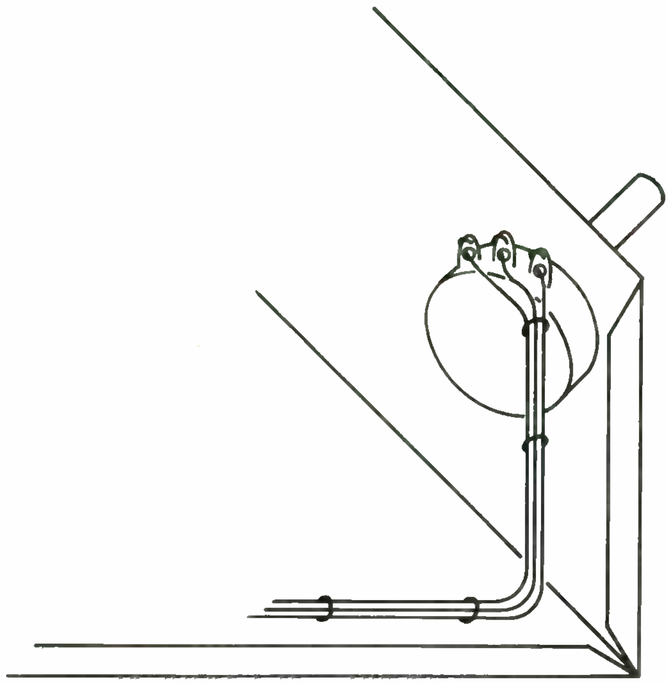


Figure 7-1B: Dress wires from the part to the chassis

In mass production of electronic equipment, the wire cables and bundles are made separately. The wires are cut to length, stripped, bundled and laced before installation. This method of producing wiring bundles ahead of installation really makes a neat wiring job, but generally is too time consuming for a technician who is making a one-of-a-kind electronic assembly. The technician will usually run the wires into rough bundles while soldering the connections. Then after all the soldering is finished, he will lace or tie the bundles together. A compromise between both wiring methods will produce an excellent cabling job. Here's all you do. Color code the wires so you can identify them, and cut them slightly longer than necessary. Fasten one end of all the wires to their connections. Then run the wires into bundles. Before connecting the other end of each wire, tie or lace the bundles. After the bundles are tied, then fasten the remaining end of each wire to its proper tiepoint. The bundles will look neat and uniform with no bulges from excessive wire.

A first class wiring job will never have any floating connections. Each connection, before it is soldered, should be mechanically anchored to a terminal strip, part lug, or other firmly fastened tiepoint. One end of a resistor connected to a wire is an example of a floating connection (Figure 7-1C). Another common floating connection is an

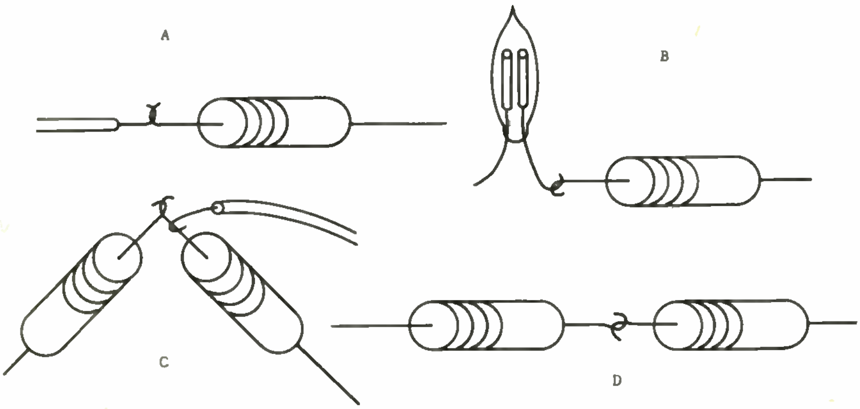


Figure 7-1C: Floating connections

NE-2 lamp lead connected directly to its current-limiting resistor. Two resistors connected in series is another example of connections that need a mechanical tiepoint. This floating type of construction is common in inexpensive electronic apparatus, and is often done by inexperienced electronic mechanics.

Another poor wiring technique is the overloaded connection. A terminal strip, lug, or whatever becomes a convenient tiepoint for a multitude of connections. Whenever an overabundance of parts and wires are fastened to one place, you've got a mess. Most of the time, good design and layout will prevent this from happening; for the cases where overloaded connections do occur, parallel some of the connections to one or more tiepoints.

Whenever you are wiring amplifiers or other devices which have very weak signals, keep the input and output wiring separated. Inductive or capacitive coupling can occur between parallel wires, causing undesirable feedback. Any 60 HZ power wiring should also be kept away from small signal-carrying wires. Twisting the pair of wires carrying line or filament current will minimize interference.

7-2. WAYS FOR MOUNTING COMPONENTS

One of the major obstacles in electronic construction work is mounting the parts so they are physically strong. Hookup wires and small components such as resistors, capacitors, diodes, transistors, etc., must be fastened to some type of rigid connection. Some electronic components have mechanically strong terminals which can be used for junction points. Sockets, potentiometers, switches, lamp assemblies, can capacitors and other similar devices have terminals suitable for making tiepoints.

There are many different types of terminal strips and posts (Figure 7-2A) which can be used for mounting parts. Often it's possible to

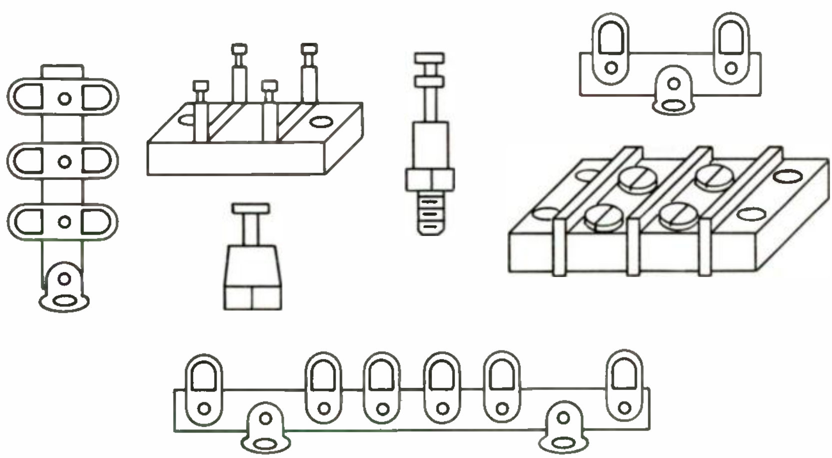


Figure 7-2A: Common terminal connectors

mount the terminal strips with an existing screw. For instance, the mounting screws of a power transformer make excellent places to fasten terminal strips. Most power transformers have four mounting screws which can also hold four terminal strips. Some transformers are held together with machine screws and nuts, again a ready-made place to connect terminal strips.

Fuse clips make great places to mount top-hat rectifiers; just snap them in like a fuse. Each fuse clip can hold two rectifiers. Use two fuse clips side by side for mounting the four rectifiers in a full-wave bridge circuit.

Mounting power transistors, SCRs and triacs to heat sinks can be a problem. Usually the case of these devices is connected to one of the active elements and must be insulated electrically from the heat sink. A mica washer, thermafilm insulating washer or anodized aluminum wafer should be used between the heat sink and the case. Don't forget to insulate the transistor mounting screws from the heat sink with hollow plastic spacers. For maximum heat transfer from the power device to the heat sink, use a thin film of silicon grease on the parallel surfaces.

Socket turrets and terminals (Figure 7-2B) are available with six, nine, and twelve terminals. Many times the circuitry of an entire stage

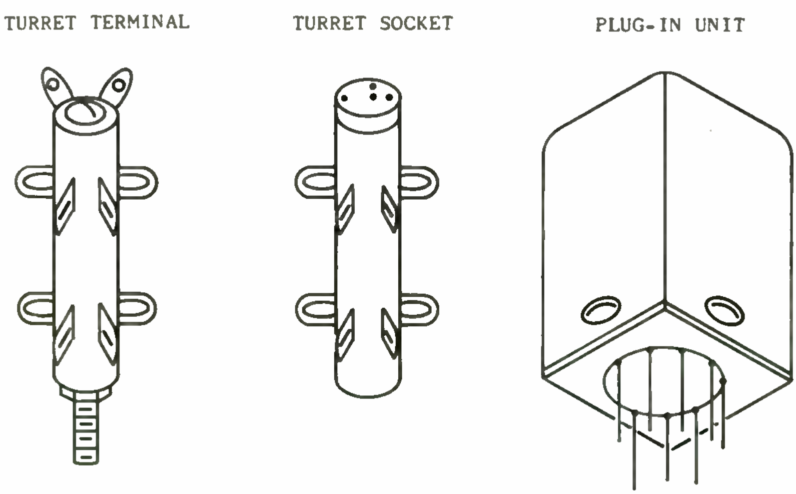


Figure 7-2B: Turret terminal, sockets, and plug-in units can be mounted directly on one of these turrets, making a clean, compact wiring setup. Turrets are made for transistors, tubes and plug-in units. Round and square plug-in units with an aluminum case make an excellent place to mount more components above the chassis. Some of the plug-ins have turrets in them, and some have cards with terminals. Plug-in units are made to fit all standard tube sockets.

If you are building a circuit with a lot of common connections or ground connections, use a buss bar along the length of the circuit. Generally one side of the resistors or capacitors is connected to a socket and the other side can be fastened to the buss bar. This is an easy way to furnish a mount for a lot of small parts.

Usually it is bad practice to mount components on top of other components. There are few exceptions. A resistor which is mechanically fastened at both ends can support a small parallel bypass capacitor fastened to its lead (Figure 7-2C). Another example is a

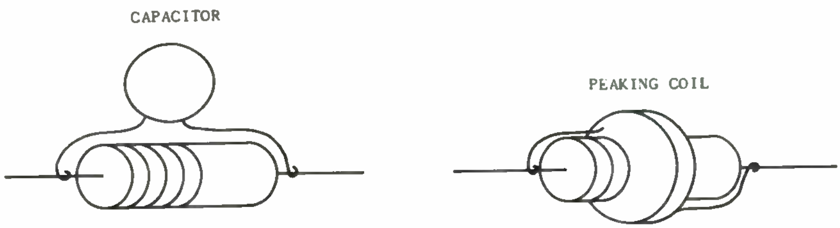


Figure 7-2C: Resistors used as mounting devices

resistor used for mounting a peaking coil. A parallel load resistor makes a perfect mount for the peaking coil.

Terminal boards make it easy to mount a lot of parts in a row. Most terminals are swaged on the non-terminal side of the board. When you fasten the board to the chassis, remember to insulate the bottom of the terminals or stand-off the board; then everything will not be shorted together.

7-3. GUIDE TO PARTS PLACEMENT

There are many factors to consider when deciding on the parts placement and layout for an electronic project. The following list shows some of the things which must be considered:

A. Chassis design
B. Front panel layout
C. Internal parts
D. Simplification of wiring
E. Electrical compatibility
F. Accessible test points

The final parts placement is usually a compromise solution resulting from careful consideration of all the listed items.

To some degree the kind of chassis determines the placement of the parts. Large items may fit in only one area of the chassis. The way the case is assembled and disassembled governs many of the positions of the parts. The easiest type of equipment to wire is one that is relatively open with room for your hands to work, and one that doesn't require cables between sections of the chassis. If you are building a console type cabinet with a sloping front panel, it means that all the parts should fasten to the front panel or to a sub-chassis which is connected to the front panel. Then, when the back and side sections are removed, there will be no parts or wires connected to them (see Chapter 9 for chassis construction).

The front panel should be designed for ease of operation, uniform component placement and pleasing appearance. Meters are generally placed highest so they are easy to see. Jacks and plugs are usually located close to the bottom so their leads will not interfere or cover up any other front panel component. If there are a number of switches, try to position the switches left to right in the order of their use. If lamps indicate switch positions, keep the lamp close to the respective switch, preferably directly above it. Fuses are often placed at the back of equipment but are convenient on the front panel.

If you construct a multipurpose instrument, keep all the controls for each section together. Another factor that sometimes is overlooked is knob size. Be sure to leave enough room between front panel components for the knobs, calibration marks and finger space. It's very irritating to try to turn a knob or control and not have enough space for your fingers!

Mount the internal parts behind the front panel or on the chassis section which is fastened to it. Large heavy components such as transformers should be centrally located, preferably near the bottom of the chassis to keep the instrument stable. Consider heat dissipation when placing power resistors, power transistors, heat sinks, tubes, or any device which consumes a lot of wattage. A large power resistor mounted close to a transistor case is going to be trouble. A simple method to dissipate the heat from a power resistor is to install the resistor without shortening the leads. Use the extra lead length to keep the resistor above the rest of the components. The location of heat sinks should be designed to minimize internal heat build-up. Often heat sinks can be mounted externally, or power transistors can be mounted to the outside of the electronic device.

Thoughtful positioning of the parts and terminal strips can eliminate excessive amounts of hookup wire. The ideal electronic circuitry would be designed so no connecting wires would be necessary. All connections would be made with the component leads fastened to the component lugs. Naturally the ideal wiring job can never be achieved, but you should always work to eliminate as many wires as possible. When you look at the layout of a complicated electronic project and notice very few wires, you can be sure that a lot of thought and effort has made this apparent simplicity possible.

When you install capacitors, precision resistors, or any other component whose value is marked on the case, position the part so its value can be read easily. It's no fun trying to check parts' values when all of the labels are turned inwards toward the circuit. Easy-to-read parts' values are also a great help in locating and identifying circuits when troubleshooting.

Another factor that always has to be considered and sometimes is overlooked is the electrical interaction of parts, leads, and chassis to each other. In DC or low frequency circuits this problem is seldom noticed, but in high frequency circuits unwanted capacitance, inductance, magnetic and electrostatic fields are always a problem. The layout of parts in these types of circuits is very critical, taking a lot of engineering time and the construction of many trial circuits before the bugs are worked out. Many electrical interaction problems can be minimized by keeping the inputs away from outputs, keeping small weak signals away from large amplified signals, twisting power line wires together, keeping magnetic fields at right angles to each other, and using shielded cable to minimize radiation.

Don't forget testpoints! Sooner or later every electronic device is going to malfunction and need repair. A pet gripe of most repair technicians is a lack of good, easy-to-reach-and-identify testpoints. Repair technicians know that many electronic devices seem to have been designed to make testing and troubleshooting especially difficult. What's a good testpoint? Any connection where meaningful voltage, current or resistance can be measured. Inputs and outputs to circuits, stages and sections are good troubleshooting points. Find the defective section first, then the bad stage within the section, and finally the circuit which is causing all the trouble.

Whenever you cover up a connection with parts or wires you have unintentionally hidden a testpoint. Every time a lot of components are jammed into a small area, troubleshooting becomes tougher. Identify key points with labels. An example of points which should be clearly labeled might include B+, B-, ground, inputs and outputs to key sections, and any place where significant voltage, current, resistance or waveforms can be measured.

7-4. METHODS FOR LACING AND WIRE HARNESSING

Lacing and wire harnessing put the final touch on an electronic project and turn an average job into a professional appearing job. There are a number of methods used to cable wires together. Some lacing materials cost practically nothing while others are fairly expensive. The finished wiring will always appear neater regardless of the lacing or harnessing method used.

Commercial electronic manufacturers lace their wires into bundles before installation. This is the best method to use for mass production, but is generally too time consuming for individual projects. Wires can be laced into bundles after all the connections have been made. This technique has shortcomings because some wires will be too short and others too long to conform properly in the bundle. The best method for one-of-a-kind construction is harnessing the wires after one end of each wire has been fastened. If the remaining ends of the wires are color coded or marked and kept slightly longer than expected, after cabling they can be soldered into place, which results in a professional looking job.

Probably the simplest cabling method consists of wrapping two turns of #22 gauge solid hookup wire around the wire bundle. Fasten the two ends together pigtail fashion, twist until tight, bend the pigtail over on itself and into the bundle (Figure 7-4A). Putting one of these ties every couple of inches makes a beautiful job. In all cabling methods the best final appearance will result if the wires in the bundles are positioned parallel to each other with minimum twisting before the bundle is cabled.

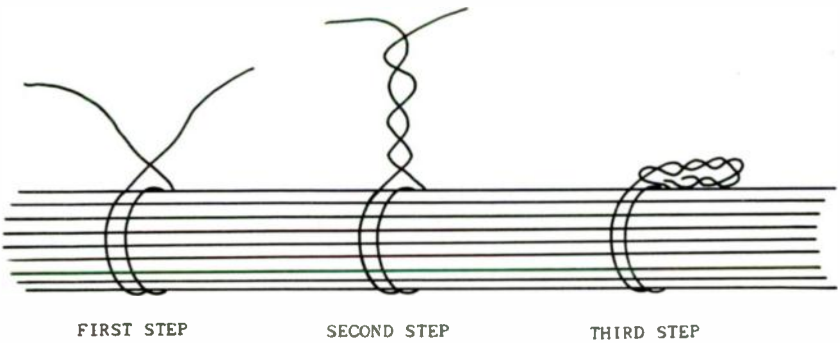


Figure 7-4A: Hookup wire cable ties

Nylon, linen, cotton and plastic are common materials used for lacing cords and tapes. A common error when lacing a wire bundle with a cord or tape is to connect each loop around itself instead of making a knot at each wrap-around (Figure 7-4B). The knot lace is far superior because if any wrap-around breaks or becomes loose, the remaining harness will still hold tight. Wire bundles that look professional have parallel wires (few twists), uniformly spaced loops, and the main connecting cord positioned parallel with wires on top of the bundle.

Figure 7-4B: Lacing techniques

Here's another simple way to bundle wires: Cut shrinkable tubing into 3/8-inch sections. Position the tubing sections at 2-inch intervals around the wire bundle. Then with a heat gun or soldering element shrink the tubing . . . and you have instant harnessing!

Plastic spiral wrapping also works great for cabling (Figure 7-4C). The spiral wrapping has the added advantage of providing some

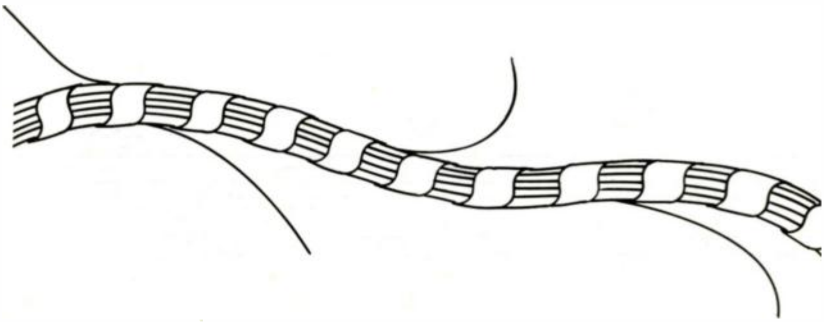


Figure 7-4C: Spiral wrapping harness

mechanical protection for the bundle. Wires can enter or exit anywhere along the spiral wrap. Wire additions are fairly easy to add to the bundles using this material.

Cable ties are a popular method for harnessing wires. Figure 7-4D shows some of the common cable ties. Most of these ties can be

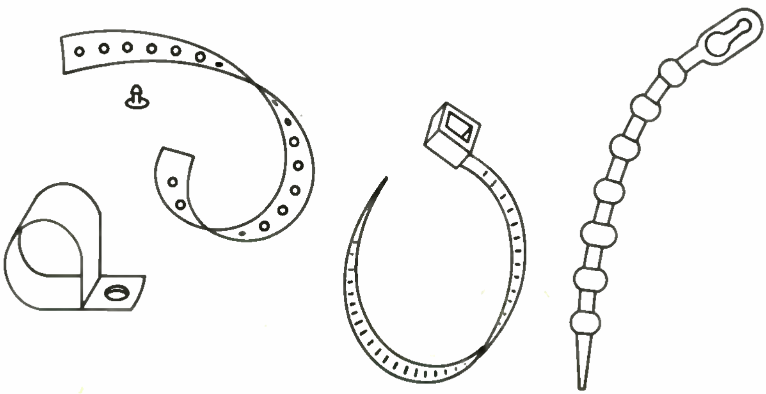


Figure 7-4D: Cable ties

fastened by hand or with special tools. Many companies prefer cable ties because they are very fast to install. For the individual project, cable ties are no better than any other type of harnessing technique. Keep the wires parallel, the bundle firm and the harnessing uniform and you will be happy with any of the discussed cabling techniques.

8

Guidelines for Designing and Making Printed Circuits

Designing a printed circuit from a schematic can be a real time-consuming job. There are all sorts of things to consider, such as overall board size, part size, foil pattern, layout, connections, and many others. If you use the systematic approach which is suggested in this chapter, printed circuit designing will be interesting and rewarding.

Once the printed circuit layout has been decided, the actual board must be made. There are various successful techniques available to produce printed circuits. Choose the method that best suits your needs. Some techniques are great for mass production, some for one-of-a-kind, some for precision layout, some for a fast layout, some expensive and some very inexpensive.

Part of the satisfaction in doing any electronic construction job is the appearance of the finished product. Finished printed circuits are no exception. A carefully designed printed circuit with all the components mounted in an orderly arrangement can be a joy to behold.

8-1. BLUEPRINT FOR DESIGNING A PRINTED CIRCUIT

Start with the schematic. Most schematics are already drawn in an orderly and systematic manner. Generally, using the schematic as a guide will produce a clean layout for the printed circuit. Figure 8-1A shows a square-wave generator schematic which has the rough outlines of the foil pattern outlined. When you outline the foil pattern on the schematic keep in mind the following points:

1. Determine where the external connections (input, output, power supply, etc.) are going to be made. Are you going to have wires connected to one end of the board, both ends, throughout the board or whatever?
2. Try to position the foil pattern so no extra connecting wires are needed on top of the board or on the foil side. The ideal printed circuit has no conductors except the foil and the parts' leads.
3. Keep in mind the mounting of the printed circuit board. If the board is to be fastened directly, provide foil areas for the fasteners.
4. A ground or common path around the perimeter of the board is recommended but not absolutely necessary.
5. Try to leave as much foil area as possible for parts that run hot. Some of the heat can be dissipated through the copper foil.
6. Most printed circuits use low voltage and there is little likelihood of arc-over between foil patterns. However, if higher voltage is present be sure to provide enough space between the conducting areas to prevent accidental arcing.

Once the rough foil pattern is established draw another pattern exact size. How small or large do you want the board to be? If you want the board to be as small as possible, the components' size will determine the overall size. Do you want to mount the capacitors and resistors lengthwise or vertical? Are the transistors to be soldered directly into the circuit or are they going to be put in sockets? Is the board going to be plugged into a PC strip socket or are the external connections going to be fastened with hookup wire? Decide the answers to these questions and then design an exact-size scale model as shown in Figure 8-1B.

Notice how the exact-size version has been reduced in size simply by using the part dimensions as a guide. The square-wave generator PC could be reduced even more by mounting the resistors vertically. After the scale foil pattern is finished, lay the parts in their positions to make certain enough room is available for each one. Don't be disappointed if the first try on the scale pattern is a failure. It may take three or four practice versions before a satisfactory design is established. Keep trying and you'll come up with a masterpiece!

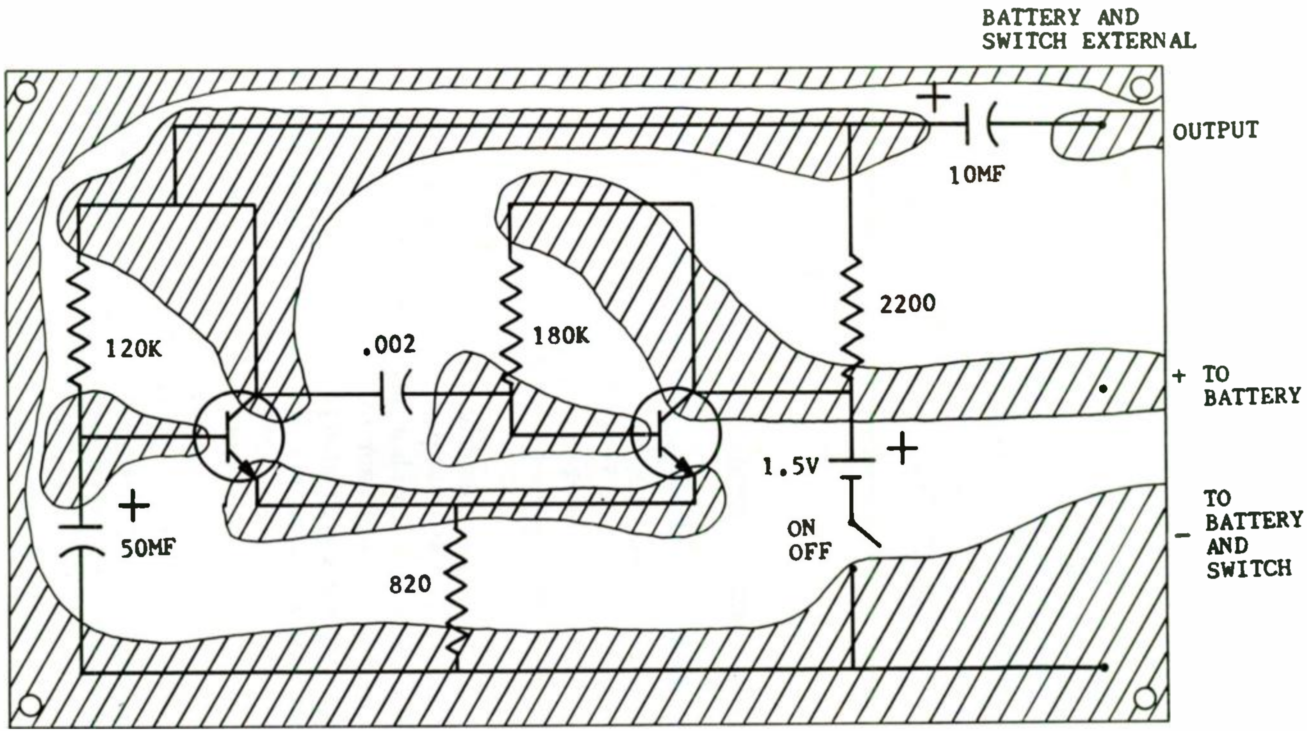


Figure 8-1A: Laying out the foil pattern for a square-wave generator printed circuit

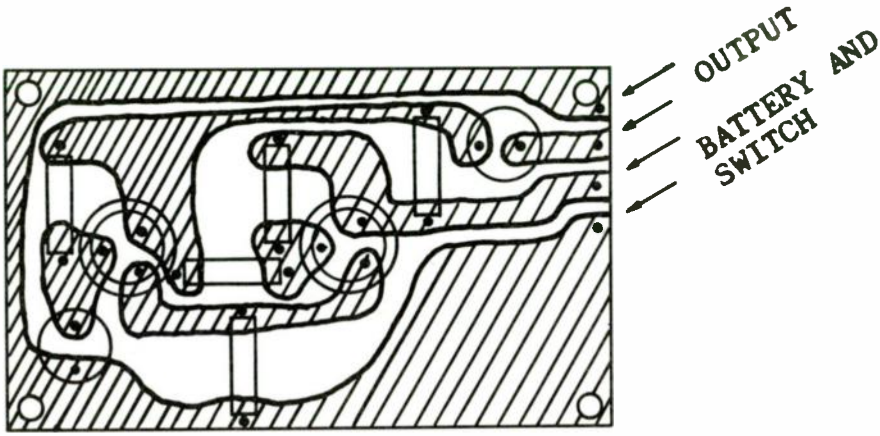


Figure 8-1B: Exact scale foil pattern

8-2. STEPS TO MAKING A PRINTED CIRCUIT

The next step after the foil pattern has been designed is to transfer the pattern on the PC board. Lay the pattern on a piece of pencil carbon paper over the foil side of the PC board. Follow the pattern, pressing firmly with a #2 pencil. Check to make certain the carbon is transferring the layout to the copper. Copy all the foil outlines and all the connection dots.

When the transfer is completed, lightly center punch all of the hole positions. Then apply resist paint or ink to the foil paths. An easy way to put on the resist is with a small artist's brush. You can buy special resist paint but asphaltum works just as well. Most hardware stores stock inexpensive asphaltum paint. If some of the resist runs out of the foil path, don't worry about it until the resist dries. Then all you have to do is scrape the excess resist away with a razor blade; this is a lot less messy than trying to correct the mistake when the paint is wet.

In about a half-hour the resist should be dry enough to place the PC board in the etchant solution. Most etchant solutions will generally remove the copper foil in about twenty minutes. The etchant can be used over and over, but will take a little longer to remove the copper each time it is used. Use a glass or plastic tray to hold the PC board while etching. When all the copper has been removed, wash the PC board in water and inspect carefully. If you're satisfied with the job, you're ready to remove the resist.

Almost any solvent will remove the resist: turpentine, mineral spirits, kerosene, etc. After the resist is dissolved, drill the mounting holes in the PC board. Use a drill bit just slightly larger than the diameter of the part leads. If you use a bit too large it will remove excessive copper and may cause the foil bond to fail when soldering. Clean the foil with steel wool and you are all ready to mount parts.

The previous paragraphs suggested one simple easy method for making a printed circuit. There are many other techniques which can also be used to make PC boards. You can use pressure adhesive resist tape and resist circles to make the circuit. Rolls of resist tape are available in many widths: 1/32, 1/16, 3/32, 1/8, 1/4, etc. Resist circles are also available in various diameters (Figure 8-2A).

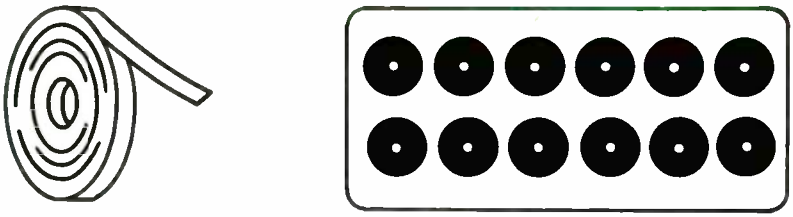


Figure 8-2A: Resist tape and resist circles

After the circuit pattern has been established, stick a resist circle at each hole position and connect each circle with the tape, producing the various foil paths. When the circuit is finished, etch the board, remove the tape and circles, and you will have a professional appearing printed circuit. Figure 8-2B shows the layout of a square-wave generator using resist tape and circles. Compare this technique with the method shown in Figure 8-1A. Both printed circuits will work fine.

Here's another successful technique for making printed circuits, using a photographic process. Draw the foil pattern on paper larger than full scale. Use India ink or a black felt-tip marker to black out the various areas of the circuit. If you black out the foil areas which are going to be etched, you can use the photographic negative. On the other hand, if you black out the foil areas which are going to be saved, a photographic positive must be made from the negative. Either process will work. Figure 8-2C shows the foil pattern for the square-wave generator in white and the areas to be etched in black.

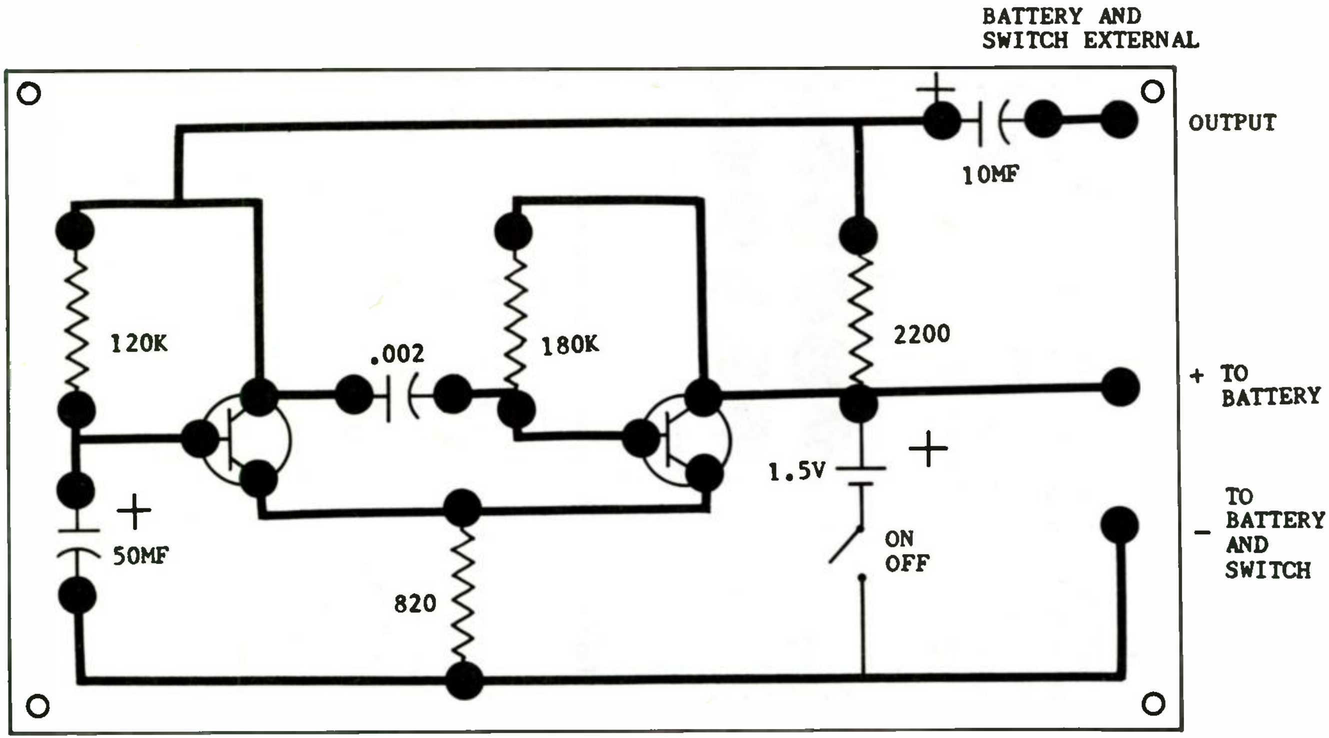


Figure 8-2B: Using resist tape and circles to lay out the foil pattern for a square-wave generator

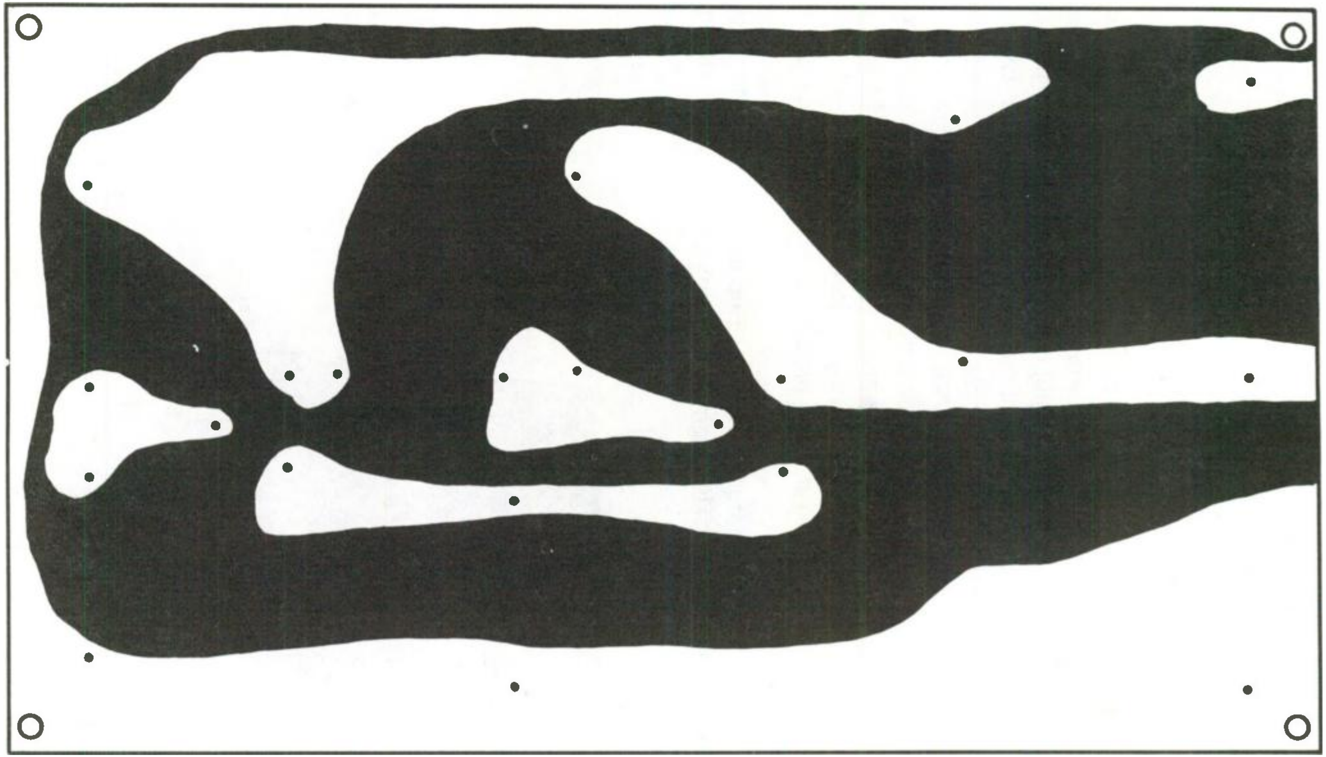


Figure 8-2C: Printed circuit pattern for photographic process

By making the original pattern larger than full scale, a more accurate drawing can be made. Also, small imperfections will tend to disappear when the camera reduces it to normal scale. The type of camera available will determine how large the original pattern can be made. As soon as the photographic negative is finished, you are ready for the next step.

Printed circuit boards which are photosensitive are available. They are packaged in a light-proof wrapper which should be opened only in a dark room. Lay the photographic negative of the printed circuit over the photosensitive side of the printed circuit board. Expose the board to light for ten to twelve minutes. Then develop the circuit by placing the board in a developing solution for about a minute. The areas which received light will retain a photo-resistive coating. Next, etch the board as you would for the usual printed circuit. The photo-resist can be removed from the foil by a cleaning pad or steel wool. This is a great method to use for producing many identical circuit boards.

The silk screen technique is another fine method to use to mass-produce printed circuits. The beginning of this process is identical to

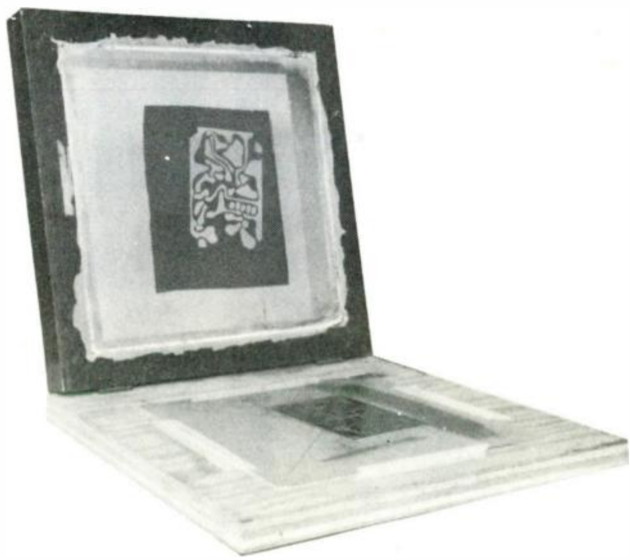


Figure 8-2D: Silk screen jig for producing printed circuit patterns the method just described. After the photographic negative or positive of the PC board is made, it is used to expose a photo-stencil film. When the photo-stencil film has been exposed, developed and washed, it is ready to apply to the silk screen. The silk screen has been stretched and fastened to a wooden frame (Figure 8-2D). Lay the silk screen on top of the washed photo-stencil film which will adhere to the screen.

You are now ready to produce silk screen printed circuits. Place an ordinary PC board foil side up directly under the silk screen pattern. Uniformly squeegee resist ink across the silk screen. Lift up the screen. Presto—an instant printed circuit! Do this for as many circuit boards as you need. It takes only about twenty seconds to ink the foil pattern for each board.

Do you want to make a fast, professional appearing printed circuit without using any resist or etchant? Use pre-etched pressure-sensitive copper circuit patterns for instant PC boards (Figure 8-2E). All you need is a standard laminated board (no copper foil) and a package of universal circuit patterns. It's easy. Follow the schematic while selecting the copper patterns you need. Each pattern has a paper backing. Peel off the backing and stick the pattern in place. Connect the patterns with hookup wires or with pressure-sensitive conductor paths. Do you

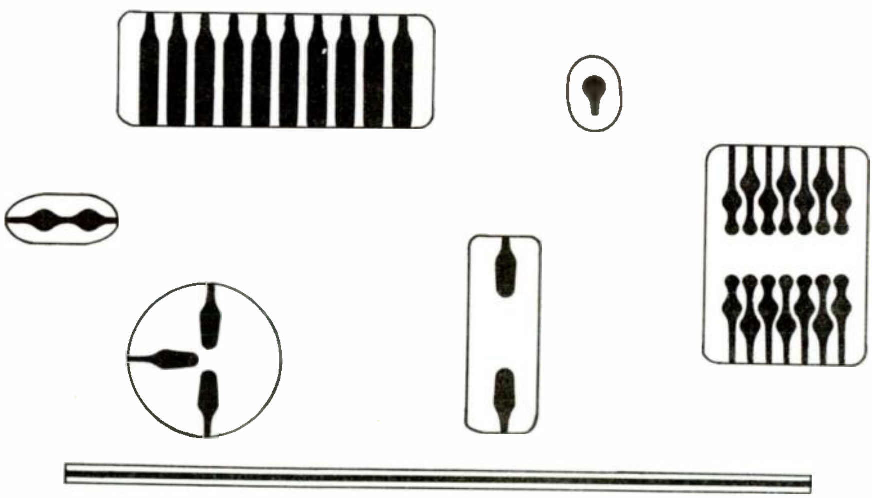


Figure 8-2E: Pre-etched pressure-sensitive copper circuit component patterns for PC boards (Bishop Graphics, Inc.)

want to plug in the board? Use pressure-sensitive connector strips. If you want to reposition the patterns or use them somewhere else, just peel them up and restick them in the new place.

8-3. HOW TO MOUNT PARTS ON PRINTED CIRCUITS

After the PC board has been etched and drilled, the time has come to mount parts. Generally the fastest way to complete this phase of the project is to insert all of the components into their respective PC board holes before soldering. Small resistors (1/4 W, 1/2 W) and capacitors are usually mounted so that their surface is touching the board. It's a good idea to mount higher wattage parts up and away from the board so that their heat can be dissipated. A section of sleeving on each part lead can act as a spacer between the part and the board. If you are mounting glass diodes or other fragile parts, bend a loop in the leads before inserting them into the holes (Figure 8-3A).

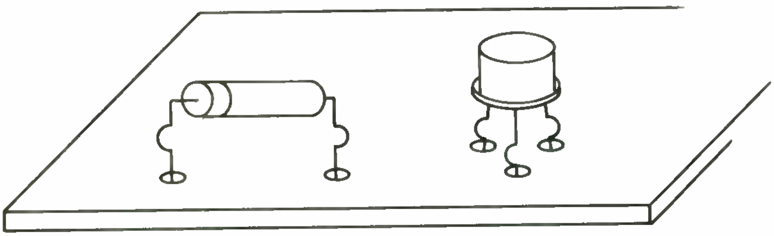


Figure 8-3A: Mounting fragile components

The lead loop will help three ways. It will act as a strain relief in case the board is stressed. It will act as a small heat sink when the lead is soldered. It will act as a spacer to keep the part the specified distance from the PC board. Most electronic components are designed in styles especially suited for PC board mounting. Figure 8-3B shows some of the common parts whose terminals are made to fit into printed circuit holes.

If possible, when you are installing transistors or other solid-state components, use sockets. Solid-state parts are extremely reliable and seldom go bad, so many manufacturers solder them directly into the circuit. However, when a defect does occur it's a big help to be able to

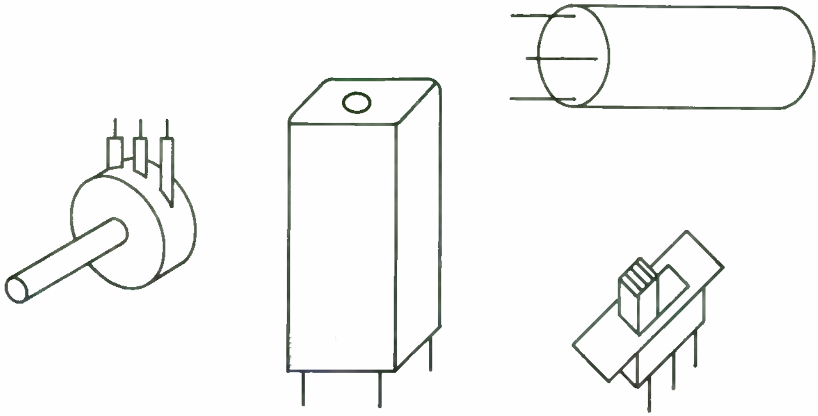


Figure 8-3B: Printed circuit components

remove solid-state parts quickly with no desoldering damage. They can be checked easily out of the circuit and their removal provides an efficient way to isolate various electronic stages from each other.

Don't forget when mounting parts to keep the parts' value labels up so they can be read after installation. Make sure that polarity markings are visible on capacitors, diodes, rectifiers and other polarized devices. If you really want to become fussy, keep all the resistor color bands in the same direction. It doesn't matter electrically but it improves the final appearance slightly.

If you are going to mount a lot of parts in printed circuits, make a lead-bending jig out of a piece of hardwood (Figure 8-3C). This is a simple tool which guides the bending of leads for resistors, capacitors, etc., so they are uniform and fit the PC hole spacing. Make the steps 1/2-inch apart. The smallest step is 1/4-inch wide with each succeeding step increasing 1/8-inch until the maximum size step is reached. Choose the step which is the correct size for the part. Lay the part on the jig, bending the leads down at 90° angles with your fingers. Each part which is bent on the same step will have uniformly bent leads. Mark the steps with the name of the part that fits—1/2-inch step for 1/2 watt resistor, 3/4-inch step for 1 watt resistor, etc.

As the parts are inserted into the PC board, bend the leads (90°) over against the foil so the part will not fall out. Try to bend the lead so it will lie parallel with its copper foil strip. If the parts' leads are

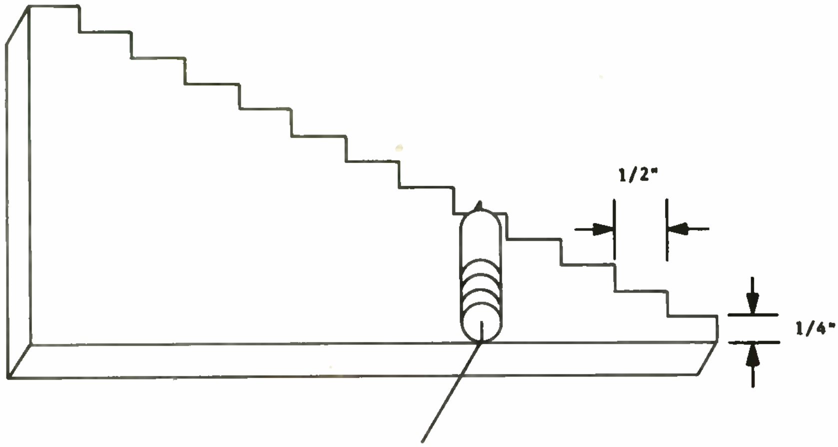


Figure 8-3C: Lead bending jig

positioned in the same direction as the foil, the chances for a solder bridge will be reduced. After all the parts have been inserted and the leads bent over, cut the excess leads with a side-cutting pliers. There are special pliers made for this job which crimp and cut the lead in the same operation. The crimping keeps the parts from falling out of their holes before soldering, but generally the parts will stay in place until soldering if they are just bent over the foil.

Printed circuit connections can be soldered individually (see section 6-3 in Chapter 6) or all at once in a solder pot or solder wave machine. Generally, one-of-a-kind circuits or prototype models are hand soldered while mass-produced circuits are dipped and soldered in one operation.

8-4. SUCCESSFUL PC TROUBLESHOOTING TECHNIQUES

Printed circuits can be more difficult to troubleshoot than hand wired circuits. Difficulties arise because PCs are more compact, conductors and parts are separated by the board, and most active elements are soldered into the circuit. Many PCs are designed to plug into sockets so the entire circuit can be removed for repair. If you have replacement circuits this technique works fine. The trouble arises when

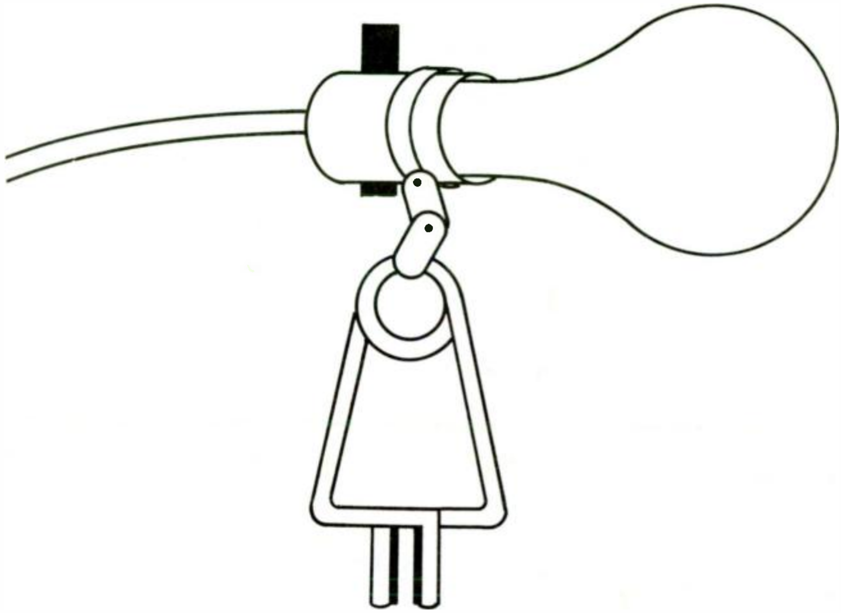


Figure 8-4A: Inexpensive clamp-on lamp for troubleshooting

there are no replacement circuits and the original circuit must be repaired. In these cases plug-in PC boards or modules are not a great deal of help, because in most cases they must be checked while they are operating in the equipment.

A great help to the troubleshooter is service information printed directly on the PC board. Many printed circuits have power supply and other key voltages marked directly next to testpoints. Important testpoints for input-output signal waveforms are sometimes indicated. Many technicians sometimes overlook this worthwhile information while working on PCs. Many times the circuit board may be in a dark area of the equipment or coated with dust, making it difficult to see and find this data. It's worth your time to take a couple of minutes to find and analyze this test information. A portable lamp with a spring-loaded clamp can do wonders to light up the inside of a cabinet (Figure 8-4A). Make sure to have a long line cord on the lamp. You never know where the closest outlet will be located. Often all that is necessary to turn a hard job into a simple one is adequate lighting.

The circuit board may need cleaning. A small vacuum cleaner with a hose attachment can be a big help but sometimes is inconvenient or unavailable. The next best thing is a soft artist's brush, about 1/2-inch, to reach between the PC parts to remove dust and dirt. In really bad cases you may have to dampen the brush slightly in order to remove the dust. Lighting the board and cleaning it can really pay off with a wealth of previously hidden service information.

If you are making a PC, don't forget to include as much service data as possible directly on the board. Press-on letters, embossed tape, masking tape labels, or even felt-tip marking pens can be used. Mass-produced PC boards usually have this data silk-screened on the part side of the board.

A little thing that sometimes makes PC test measurements difficult is the type of connector or prod in test leads. Generally there is not much surface area on the parts' leads to clip on an alligator clip. If you do manage to clip it on, the slightest movement will cause the clip to release and maybe fall into the circuit, causing additional troubles. You can use leads with minigator clips but even these small clips are too large to be really effective in most PCs. The best solution is to use test leads terminated with special miniature insulated hooks (Figure 8-4B). These hooks are made especially for printed-circuit testing and work like a charm. Each connector consists of a spring-loaded hook inside a plastic housing. Finger pressure is required to expose the hook. After the hook is connected and the pressure released it will retract, locking itself around the wire or testpoint, completely insulated from other nearby parts or conductors. These connectors are small enough to reach and hook the smallest PC component lead.

Good service information is usually a must for most electronic repair work. It is especially helpful in printed-circuit troubleshooting. Figure 8-4C shows one method used to correlate the schematic drawing with the corresponding areas in the PC board. Key areas of the circuit are assigned a number. The same number points to the actual circuit connection in a photograph of the PC board. This type of information can save you countless hours of unnecessary circuit tracing.

If you don't have good service information, don't panic when you look at the foil side of a PC board. At first glance it will look like an impossible maze. Try to identify one area of the board at a time, such as a socket or transformer. After you have familiarized yourself with that area, follow foil paths to another easier-to-identify area and try to make sense out of it. It's a slow process but it can be done. You can shine a bright lamp (Figure 8-4A) on the part side of the board while looking at the other side. The board will become translucent, enabling you to correlate part shapes with the foil paths. This is very helpful when trying to identify test points in a strange PC board.

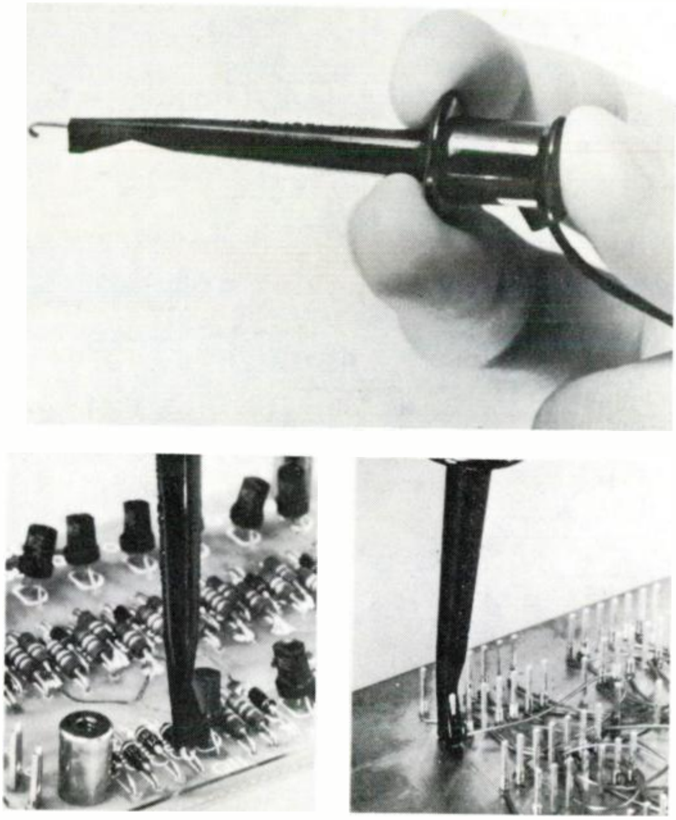


Figure 8-4B: Mini-test clip hook connections (Pomona Electronics)

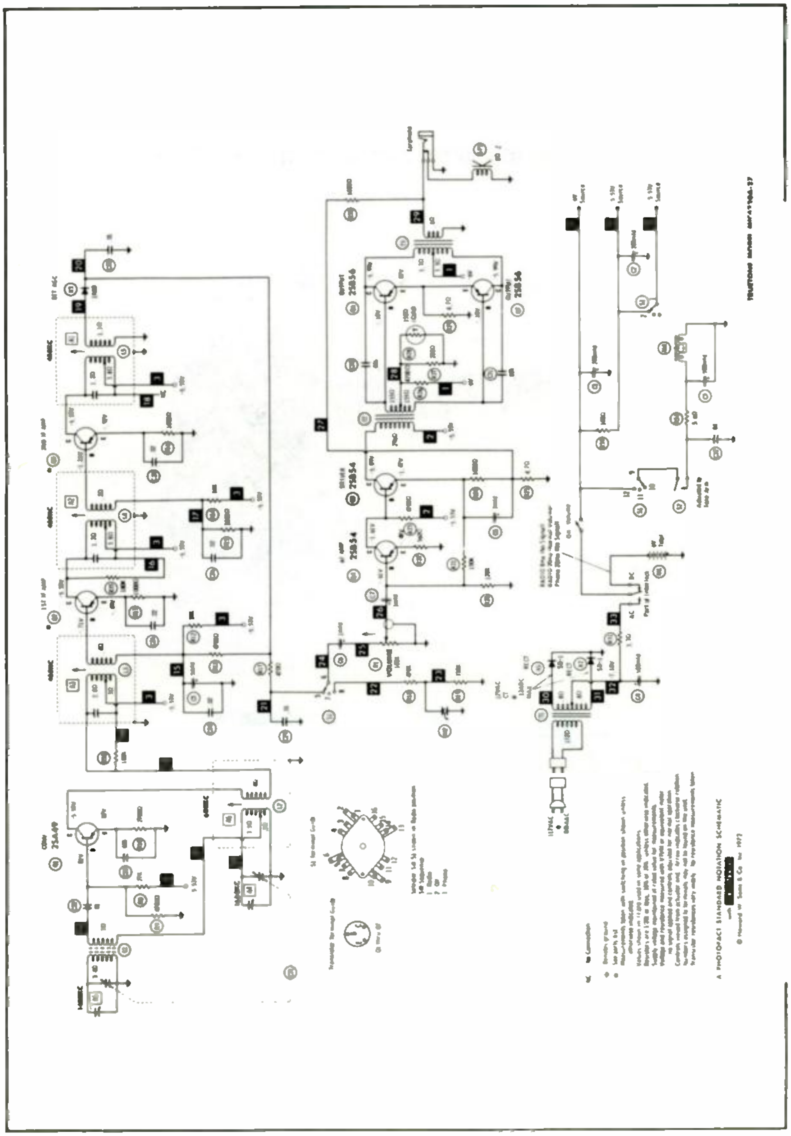


Figure 8-4C: Service information correlating the schematic with the PC board
(Courtesy Howard W. Sams & Co., Inc.)

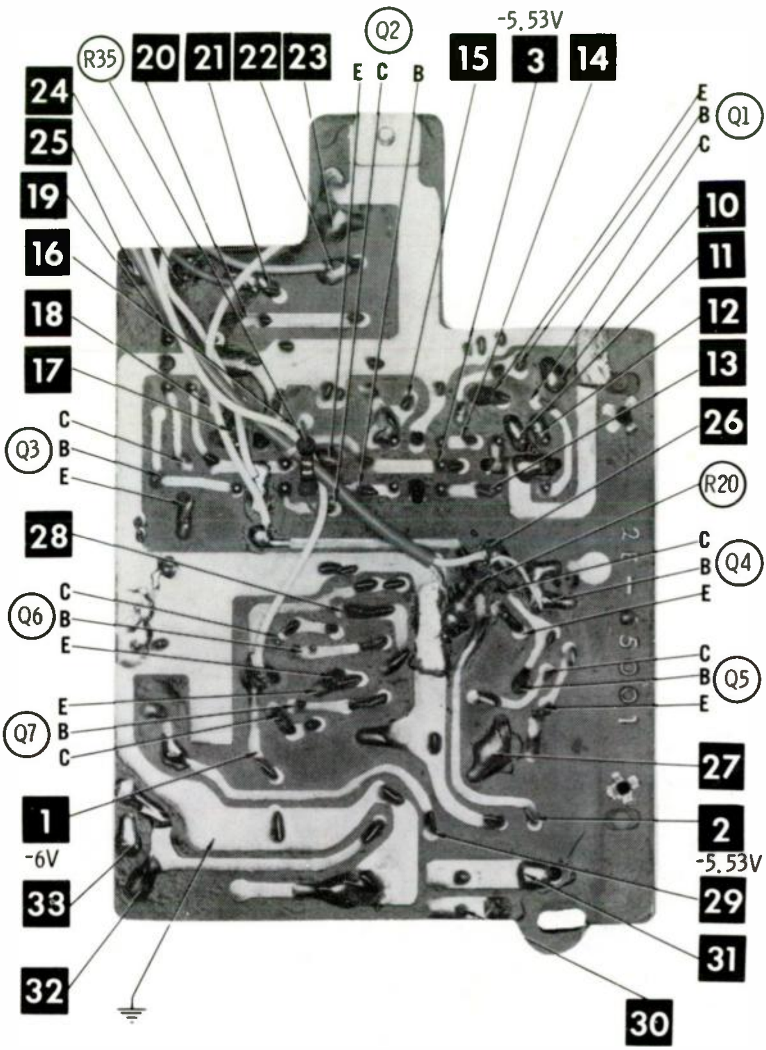


Figure 8-4C: (Continued)

9

Time and Work-Saving Shortcuts for Chassis Construction

Most electronic circuits will eventually end up in some type of chassis and/or cabinet. Commercial chassis and cabinets are often fairly expensive and their routine design doesn't leave much for the imagination. Many technicians do make their own chassis but many techs refrain from chassis construction for one reason or the other. The following chapter offers ideas on chassis design and construction which can be successful with minimum time and work. Practical techniques for making openings and holes, labeling, and fastening chassis and cabinets are discussed.

9-1. BLUEPRINT FOR DESIGNING A MINIBOX

A simple, easy-to-make minibox is all that is necessary for many worthwhile electronic projects. Miniboxes can be made from various kinds of sheet metal in all shapes and sizes. The beauty of the minibox is that only two pieces of sheet metal are needed, and they will snap together, staying that way with or without fasteners.

Figure 9-1A shows the plans for a typical minibox. If you have access to sheet metal tools (box and pan brake, squaring shears, etc.),

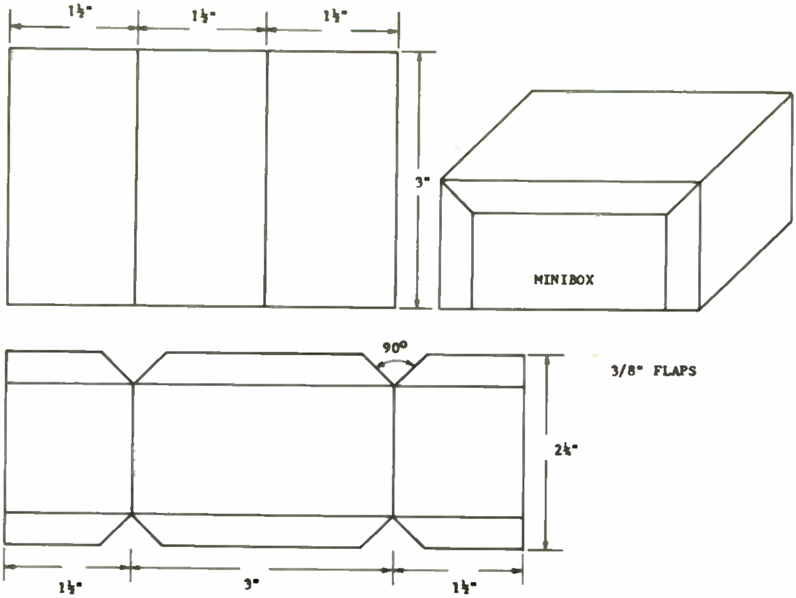


Figure 9-1A: Minibox plans

you can use any type of sheet metal. Generally, 22 gauge metal will work fine. If you just have common hand tools available, the best bet is to use 22 gauge aluminum. Carefully transfer the pattern to the sheet metal, using a scribe or a sharp, soft pencil. Cut out the large areas of the pattern with sheet metal shears. Then cut out the triangular parts of the edges. Lightly file the edges to remove any burrs or rough spots.

The two sections are now ready to bend. Bend the 3/8-inch flaps 90° to the main body. Bend all the flaps on each side in the same bending operation. After the flaps are finished, bend the ends of each section 90°. If you have made accurate measurements and your bends are sharp, the two sections should slide together for a friction fit. That's all there is to it. Once you get the knack you can make a complete minibox from start to finish in less than twenty minutes.

9-2. HOW TO DESIGN A METAL CONSOLE CHASSIS

Miniboxes are great for a lot of electronic devices but there are times when a more sophisticated enclosure is desired. The console type makes an efficient chassis while also serving as an eye-pleasing cabinet. Keep in mind the following points when designing a chassis of this type:

1. Don't sacrifice size just for the sake of having a compact chassis. Remember, you and your hands are going to be working in the size area you select.
2. If all the components can be mounted on one section of the chassis, you won't have to interconnect chassis sections with cables.
3. Try to design a chassis which when taken apart will give maximum access room for construction and troubleshooting.
4. Remember that very often the simplest design is the best design. A chassis composed of many sections and odd angles will often be difficult and frustrating to build. The ultimate chassis-cabinet has two sections. One section has all the controls and components mounted on it while the other section merely serves as a dust cover.
5. Anticipate cutting and bending problems while thinking of the design. The best design in the world is worthless if it is impractical or unfeasible to construct. If you are using a box and pan brake you are limited by the size and clearance of the fingers.
6. Make numerous sketches so you can decide on the best design.
7. Make a cardboard model. Treat the cardboard model exactly as if it were metal. Use the metal bending and cutting equipment on the cardboard. If your design is impossible, find it out on cardboard and save yourself a lot of time and grief. Make all the mistakes on cardboard so when you are ready for the metal work everything will go like a dream. If you don't know how much metal to allow for a bend, try the bend on a metal scrap and find the answer.
8. Try to keep away from designs that require almost perfect sheet metal construction for a professional appearance. Good designs can cover up a multitude of sheet metal errors. Covers and flaps can cover up all kinds of sheet metal mistakes. If you keep the easiest-to-make sections of the chassis on the outside, the rest of the chassis will look better.

Figure 9-2A shows a sample console type of chassis-cabinet pattern. It has been designed with all of the previous points in mind. The construction is easy and straightforward. Transfer the pattern to the

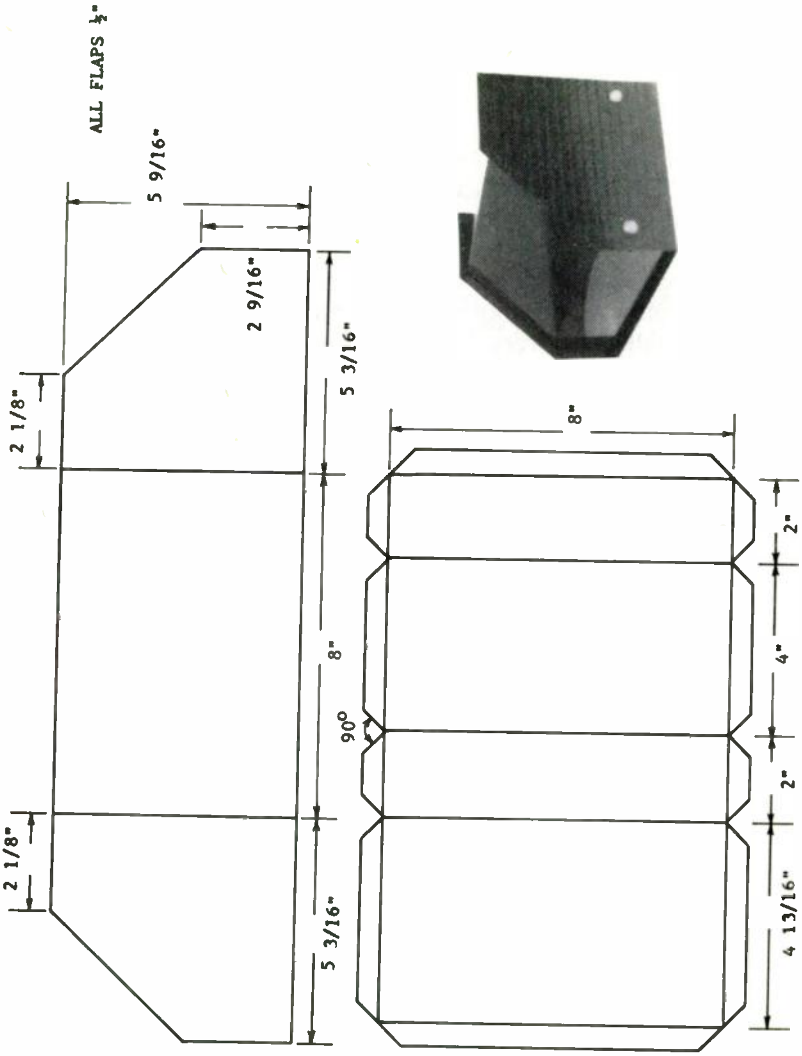


Figure 9-2A: Console type chassis design metal and cut out (see the preceding section, 9-1). All cuts can be made on a squaring shear except for the notches in the flaps. Deburr and touch up any rough edges with a smooth file. File off the sharp corners on the cover and be sure its edges are straight and smooth.

(Notice, at this stage of construction it is wise to make all the openings and holes in the metal. See the following section, 9-3.) After the openings have been smoothed and deburred, bend all the chassis flaps at right angles. Then make a 45° bend at chassis line Y. Make another 45° bend at chassis line X. To finish the chassis section, bend line Z 90°. The cover section requires two 90° bends, one at line A and the other at line B. Slip the chassis on the cover and the cabinet is completed. This sample console chassis is very fast to make and will invariably produce a professional appearance.

If you don't have a box and pan brake at your disposal for the bending operation, a satisfactory substitute can be made using one-inch by one-inch wood strips. Cut the wood strips the exact length of the bend which you are going to make. Clamp the strips above and below the bend (see Figure 9-2B). Then, with another piece of wood, bend the metal to the desired angle. Repeat this operation for each bend required.

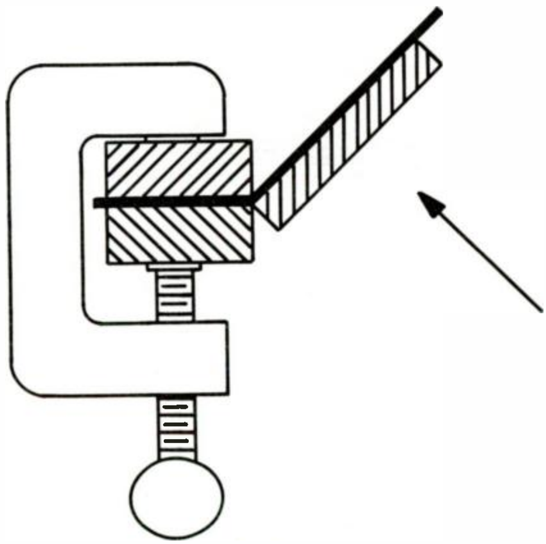


Figure 9-2B: Bending sheet metal using wood strips

9-3. HOW TO MAKE OPENINGS AND HOLES

Making openings and holes in sheet metal is a breeze when you use the right tools and techniques. The basic hole-making tool is the drill. Drilling accurate sheet metal holes is easy if you just follow a few simple suggestions:

1. Center punch all your holes. Just a light hammer tap on a center punch is all that's necessary for each hole center.
2. A small drill bit should be used to initially drill all holes. The small bit will follow the center punch hole accurately and not "walk" off center.
3. Larger holes should be drilled with a series of bits, each one larger than the previous one, until the correct size hole is attained. This will prevent the hole from becoming oversize, ragged or squarish.

A tapered hand reamer (Figure 9-3A) is a handy device for making large holes. Drill all your larger holes undersize. Insert the reamer in the

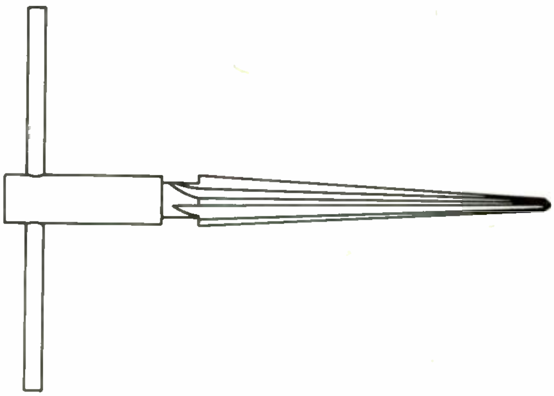


Figure 9-3A: Tapered hand reamer

hole and twist until the hole size is correct. With the reamer you can make a very round opening faster than you can by using a succession of drills to produce a large round hole. Another advantage of a reamed hole is the absence of burrs.

Holes larger than 1/2-inch are generally made with special hole-making tools. The chassis punch and the fly cutter (Figure 9-3B) are common tools used for this purpose. The chassis punch works like a dream. Drill a hole to accept the center bolt of the chassis punch. Push the bolt into the noncutting side of the punch and insert into the chassis hole. Try to keep this section of the punch on the unseen side of the hole. Screw on the cutting side of the punch until its edge meets the chassis. Put a box wrench on the bolt head and turn slowly. The cutting side of the punch will be pulled through the metal, producing a near perfect opening. The entire operation takes only a few minutes. If you put oil on the punch's cutting edges and the bolt threads, you'll extend the life of the punch as well as make the hole cutting easier. Chassis punches are available in most common sizes. Most punches produce round holes, but square and special type hole punches are available.

The fly cutter is used to make the largest kinds of openings in sheet metal, usually for panel meters. Fly cutters are adjustable for many size-cutting radii. Lay the sheet metal on a piece of wood and clamp to a drill press table, making sure it is held securely. Adjust the drill press for a slow speed. Insert the stem of the fly cutter into the drill press chuck and you are ready to cut the hole. Keep the circumference of the hole well oiled while cutting. Apply a steady even force on the drill press handle until the hole is cut. Remember when you are using the fly cutter to keep yourself, clamps, or anything else away from the turning radius of the cutter. It can do a lot of damage in a short time!

So much for round holes. How do you make square, rectangular, or irregular shaped openings in sheet metal? The ordinary hacksaw can often be used. Make certain you are using a blade with very fine teeth (32 teeth per inch). Drill a hole large enough to accept the blade in each corner of the opening. Saw from hole to hole and you've got your opening. You might have to clean up the corners with a smooth flat file.

Square chassis punches are great for making the corners of large square or rectangular openings. Often a rectangular opening can be made using a square chassis punch. Punch two, three, or however many holes you want next to each other to make the required size opening. The nibbling tool is very handy for cutting odd size, square and rectangular holes in sheet metal (Figure 9-3C). All you need to start cutting is a hole large enough to insert the nibbling tool's head. The tool will cut a smooth opening, leaving flat edges. It can cut in all directions almost as easily as scissors can cut lightweight cardboard.

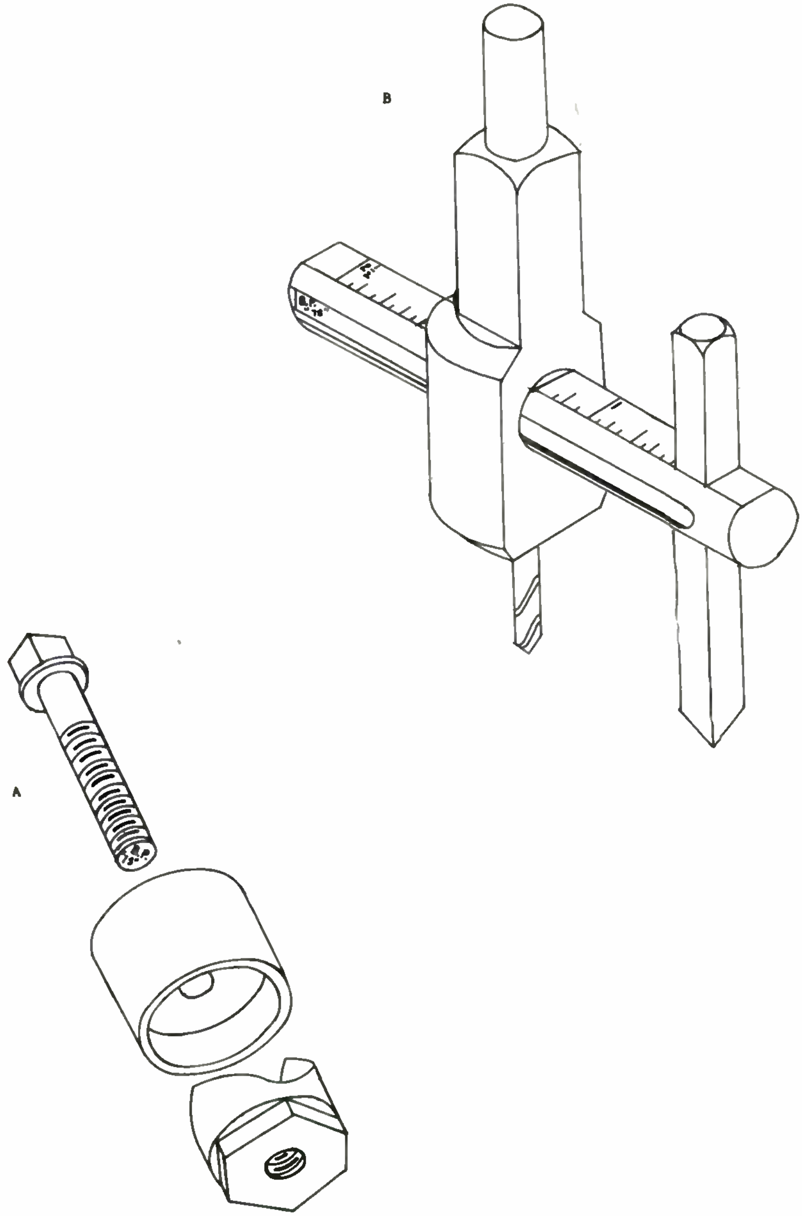


Figure 9-3B: Chassis punch and fly cutter

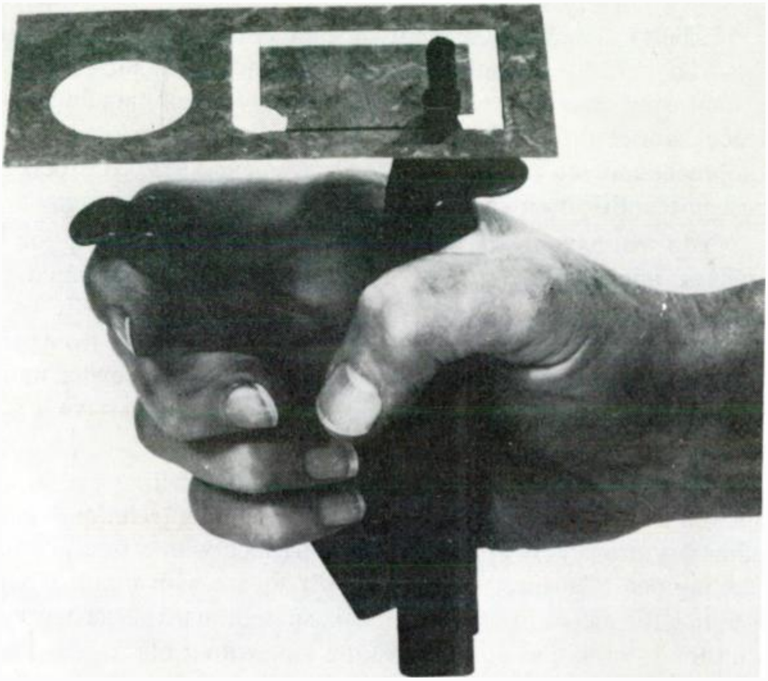


Figure 9-3C: Sheet metal nibbling tool (Adel Tool Co.)

Small rectangular openings (for slide switches, lever switches, etc.) are often needed and are hard to make. These openings are too small for the use of a punch or nibbling tool. Here's a way that's fairly speedy and makes a nice appearing hole. Scribe the opening lines accurately on the metal. Drill a series of holes from one end of the opening to the other. Use a drill bit which is slightly smaller in diameter than the width of the opening. Drill each hole directly next to the previous one. Then file the remaining metal away, using a medium-cut square file, and finish up with a smooth flat file. If you have drilled your holes accurately you'll have a professional appearing opening.

9-4. EASY-TO-MAKE LABELS

Labels can make or break the appearance of electronic apparatuses. They can make the operation of an instrument logical and easy to learn or confusing and difficult. Good labeling requires planning and patience. Notice the labels on any good quality professional electronic equipment and you can see that the electronic industry considers labeling and identification an important part of equipment design.

You will have the best chance for a successful labeling job if the labels are applied to the front panel before any parts are mounted. Make certain the labels are straight and centered over the holes. It's a good idea to mark light pencil lines or to use masking tape on the front panel as a labeling guide. Try to make the length of the labels somewhat uniform. Don't forget knobs! Knobs which have been forgotten have a way of covering up the best labels.

There are all sorts of methods to use for labeling one-of-a-kind electronic equipment. One of the simplest labeling techniques used for temporary projects is printed on masking tape with a fine line felt-tip marking pen. Cut the masking tape off square with a pair of scissors and stick the pieces of tape on a clean, smooth, hard surface. Carefully print the information on the masking tape with a black marking pen. When all the labels are finished, peel each one off the writing surface and restick to the appropriate place on the electronic equipment—simple, neat, and effective.

Most technicians want their labels to be a little more professional and permanent than the masking tape variety. A popular labeling method utilizes embossed tape. The tape is placed in a label-making tool and the correct letters and/or numbers are selected and raised on vinyl or metal tape (Figure 9-4A). Most of these tapes have pressure-sensitive adhesive backing which will stick to most kinds of surfaces. Some of these labels have a tendency to pop up or become loose after a period of time if they haven't been firmly applied to a clean surface.

Decals make fine labels but are very time consuming to apply. Cut the appropriate words or numbers from the decal sheet and soak in a flat pan of water. In a minute or two the decals will become loose enough from their paper backing for application. Mosten the area of the panel where the decal is going to be placed. Slide the decal from the backing paper on to the panel, positioning it in place. Press firmly over the decal

Figure 9-4A: Embossed label maker (Dymo M-11 Tapewriter®—Dymo Products Co.)

with a clean dry piece of cloth to remove excessive water and air bubbles.. After all the decals have been applied and are dry, spray them with a clear acrylic finish to protect them from accidental scraping and removal.

Dry transfer lettering gives the same fine finished appearance as decals but is much faster and easier to apply. The appropriate word, number, dial pattern, symbol, graduation line, is chosen and placed over the area where it is needed. Rub the dry transfer label lightly with a dull pencil to transfer it to the electronic equipment. Carefully peel away the carrier sheet, leaving the label intact. Then cover the label with its backing sheet, burnishing lightly with a pencil to cause better adhesion. If you make a mistake, the label can usually be removed with masking tape or carefully scraped away with a knife. Finally, spray with a clear acrylic finish to complete the labeling job. That's all there is to it!

Here's a slick way to use dry transfer labels: Transfer the labels to strips of thin white cardboard, aluminum, plastic, etc. Then glue the strips onto the equipment. The beauty of this method is that the labels can be transferred on a flat surface unhindered by holes or other chassis obstructions. You can also use this method to label a project after the controls have been mounted. If you make a mistake, just toss the label away and try again. When all the label strips are in place, spray with the clear acrylic finish.

Occasionally when using dry transfer labels you will run out of the words or numbers that are needed. Don't panic! Generally the word can be completed with individual letters pirated from unused words. This process takes a little more time but works satisfactorily. In a pinch you can make letters, numbers, and even simple symbols by using parts of available dry transfer characters. For instance, a *V* and an *I* can be placed together to produce a very acceptable *N*. Most characters can be made in this fashion.

9-5. PRACTICAL FASTENING TECHNIQUES

When the chassis opening and holes have been made and the flaps and sides have been bent, it is time to fasten the chassis sections to each other. There are many ways to fasten sheet metal together. This chapter discusses some of the most popular fastening techniques.

Probably the most common method used to fasten sheet metal is with sheet metal screws. Sheet metal screws are popular because their installation is simple, fast, and effective. Number 4 and 6 sheet metal screws 3/8-inch long are the most common sizes used for chassis assembly.

Clamp the chassis sections together before drilling the screw holes. The clamp or clamps will keep the various parts in perfect alignment while drilling. Drill both pieces of metal together with a drill bit that is the same diameter as the inside sheet metal screw diameter (Figure 9-5A). After all the holes have been drilled with the inside diameter drill, remove the clamps and separate the chassis sections. Redrill all the outside sections of metal with a drill that is the same diameter as the outside diameter of the sheet metal screw (Figure 9-5A). The screw threads should thread into the inside metal only. If the screw threads into both sections of metal, the outside piece will not pull down tightly against the inside piece. Deburr any holes to make a tight fit. A simple way to deburr a hole is to hand-twist a larger drill bit around the burred surface. Apply enough force on the deburring drill to cut away the burrs. The hole will clean up and none of the surrounding surface will become scratched.

Machine screws are also used to fasten chassis sections together. One of the troubles with machine screws is that they require a nut and

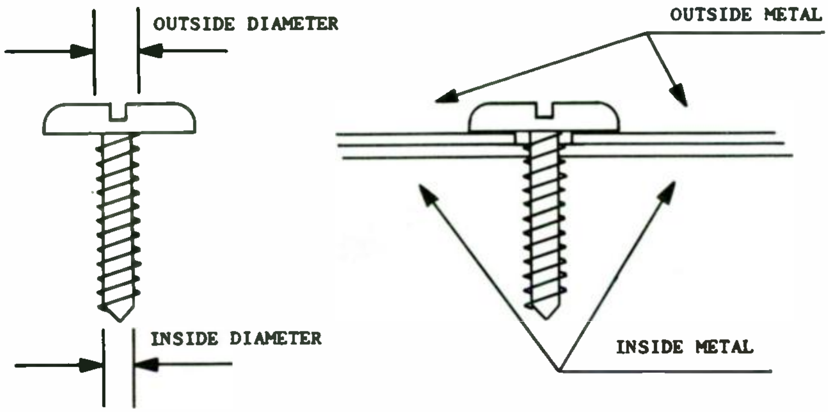


Figure 9-5A: Fastening with sheet metal screws

lockwasher to be secure. Very often it is impossible to hold a nut on the inside of a joint. Nuts can be soldered in place, but generally this is too time consuming for most connections. If you use machine screws and nuts, the holes can be drilled slightly oversize. Then you can use the play between the hole and the screw to correct any small irregularity in the fit.

Spot welding is also a fine method of connecting sheet metal together. It is a strong and speedy fastening technique. If you do spot-weld it is a good idea to clamp the metal in the correct position before welding. If you want to minimize the spot-weld mark on the outside chassis section, slip a small piece of copper sheet metal between the electrode and the outside metal.

Sheet metal fasteners and nuts can be used with sheet metal screws or with machine screws (Figure 9-5B). The advantages of these devices are numerous. They don't need lock washers. No tool is needed to hold the nut while tightening. Some styles clip directly over the hole, centering and holding themselves. They are small, take very little room, and are fast and simple to install.

Blind side rivets are great for holding sheet metal sections together. They require no hammering or anvil and they install from the outside of the chassis. They are simple and fast to install. Clamp the sections of the chassis together before drilling. Drill the holes through both pieces of metal with a #30 drill bit. After all the holes are drilled, you are ready to rivet. Just slip a rivet in the rivet tool (Figure 9-5C) and insert it into one

Figure 9-5B: Sheet metal fastening devices (Eaton Corporation)

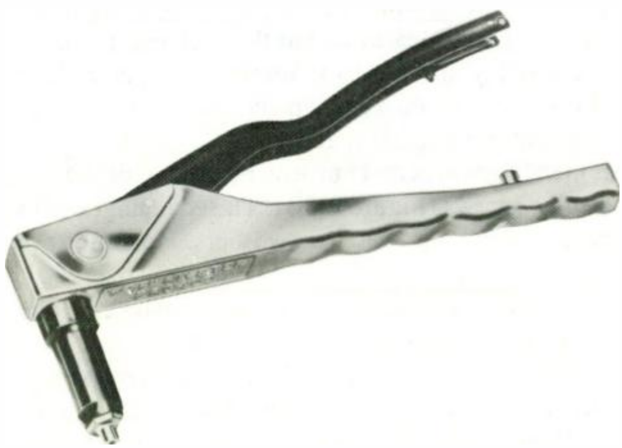


Figure 9-5C: Sheet metal riveter. PRG 402 Hand "Pop" Riveter (USM Corporation "Pop" Rivet Division)