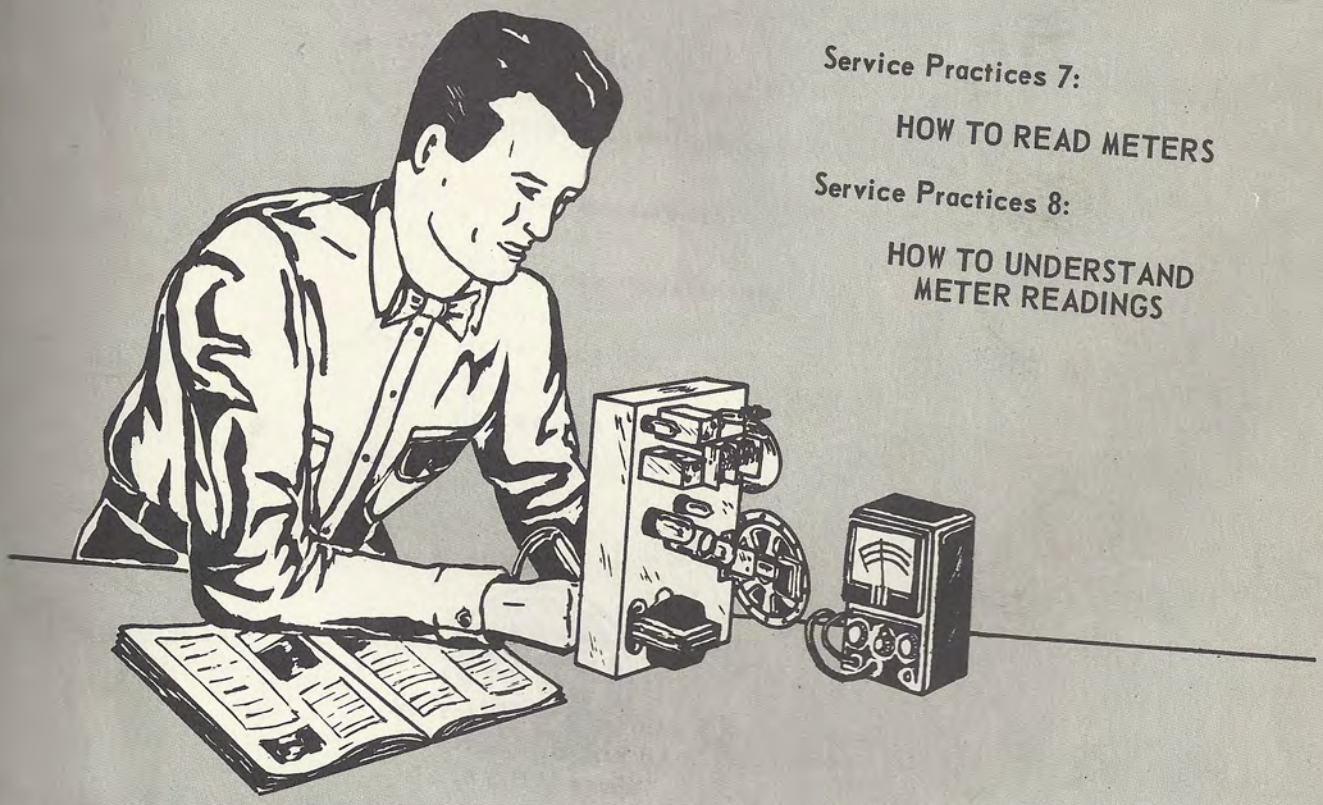
Study Group 4

ELECTRONIC FUNDAMENTALS



Service Practices 7:

HOW TO READ METERS

Service Practices 8:

HOW TO UNDERSTAND METER READINGS

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York, N. Y.

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 7

HOW TO READ METERS

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Service Practices 7

INTRODUCTION

Radio and TV servicemen use many kinds of test equipment. A small repair shop may have several hundred dollars invested in meters and other test equipment, while a large, well-equipped shop may contain two or three thousand dollars worth of such equipment. Much of the equipment used in modern radio and TV shops is bought to help the serviceman locate radio and television receiver troubles faster and more easily. When a piece of test equipment is used often enough, its cost is usually justified by time saving and greater efficiency in trouble shooting.

Yet, if a man understands the theory behind electrical radio and television circuits, troubles may be located without investing in a lot of expensive equipment.

There is one piece of equipment, however, which is absolutely necessary — a piece of equipment that no successful serviceman can do without. It is a meter to measure current, voltage, and resistance — in other words, a multimeter. The meter that you have been assembling in Experiment Lessons 3, 5, and 7 is such a meter.

It is a little early in the course to discuss the theory behind the multimeter. As soon as you are prepared with the basic knowledge necessary to understand meter theory, it will be the subject of a theory lesson. However, it is possible to use such a meter even without knowing exactly why it does what it does.

7-1. CARE OF METERS

Of all the equipment that radio and TV servicemen use, few instruments are as liable as a meter to be damaged because of a moment's carelessness. So, a serviceman must learn never to use his meter without thinking of what he's doing, to take care of his meter, and to protect it from damage. Few servicemen can afford to own more than one multimeter at a time. For that reason, if your meter is damaged you may be prevented from handling a large portion of the service calls that may come your way while the meter is being repaired. Time and money lost through a moment's inattention or carelessness cannot be replaced. Therefore, it pays to learn how to use and care for your meter. Then your meter will always be in working condition when you need it.

The basic meter movement is usually as

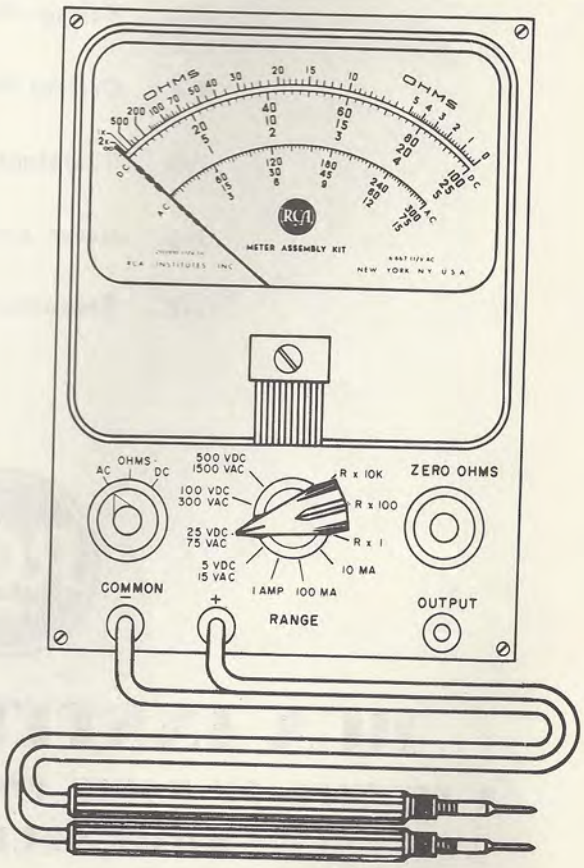


Fig. 7-1

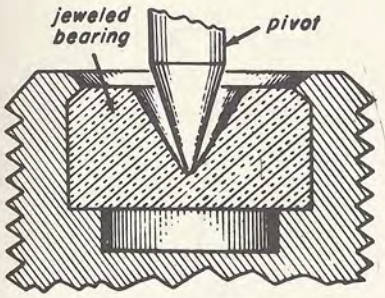


Fig. 7-2

delicate as a watch movement. The moving part (the pointer or needle) is attached to a small coil of wire that rides on sapphire-jeweled pivot bearings, as shown in Fig. 7-2. As in a watch, the movement has hair springs and is carefully balanced. Rough handling can cause a chipped jewel bearing, a distorted hair spring, or even force the pivots from the bearings. When a meter is dropped or handled roughly, a small particle of the pivot or jewel or of some other part may get between windings of the moving coil and cause the needle to be "sticky". See that the meter is not dropped and that it does not receive any shocks that can be avoided. A careful serviceman, when carrying a portable meter in his automobile, places it on the upholstered seat of his car in such a way that it cannot accidentally fall off if the car should go over an unexpected bump, or he provides a sponge-rubber lined case to hold the meter when traveling on service calls.

Whenever the meter is used to measure voltage, current, or resistance, some current flows through the moving coil. The wire used in winding the moving coil is very fine. If too much current is permitted to pass through it, either the coil or one of the hair springs connected to it may burn out. If the hair spring or coil does not burn out, the excess current may cause the springs to heat enough to change the tension of the spring. When this happens, the meter loses accuracy. In any event, when too much current flows through the moving coil, the needle is liable to bang against the needle stop at the end of the scale or against the side of the meter case. This causes the needle to bend and makes the meter less accurate.

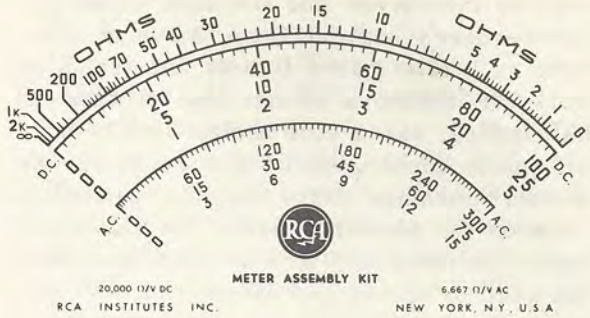


Fig. 7-3

7-2. METER SCALES

Examine Fig. 7-3, which shows the face of your multimeter. On the face, the scales are printed. According to the dictionary, a scale is a series of markings on a line used in measuring something. For example, a ruler has such markings made with regular distances between them so that feet, inches, and parts of inches may be measured off. A thermometer has a scale that measures degrees of temperature. The scales on your meter measure resistance in ohms, current in milliamperes, or electrical pressure in volts. The topmost scale is used when measuring resistance. Below the resistance scales are the scales for measuring voltage and current. When using a multimeter, it is important to know how to select the proper scale and know how to read it. In this lesson, you will examine each of these scales and see how each is used.

D-C Meter Scales. Figure 7-4 shows the scale used when measuring direct current or voltage. Other multimeters used by radiomen have similar scales. As you know from your study of Theory Lesson 5, direct current flows only in one direction. A source of such current is the battery. The d-c scales on your meter are used for measuring either current or voltage. If you examine Fig. 7-4, you will see that the mark-

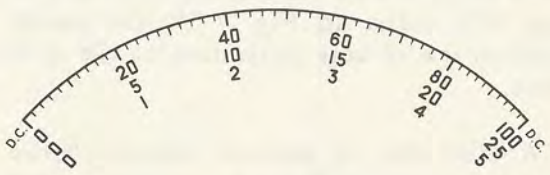


Fig. 7-4

ings on the curved line are made with regular distances between them, as on a ruler. Just as a ruler has a line of one length to mark off inches, a shorter line to mark off half-inches, and a still shorter line to mark off quarter-inches, so, on the d-c scale, the shorter markings stand for the quantities between the numbered marks. We call these marks *calibrations*, a word that you must get used to seeing and using.

Three sets of numbers are used with the d-c calibrations to make three d-c scales. The top line of numbers, below the calibrations, marks off the d-c scale, in intervals of 20, from 0 to 100. Each of these intervals is divided again. For example, the distance between 0 and 20 is divided into 10 units. Halfway between 0 and 20 is a line that stands for ½ of 20, or 10 units. In the same way, halfway between 20 and 40 is the 30-unit point, and halfway between 40 and 60 is the 50-unit point; 70 is halfway between 60 and 80, and 90 is halfway between 80 and 100. The short calibrations between these points stand for two units each; the first four calibrations right after 0 are 2, 4, 6, and 8, and, at the other end of the scale, the four short calibrations between 90 and 100 are (reading from left to right) 92, 94, 96, and 98.

The second set of numbers just below 0 to 100 numbers, can be used to give the scale a value of from 0 to 25. The distance between 0 and 25 is divided into intervals of 5; so, reading across from left to right, you see the numbers 0, 5, 10, 15, 20, and 25. Each of these intervals of 5 includes 10 of the very short calibrations. Therefore, each of the short calibrations stand for ½ unit, and two of these short calibrations stand for 1 unit. For example, in Fig. 7-5*a* the pointer rests on the third very short calibration to the right of the 10 calibration point. Because each of these short lines represents ½ (on the 0 to 25 scale), we add 1½ to 10 and we read 11½ units. In Fig. 7-5*b*, the needle rests on the 18 unit calibration on the same scale.

A third line of numbers appears below the d-c calibrations and provides a 0-5 scale. This scale is marked off in intervals of 1. Reading from left to right, you see the numbers 0, 1, 2, 3, 4, and 5. Each of these intervals is divided by 10 short calibrations. Therefore, each short calibration line represents 1/10 of a unit. So, the position of the needle in Fig. 7-5*a* indicates 2.3 units on the 0-5 scale, and the position of the needle in Fig. 7-5*b* indicates 3.6 units.

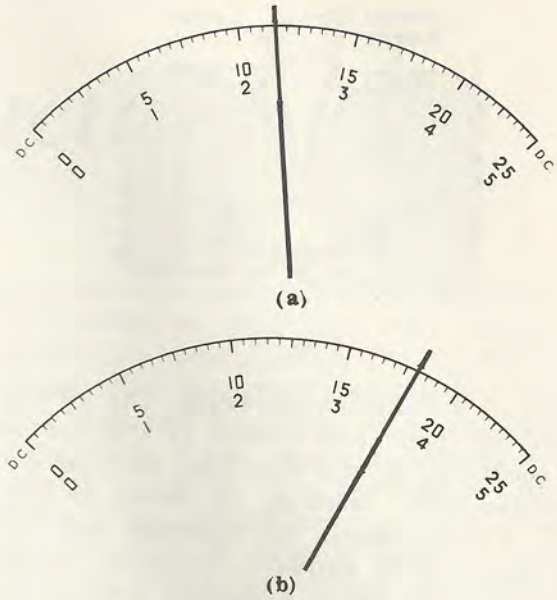
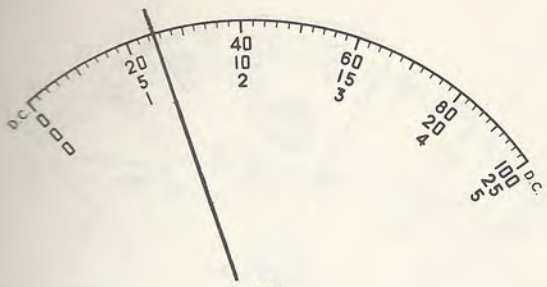
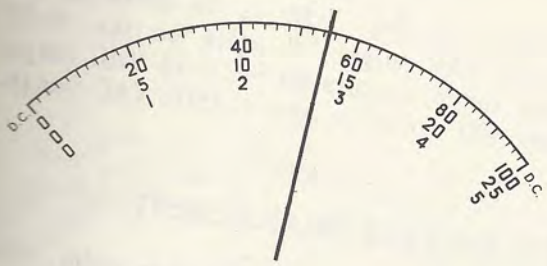


Fig. 7-5

In using this meter or any meter, you will find that the meter pointer sometimes rests between one calibration and the next. Just as when you measure with a ruler, things do not always exactly measure up to the inch- or half-inch line; so you must decide how close to the line they come. It is sometimes necessary to use your judgment to say what part of the distance between the calibrations is indicated by the meter needle. For example, in Fig. 7-6*a* the pointer is halfway between the 12th and 13th short calibrations on the 0-to-100 scale. The difference between each calibration is two units; half the distance represents one unit. So, the reading for this position of the pointer is 25 units. However, the same needle position on the 0-to-25 scale indicates only 6¼ units, while, on the 0-to-5 scale, it indicates 1.25 units. In Fig. 7-6*b*, using the 0-to-100 scale, the pointer rests between the 27th and 28th short calibrations and so indicates 55 units on the 0 to 100 scale. The same position



(a)



(b)

Fig. 7-6

of the needle represents 13¾ units on the 0-to-25 scale and 2.75 on the 0-5 scale.

You can get a better idea of how to use these scales by seeing how they are used in reading voltage or current. Let us consider voltage readings. If you examine the marker lines of the RANGE switch on your meter, as shown in Fig. 7-7, you will see that four d-c voltage ranges are provided. Starting at the top and working counter-clockwise (opposite to the direction of clock-hand movement), you will find 500-volt, 100-volt, 25-volt, and 5-volt d-c ranges. Note, too, that there are four a-c voltage ranges that share the same marker lines. We'll come back to these shortly.

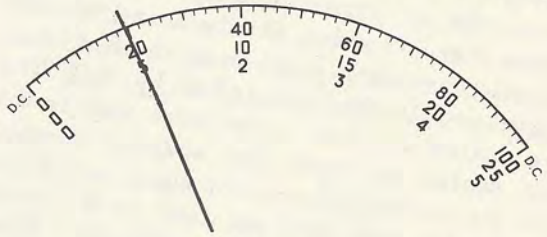
Each position of the RANGE switch makes possible a different range of readings. When the pointer of the RANGE switch points to the 5-VDC marker line, it is possible to measure voltages up to 5 vol Readings are made on the 0-5 scale on t face of the meter. When the RANGE swit points to the 25-VDC marker line, it possible to measure voltages up to 25 volt and readings are made on the 0-25 scale When the RANGE switch points to the 100 VDC line, it is possible to measure up t 100 volts, and readings are made on the 0-100 scale. When the RANGE switch points to the 500-VDC reading, it is possible to measure up to 500 volts. Readings are made on the 0-5 scale, the same scale that was used to read up to 5 volts, but readings on the scale should now be multiplied by 100. For instance, if the meter pointer rests on the 5 calibration, the reading is 500 volts; if the meter rests on the 2 calibration, the reading is 200 volts.

Fig. 7-7

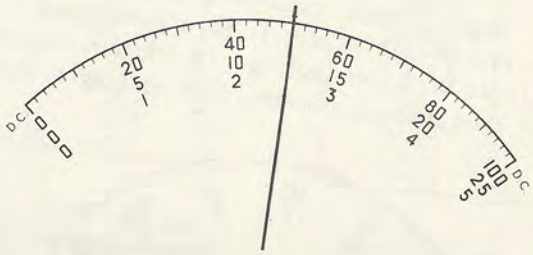
The value of the small calibrations is also multiplied by 100. So each small calibration, which stood for 1/10 volt on the 5-VDC scale, now represents 10 volts.

In Fig. 7-8*a*, the pointer rests on the 1 calibration. If we are using the 5-VDC range, the reading is 1 volt. If we are using the 500-VDC range, the reading is 100 volts.

In Fig. 7-8*b*, the pointer rests on the calibration between 2 and 3. On the 5-VDC scale, the reading is 2.5 volts. On the 500-VDC scale, the reading is 250 volts.



(a)



(b)

Fig. 7-8

A-C Voltage Scales. Your multimeter also measures a.c. A-c voltages are used in many ways. In Theory Lesson 1, you learned that high-frequency electrical waves are used in radio broadcasting. Actually, alternating voltages of very high frequency are used. Other alternating voltages and currents of very low frequencies are used every day to provide electricity for homes and factories, street lighting, trolley cars, and other electrical equipment. Most of the electrical power produced in this country is 60-cycle a.c. However, there are some places in the United States where 25-, 40-, or 50-cycle a.c. is still produced.

Most multimeters have separate d-c and a-c scales. Directions are supplied with such meters to explain which scales are used for the current and voltage ranges. The a-c scales of your multimeter, shown in Fig. 7-9, are marked off in red on the meter dial. The RANGE switch on your meter has a-c range markings at each position just below the d-c range markings. When measuring a-c voltages, use these a-c markings to position your RANGE switch; disregard the d-c markings.

The first line of numbers below the a-c calibrations on the face of the meter presents values of voltage from 0-300 volts. The next line of numbers below the a-c calibrations indicates values of voltage from 0 to 75 volts. The numbers in the third line below the a-c scale indicate voltages between 0 and 15 volts. On the 0 to 1500 volt range, the reading is taken on the 0–15 volt scale and is then multiplied by 100. The a-c scales are read in the same way as the d-c scales are read. The spacing between the a-c calibrations is not equal as on the d-c scales, but they are read in the same way that the d-c calibrations are. When the meter needle comes to rest near the low end of the scale, it is a good idea to shift to a lower voltage or current range and then take a reading. For example, the

Fig. 7-9

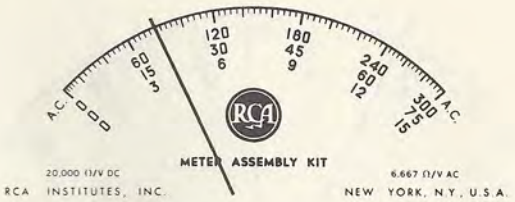


Fig. 7-10

reading in Fig. 7-10 is 80 volts on the 0–300 VAC range, 20 volts on the 0–75 VAC range, 4 volts on the 0–15 VAC range, and 400 volts on the 0–1500 VAC range.

7-3. VOLTAGE MEASUREMENT

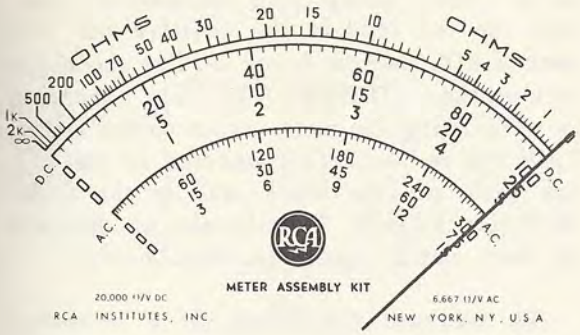
To measure voltage found in radio, television, and other electronic circuits, with any voltmeter, we should first know two things:

1. The kind of voltage: a.c. or d.c.
2. Approximately how much voltage is to be measured.

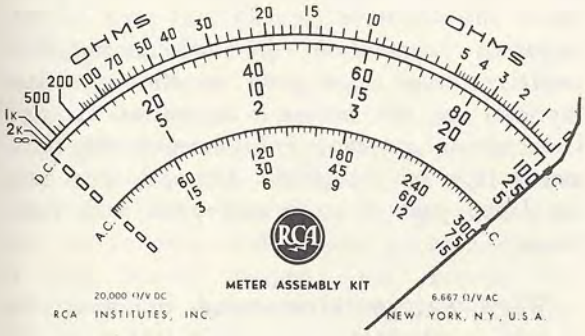
We should know the kind of voltage because most d-c voltmeters cannot measure a-c. The direction of a-c changes so often in a second that the meter needle cannot keep up with the changes and so stays in one position. When a d-c voltmeter is used to measure a-c, you may see the needle vibrating near the zero position if you look very closely. When a serviceman measures voltage in a piece of electronic equipment, he knows the kind of voltage he expects to find. He knows whether to use an a-c voltmeter or a d-c voltmeter, or, if he has a multimeter, whether to put the FUNCTION switch in the a-c position or the d-c position.

He should know how much voltage he is going to measure because if he uses the wrong voltage range he may burn out or otherwise damage the meter movement. Remember that the moving coil to which the pointer is attached is wound with very fine wire, so fine that only a very small current may safely flow through the coil.

In the case of your meter, only 50 microamperes is necessary to make the needle go to full scale, as shown in Fig. 7-11*a*. Each voltage and current range in the meter



(a)



(b)

Fig. 7-11

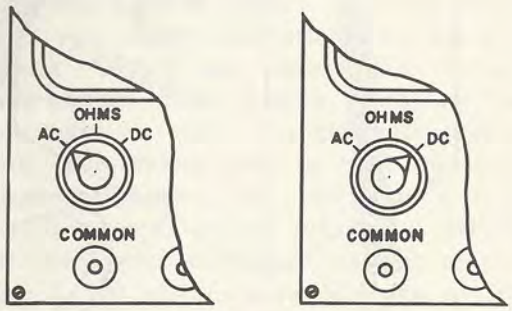
is designed so that only 50 microamperes of current, at the most, flows through the meter coil when the current or voltage being measured DOES NOT EXCEED the voltage or current shown by the position of the RANGE switch. For example, if we try to measure 100 volts with the RANGE switch on the 5-volt position, twenty times the rated current (1,000 microamperes) flows through the coil. This causes the meter needle to bang against the side of the case, as shown in Fig. 7-11*b*. This bends the needle out of shape and may possibly burn out the coil, damage the hair springs, or otherwise hurt the meter movement. So, you can see it is very important to have some idea of the amount of voltage to be measured.

Among the voltages that you are likely to measure with your meter are power-line voltages, which range from about 110 to 120 volts in the electricity supplied by most of the electric power companies in the United States. Some special power lines, usually found in factories and other business places, may be 220 to 240 volts or higher, and certain home and farm power supplies provide as low as 30 volts output. In radio receivers, d-c voltages sometimes exceed 300 volts; they practically never go beyond 500 volts. A-c voltages as high as 600 or 700 volts are found in radio receivers equipped with power transformers. On the other hand, television receivers have special power supplies that provide voltage of from 3,000 to 30,000 volts. For that reason, no serviceman touches his meter to a television receiver without having the service information, including information on voltages, from the television receiver manufacturer, or without being fully instructed in what measurements to make and how to make them.

When completed, your multimeter will be capable of measuring most of the voltages found in radio, television, and other electronic circuits. However to protect yourself and your meter, make no measurements without first taking three precautions:

1. See that the FUNCTION switch is set for the kind of measurement you are going to make. For example, the FUNCTION switch must point to AC if you are going to measure a.c., or to DC if you are going to measure d.c., as shown in Fig. 7-12 *a* and *b*.

2. See that the RANGE switch is set at the proper range for the amount of voltage to be measured. For example, when you measure filament voltages in a radio receiver that uses tubes that have 6-volt heaters and a power transformer to supply the heater voltage, you should know that the voltage must



meter set for a-c measurement
(a)

meter set for d-c measurement
(b)

Fig. 7-12

be around six volts, so you place the RANGE switch on the 0–15 VAC range. You should know that you are measuring a.c.; so you turn the FUNCTION switch to AC. However, if you are going to measure the output of the d-c power supply, which should be somewhere around 250 volts, you should place the RANGE switch on the 500 VDC position and turn the FUNCTION switch to DC. If you have no idea of how much voltage is to be measured, the best way to start is to try the highest range first. Then try the next range below, then the next, and so on.

3. Where very high voltages are expected, as in television equipment, make sure the test prods and leads are designed for measuring high voltages. If they are not, it is possible to get a shock or burn from the voltage that "leaks" through the insulation. In measuring high voltages, only high-voltage wire special protected test prods should be used.

To measure voltage properly, the test leads must be connected to the proper jacks. When using your multimeter, connect the red lead to the positive red jack marked POS and the black lead to the black jack marked COMMON. The only exception is when using the meter as an output meter. Then the red lead is connected to the yellow jack and the black lead to the COMMON (black) jack. We will take up this use of the meter again in this booklet.

To measure the output of a B-battery rated at 22½ volts, set the FUNCTION switch to DC and the RANGE switch to 25 VDC, as shown in Fig. 7-13a. Then touch the negative (black) test prod to the negative terminal of the battery and the positive (red) test prod to the positive terminal of the battery, as shown in the illustration. Be sure not to touch the bare metal tips of the prods. Instead, grip the insulated part of each test prod with your fingers.

When voltage is measured, the meter is always connected across (in shunt with) the terminals of the voltage source or between any two points where a difference in voltage exists. Figure 7-14 shows examples of measuring voltage.

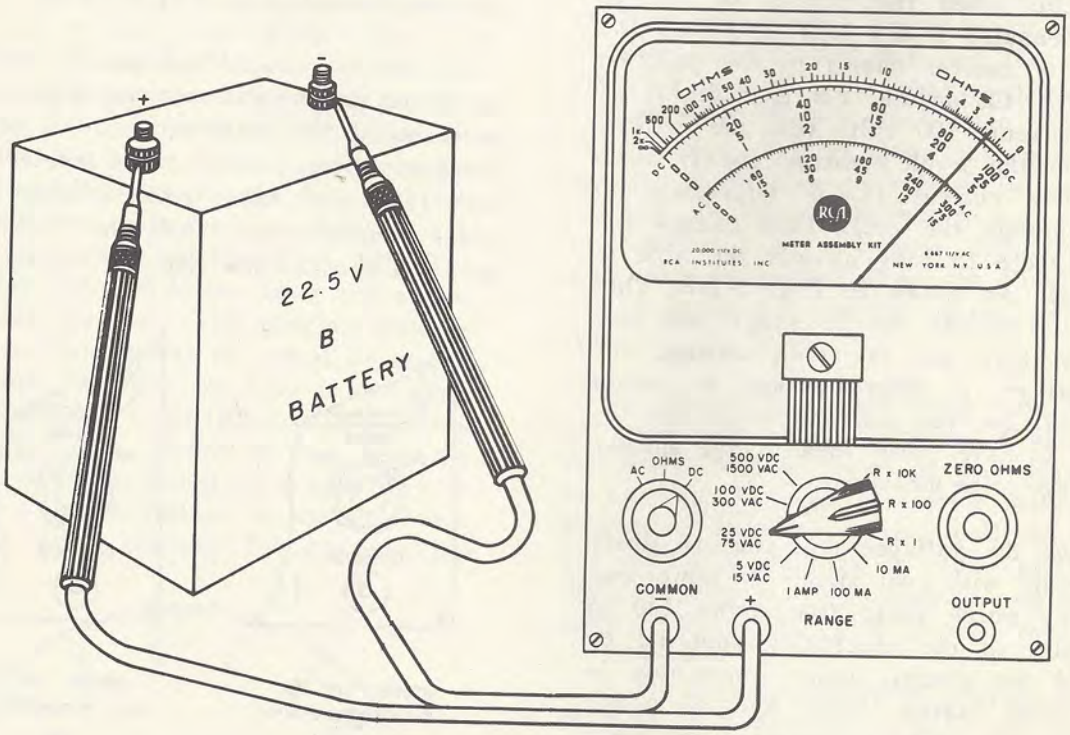


Fig. 7-13

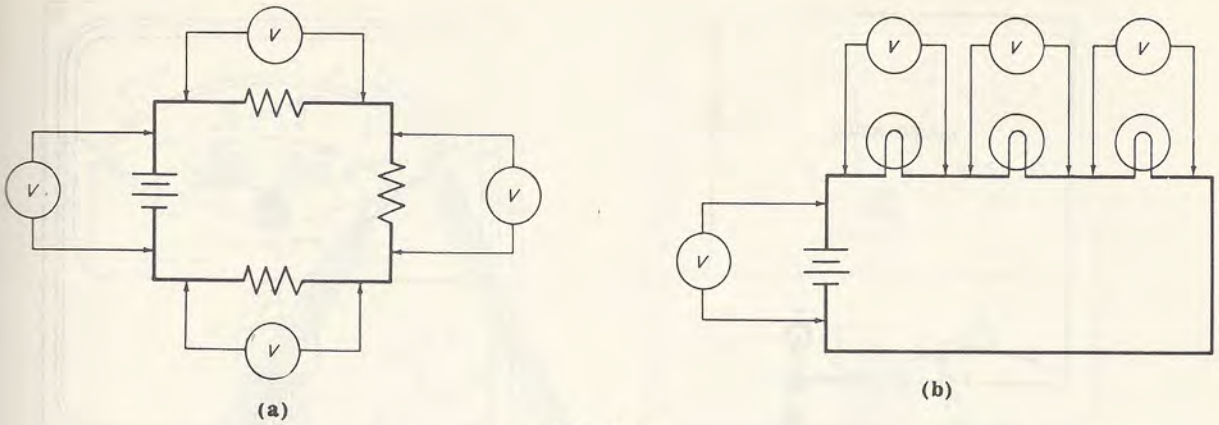


Fig. 7-14

Reversed Polarity. Sometimes, in voltage measurement, we are not sure of polarity and may touch the negative test prod to a positive terminal and the positive test prod to a negative terminal. You will know that you have reversed polarity when you see the reading of the meter go below zero. If this should happen, just reverse the test prods so that each is connected to the proper polarity. No damage will occur to the meter by reversing polarity if the proper voltage range is being used.

Measuring Unknown Voltages. When measuring a voltage whose approximate amount is unknown, *use the highest range first.* Touch one of the test prods to one terminal of the circuit being tested. Watching the meter needle, lightly brush the second terminal of the circuit with the remaining test prod, as shown in Fig. 7-15. Actually, with this brushing stroke you will make a momentary connection and immediately disconnect with the same movement. If the meter needle moves rapidly toward the high end of the scale, it is not safe to measure the voltage with that meter range. If you are using the highest range during this test, then the meter, as it is, cannot be used to read the voltage. If, however, the meter needle starts to move slowly during this brushing contact, it is safe for you to place both test prods firmly on the terminals and read the voltage. If you use the 500-volt range to measure d.c. on your multimeter and the reading falls below 100 volts, move the RANGE switch to the 100-volt range. If the reading falls below 25 volts, use the 25-volt range. If, on the 25-volt range, the reading falls below 5 volts, use the 5-volt range. Usually, the best and most accurate voltage reading is made with the range that has a top reading very close to the voltage you are measuring.

7-4. CURRENT MEASUREMENT

So far, we have discussed only the measurement of voltage. It is also important to know how to measure current. Because of the way in which the meter is connected to the circuit in current measurements, it is much easier to damage the meter movement while making current measurements than in making voltage measurements. For this reason, many an experienced serviceman hesitates to make current measurements for fear of burning out his meter. However, by using good sense and taking care, current measurements may be made with your meter as readily as voltage measurements.

Reading Current Scales. In most multimeters, the same calibrations are used to measure voltage and current. For voltage measurements, the figures used on the scale refer to volts. For current measurements, with meters used by radio and television servicemen, the calibrations refer to milliamperes, unless otherwise marked. Your multimeter has three current ranges: 0–10, 0–100 milliamperes, and one ampere (1,000 milliamperes). These current ranges are for d.c. only. There is no a-c current range. Figure 7-16 shows how the meter is set up for measuring current on each of these ranges. All current ranges are read

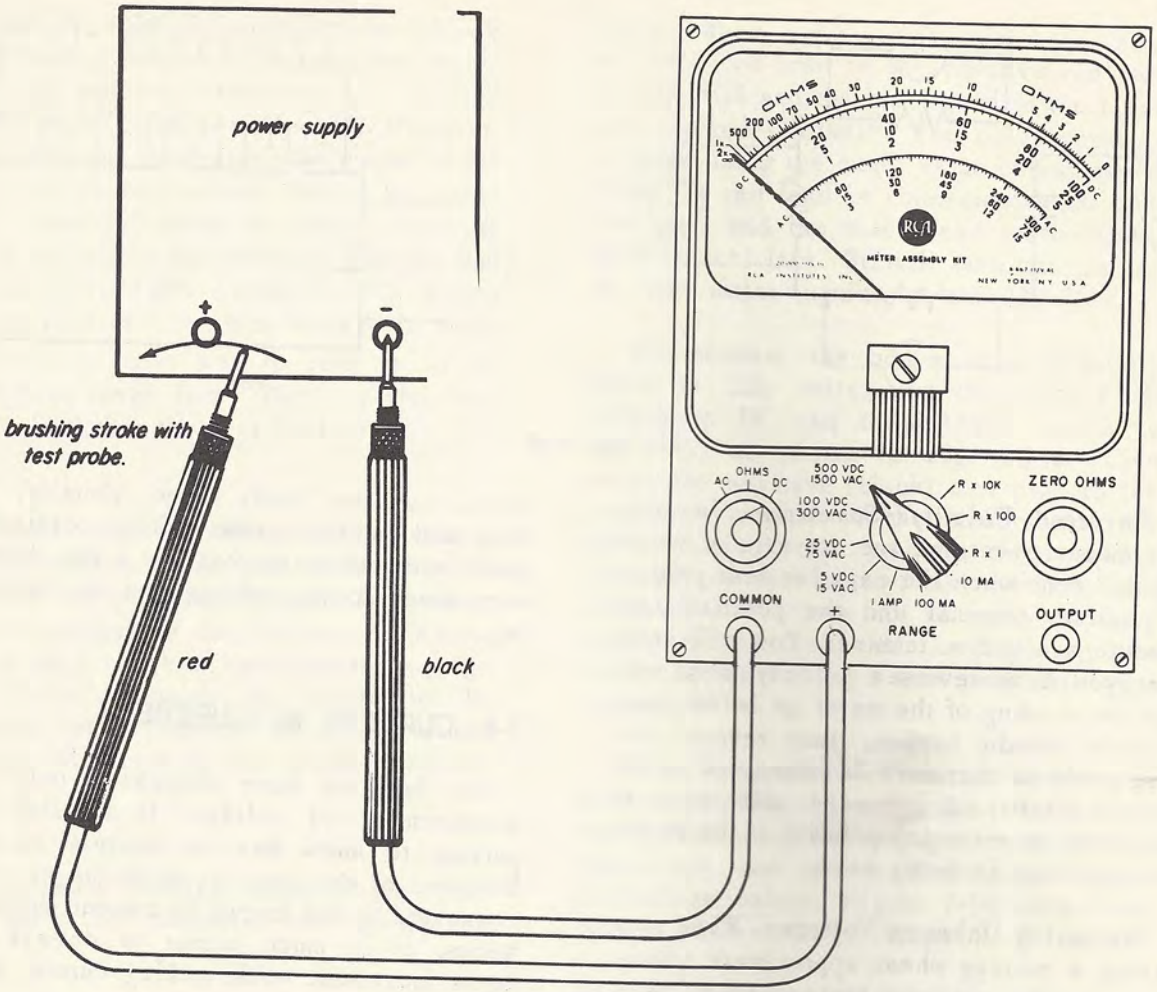


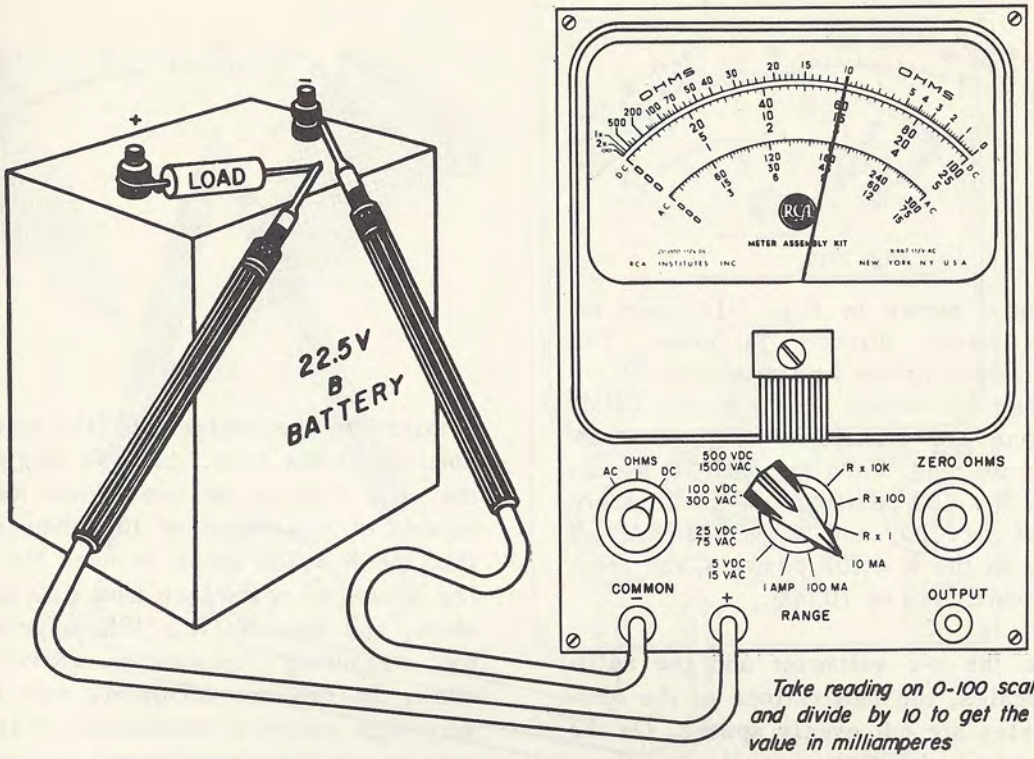
Fig. 7-15

on the 0 to 100 d-c scale. Figure 7-16*a* shows a reading of 6 ma (on the 10-MA scale); Fig. 7-16*b* shows 60 ma (on the 100-MA scale); and Fig. 7-16*c* shows 0.6 amperes (600 milliamperes) on the 1 AMP scale.

Measuring Direct Current. Look again at Fig. 7-16*a*. Three pieces of apparatus are shown connected together: a battery, a resistor, and a milliameter. Together, they form a series circuit because there is one continuous circuit without any separate branches. The source of voltage is shown as a battery, but it might be a d-c generator, a d-c power outlet, a d-c power supply, or some other source of d-c. Note that the resistor is called a *load*. By load, we mean something that uses electrical power. Whenever measuring current, the meter is connected in series with the source of electricity and the load.

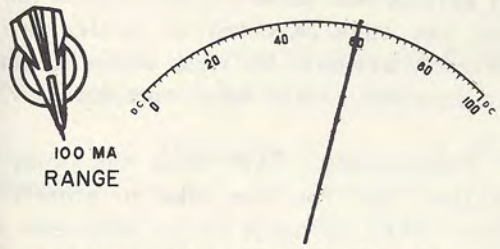
Caution: If you were to connect any of the current scales of your meter directly across a battery or other voltage source, you would instantly damage the meter movement.

Measuring Unknown Currents. It is necessary to take special care in measuring unknown currents. Start with the highest current scale first (the one-ampere current range in your multimeter). As in the case of the voltage reading, touch one prod firmly to one side of the circuit and, with a brushing stroke, make a temporary connection with the other prod to the other side of the circuit. Be sure not to touch the bare metal of the test prods. If the meter needle moves



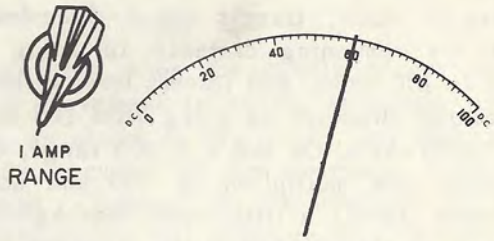
Take reading on 0-100 scale and divide by 10 to get the value in milliamperes

(a)



On 100-MA range, take reading on 0-100 scale.

(b)



On 1-amp range, take reading on 0-100 scale and multiply by 10 to get value in milliamperes

(c)

Fig. 7-16

very rapidly, the range is not high enough for measuring the current in the circuit. If the meter needle travels slowly, it is safe to make a firm connection to the circuit for a current reading. By noting the current reading, you can tell whether a lower milliampere range is safe to use. As was the case with the voltage readings, the current range that gives you a reading closest to the highest calibration on the scale is the most accurate.

7-5. RESISTANCE MEASUREMENT

In addition to measuring voltage and current, radio and television servicemen need to measure the resistance of circuits and circuit parts. For such measurements, they use an ohmmeter. In later lessons on troubleshooting and circuit checking, you will find that the ohmmeter is a very useful instrument in the hands of a man who understands the principles of electrical and radio circuits.

Reading Ohmmeter Scales. Your multimeter has three ohmmeter ranges, all of which use the same scale. When the FUNCTION switch is on OHMS, and the RANGE switch is on R x 1, R x 100, or R x 10K, the meter is set to measure ohms. When the RANGE switch is set to R x 1, the

Fig. 7-17

calibrations, shown in Fig. 7-17, give resistance values directly in ohms. The RANGE switch marker line that reads R x 1 means that the values shown by the OHMS calibrations are multiplied by *1* — thus remaining as read. When the RANGE switch is in the R x 100 position, all readings are multiplied by 100, and when the RANGE switch is in the R x 10K position, the readings are multiplied by 10,000.

Unlike the d-c voltmeter and the milliampere scales, the calibrations of the ohmmeter scales are not evenly spaced. On the R x 1 range, the meter needle travels a little more than half-scale in going from 0-to-15 ohms, travels about three-fourths of the remaining distance in going from 15 to 100 ohms, and travels most of the remaining distance in going from 100 to 2k (2,000) ohms. On the R x 100 range, these values are multiplied by 100, and so the needle travels a little more than half-scale in going from 0-1500 ohms, and most of the remaining distance in going from 1,500 ohms to 200k (200,000) ohms. In the R x 10K range, the needle travels half-scale in going from 0 to 150,000 ohms, and in most of the remaining half-scale it goes from 150,000 ohms to 20 megohms. You will note that the slightest movement of the meter needle at the high end of any of the ohmmeter scales represents a large change in ohms. In fact, on the R x 10K range, the distance between the 1 megohm and 10 megohm calibrations is very small. So, an accurate reading at that end of the scale is practically impossible. This is true for ohmmeter scales found on all standard radio and television test meters. For that reason, the makers of test meters suggest that, in using an ohmmeter, you use the range which gives you a reading *as close to the center of the scale as possible.* As shown in Fig. 7-18, the most accurate ohmmeter readings are

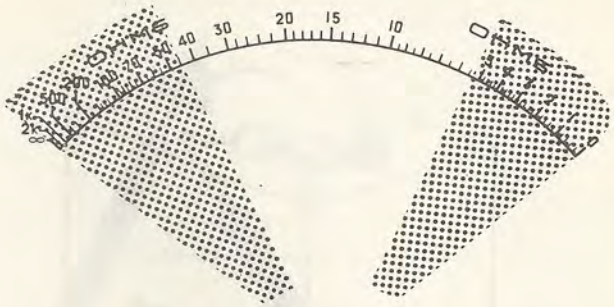


Fig. 7-18

obtained in the center half (the non-shaded portion) of the meter dial. We suggest that the R x 1 range be used when measuring values of resistance of 100 ohms or less, that the R x 100 range be used for measuring values of resistance from 100 to 10,000 ohms, and that the R x 10K range be used for measuring resistances above 10,000 ohms. To measure accurately very low and very high values of resistance, it is necessary to use more complicated and expensive equipment than the usual ohmmeter used by servicemen. However, readings at the high and low ends of ohmmeter scales are sufficiently accurate for most of the resistance measurements made by servicemen.

Precautions. The most important precaution that you can take to protect your meter when using it as an ohmmeter is to be sure that the resistor, coil, or other part being tested is not connected in any way to a source of voltage. This means that line cords must be disconnected from electric outlets of power operated equipment, or that batteries must be disconnected from all battery operated equipment, before your ohmmeter test prods touch a part under test. All ohmmeters use some source of electricity, which may be either a battery or a power supply connected to an electric outlet. Your meter uses a 1.5-volt cell on the first two ranges and a 6-volt battery on the R x 10K range. When the meter is not actually being used to measure resistance, the RANGE switch should be turned from all of the ohmmeter ranges. This is so that you will not accidentally use the ohmmeter to measure voltages or current. Actually, when the meter is not in use, the best place to leave the RANGE switch is

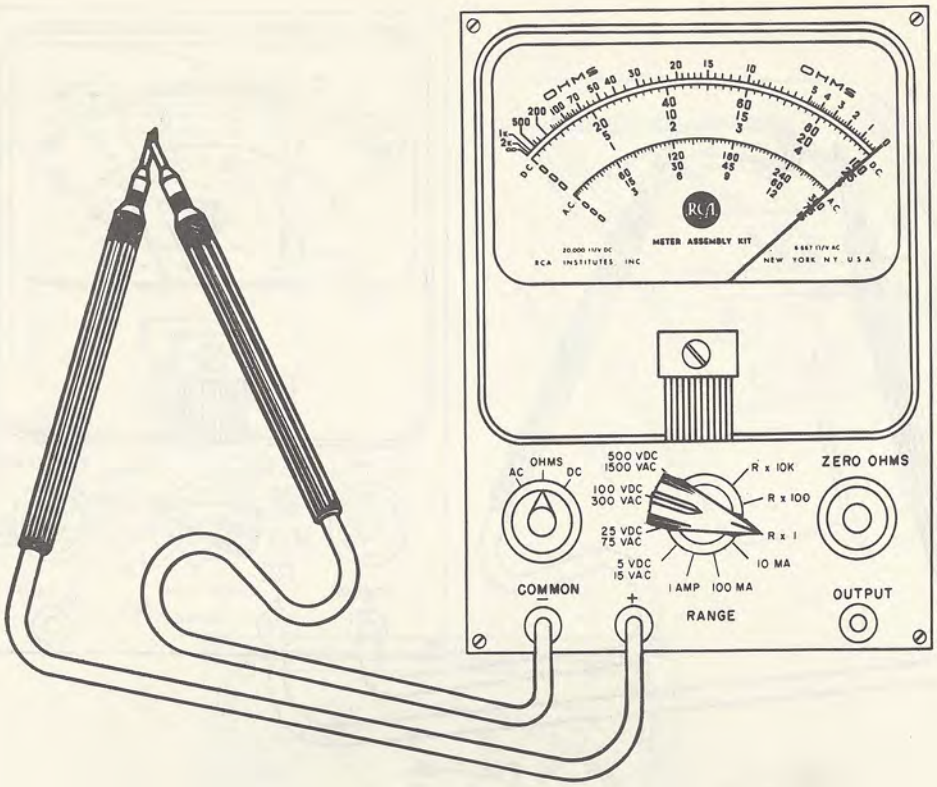


Fig. 7-19

on the 500-VDC position. Leave the FUNCTION switch on the d-c marker lines.

Using the Ohmmeter Section of Your Multimeter. To use the ohmmeter, place the red test lead in the + (red) pin jack and the black test lead in the COM pin jack. Turn the FUNCTION switch to OHMS and the RANGE switch to the desired range. Next "zero" the meter by adjusting the potentiometer marked ZERO OHMS. The adjustment is made by shorting the test prods together, as shown in Fig. 7-19 and adjusting the zero ohms knob until the meter needle rests directly over the zero calibration line. Then place the test leads across the part to be measured as shown in Fig. 7-20, and read the proper resistance scale.

7-6. METER ACCURACY

The accuracy of the meter movement used in your multimeter and of most of the meter movements used in test equipment for servicemen, is ±2-percent at full scale. This means that when the needle of any such meter movement is at the full-scale position, as shown in Fig. 7-21*a*, any error due to the accuracy of the movement will not exceed 2 percent of the reading. If, for example, this full scale reading is 100 on the 100-volt range, the error due to the accuracy of the movement is no more than 2 volts (2 percent of 100). This means, however, that *any reading* obtained on the 100 volt range *may be wrong by as much as 2 volts*. So, a 10-volt reading on the 100-volt range, as shown in Fig. 7-21*b*, may represent a voltage as low as 8 volts and as high as 12 volts. Therefore, the amount of error due to the movement may be as much as 20% of the 10-volt reading. For this reason, you have been urged to use voltage and current ranges that will give you readings as near to full scale as possible, because the nearer to full scale, the greater is the percentage of accuracy.

Another factor that affects the accuracy of meter readings is the accuracy of the resistors used in the voltage and current ranges. Naturally, resistors of ±1 percent accuracy give more

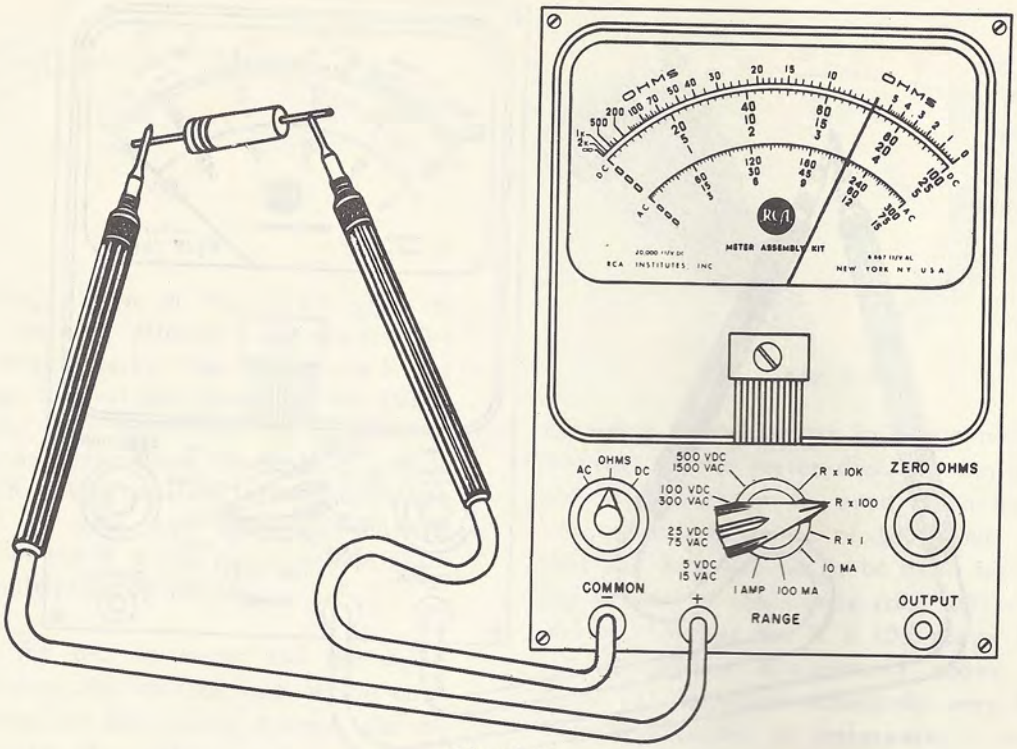


Fig. 7-20

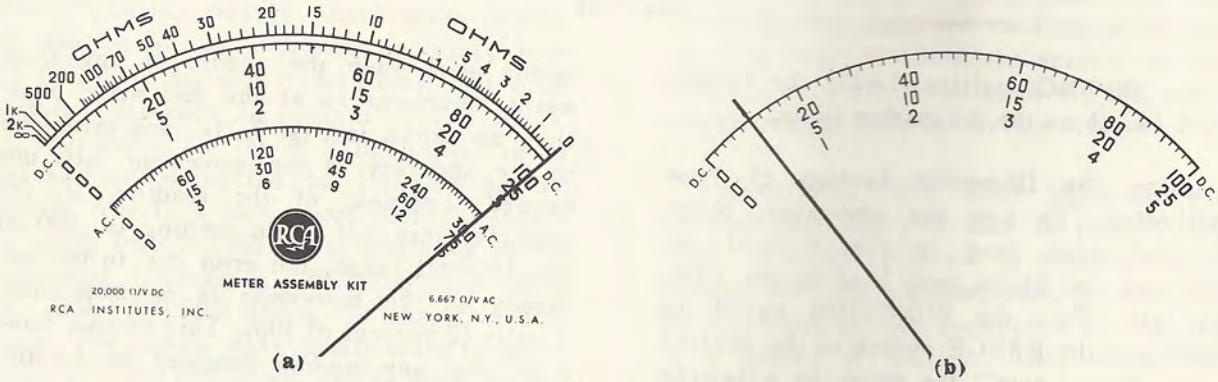


Fig. 7-21

accurate readings than resistors of higher tolerance.

Another factor that affects meter accuracy is the position of the meter — whether it is standing upright or laying flat on the bench, as in Fig. 7-22*a* and *b*. If the meter needle does not return exactly to zero in either of these positions, it may be adjusted to zero position by turning the screw shown in Fig. 7-22*c*, with a small screwdriver.

Other factors that affect the accuracy of meter readings are taken up in Service Practices 8. In that booklet, meter sensitivity is also discussed. Be sure to read it carefully so that you may better understand your meter.

7-7. PRECAUTIONS TO REMEMBER

Since your meter is so important a help in your work as a serviceman, you will want to use it carefully and accurately. As you studied this lesson, you learned certain precautions to take so that you do not damage your meter. Some of the important things to remember are listed below.

1. Never try to measure voltage on the

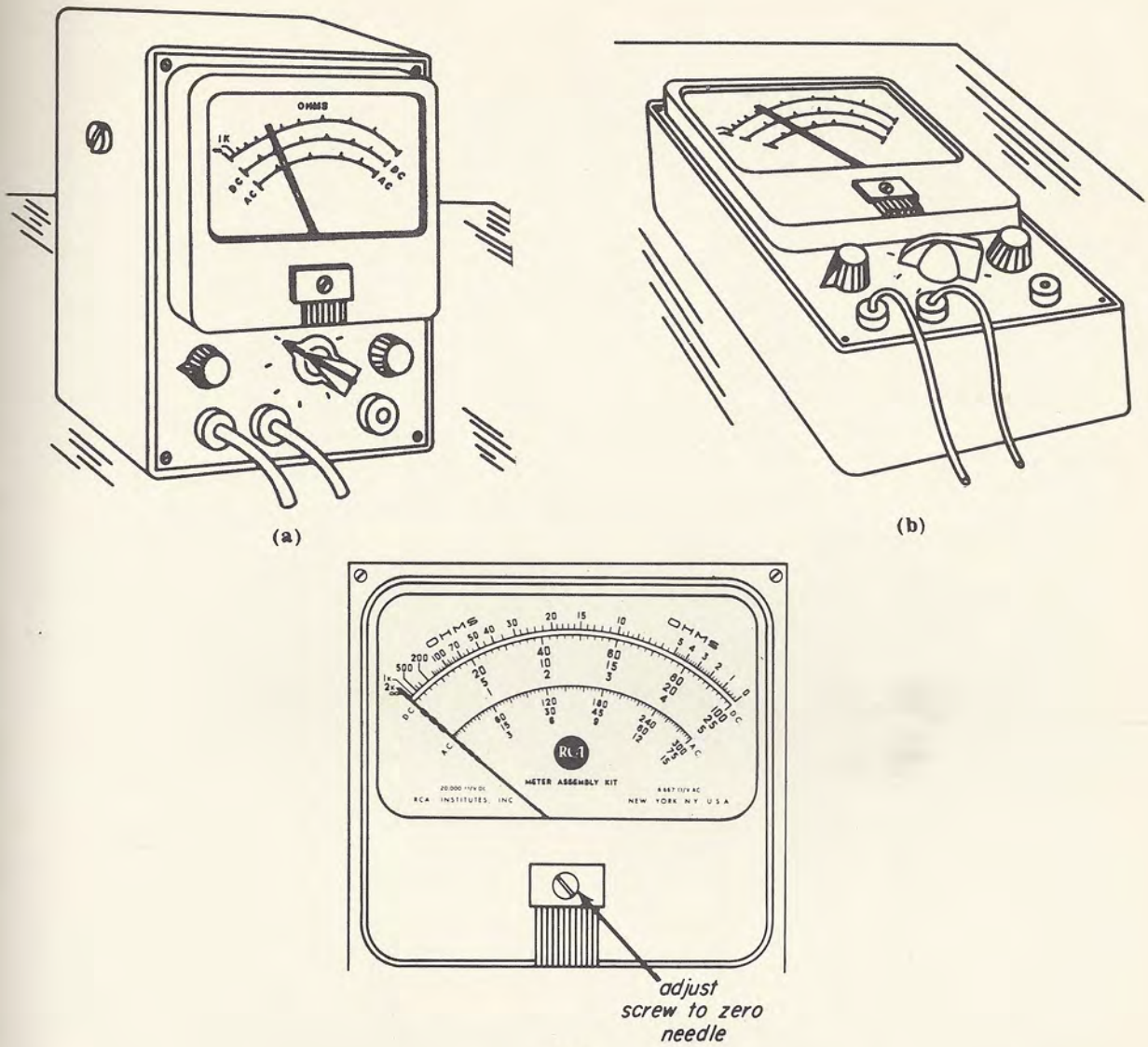


Fig. 7-22

voltmeter section of your multimeter without knowing about how much voltage you are going to measure. If you use the wrong range, you may damage or burn out your meter movement. If you are not sure of the voltage, use the highest range first.

2. When measuring an unknown current, use the highest range first.

3. Never connect any of the *current* scales of your meter *across* a battery. If you do, you will damage the meter movement.

4. When measuring resistance with your meter, be sure that the electrical part that you are measuring is not connected to a source of voltage.

5. When switching from one function to another (or from one range to another) be sure that the test leads are not connected to any part that is connected to a source of voltage.

6. When you are not using your multimeter, keep the FUNCTION switch in the DC position and the RANGE switch in the 500 VDC position. In this position, you provide the greatest protection for your meter.

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 8

HOW TO UNDERSTAND METER READINGS

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.

Service Practices 8

INTRODUCTION

Every profession or trade uses measuring instruments. One of the most important measuring instruments used by radio and television servicemen is the multimeter. It is important to be able to use your multimeter correctly and to be sure that it is always in correct operating condition.

The first part of this Service Practices booklet explains how to judge the readings you get on your multimeter. If you do not know how to judge multimeter readings, you will not be able to use your multimeter to help you find trouble in radio and TV sets. It is possible that you may mistake a correct voltage, resistance, or current for an incorrect one just because you are not using your meter properly.

The second part of this booklet discusses how to locate and correct any defects in the multimeter itself caused by incorrect wiring, defective parts, or incorrect use.

PART ONE

8-1 METER INDICATIONS

When you make a measurement with a multimeter, you must know what reading to expect if the circuit is operating properly. If you do not get the reading you expect, and you are using your meter properly, you know that there is trouble in the circuit you are measuring. But if you are not using your meter properly, you will not get a useful reading from the circuit under test — even a circuit that is operating correctly may seem to be defective.

Parallax. It is possible for you to get a correct reading on your multimeter and still not know that it is correct just because you are looking at the meter scale and pointer from the wrong angle. This is due to *parallax,* which may be defined as the seeming difference in the position of an object when seen from different positions.

Let's try a little experiment to see how parallax affects meter readings. You will need an ordinary table knife. Hold the knife over the 0-100-volt meter scale shown in Fig. 8-1*a,* with the blade straight up and down and with the lower edge about two

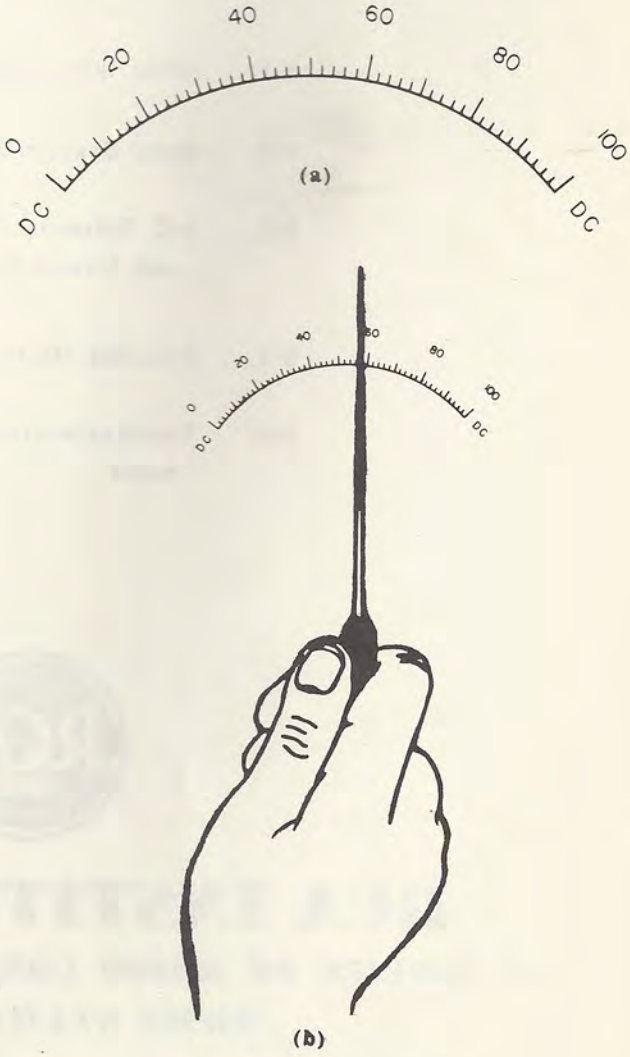


Fig. 8

inches above the scale, as shown in Fig. 8-1*b*. With your eyes about four inches above and directly over the upper edge of the blade, look at the meter scale. Note the reading. With your head moved a little to the right of the blade, take another reading. Then move your head a little to the left of the blade and take one more reading.

If you hold the knife directly over the center of the scale, the first reading should be about halfway between 40 and 60 — giving a reading of 50 volts. With your head moved to the right of the blade, the reading falls somewhere between 40 and 50 volts, while with your head to the left of the blade, the reading is between 50 and 60 volts. The only correct reading is the one taken directly over the blade. The difference between this and either of the other readings is due to parallax. The only correct way to read a meter is to place yourself directly in front of it, with the calibration, the needle, and the center point between your eyes all in the same straight line.

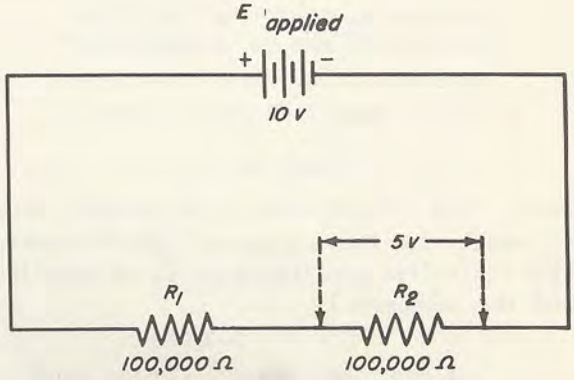
Voltage Indications. As you know, your d-c voltmeter can be used on either the 5 VDC, 25 VDC, 100 VDC, or 500 VDC ranges. When the test prods are connected to a circuit in a radio receiver to measure d-c voltage, the potential being measured always appears across a circuit containing resistance. The value of the resistance in a circuit may be very low, very high, or somewhere in between. Sometimes the circuit across which the d-c voltage is being measured is in series with other circuits that may have low, medium, or high values of resistance. Figure 8-2 shows 10 volts d.c. applied to two series resistors, R_1 and R_2. From your study of Theory Lesson 8, you know that, in a series circuit, the current flowing is the same in any part, and that the sum of the voltage drops is equal to the applied voltage. Because this is so, we can also say that *the voltage drop across any part of a series circuit is in proportion to the resistance of the part divided by the total resistance of the circuit.* Therefore, the voltage across R_2 equals the applied voltage multiplied by R_2 divided by R_1 plus R_2, or

$$E_{R2} = \frac{E_{\text{applied}} \times R_2}{R_1 + R_2}$$

$$= \frac{10 \times 100{,}000}{100{,}000 + 100{,}000}$$

$$= \frac{1{,}000{,}000}{200{,}000}$$

$$= 5 \text{ volts}$$

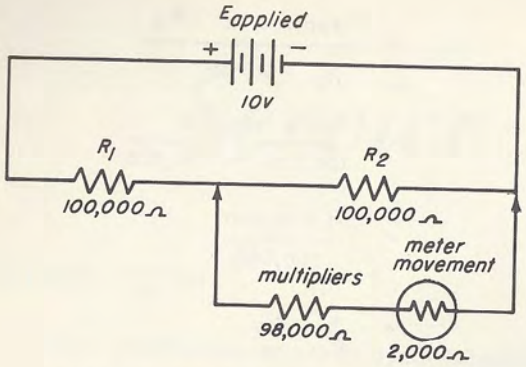


The voltage across R_2 is 5 volts

Fig. 8-2

Therefore, you expect that the reading on the multimeter will be 5 volts. Yet, if you measure the voltage across R_2, using the 5 VDC scale, the meter will show a reading of only 3.33 volts. What causes the d-c voltmeter to indicate 3.33 volts across R_2 when, according to our rule, you should expect 5 volts to appear across it if a potential of 5 volts *does* exist across R_2 without the voltmeter connected? Apparently the voltmeter affects the circuit. With the voltmeter connected, the voltage across R_2 is decreased. How does the voltmeter cause this reduced voltage reading? To find an answer, let's look at the circuit when the meter is connected across R_2.

Looking at Fig. 8-3, you can see that when the test prods are connected to R_2, the voltmeter itself becomes a part of the circuit under test. In the 5 VDC position, the voltmeter resistance equals 100,000 ohms (the 98 k-ohm multiplier in series with the 2,000-ohm resistance of the meter move-



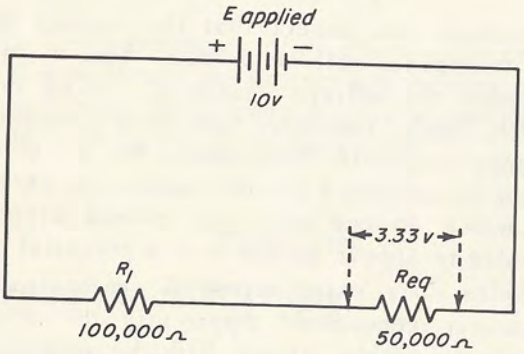
when the 100,000-ohm meter resistance is in parallel with the 100,000-ohm resistance of R_2, the effective resistance is reduced to 50,000-ohms.

Fig. 8-3

ment). This 100,000 ohms is in *parallel* with R_2, which also has a value of 100,000 ohms. The equivalent resistance of R_2 in parallel with the voltmeter is:

$$\frac{100{,}000 \times 100{,}000}{100{,}000 + 100{,}000} = \frac{(100{,}000)^2}{200{,}000}$$

$$= 50{,}000 \text{ ohms}$$



R_{eq} (the equivalent of R_2 in parallel with the 5-v d-c voltmeter) has a voltage of 3.33 volts across it.

Fig. 8-4

Figure 8-4 shows that connecting the voltmeter across the circuit makes it seem that the resistance of R_2 is reduced from 100 k- to 50 k-ohms. With the voltmeter connected, R_2 is now identified as R_{eq}. The 10-volt potential applied to the circuit does not divide equally between both resistors as before but now causes a *smaller* voltage to appear across R_{eq}, since it has been reduced in value from 100 k- to 50 k-ohms by the shunting effect of the voltmeter circuit. The voltage across R_2 in parallel with the voltmeter (R_{eq}) as read by the meter is:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 50{,}000}{100{,}000 + 50{,}000}$$

$$= \frac{500{,}000}{150{,}000}$$

$$= 3.33 \text{ volts}$$

where

E_{Req} is the potential across the parallel combination of R_2 and the voltmeter.

$E_{applied}$ is 10 volts

R_1 is the 100,000-ohm resistor.

If you measure the voltage across R_2 with the RANGE selector switch in the 25 VDC position instead of the 5 VDC position, the circuit will be as shown in Fig. 8-5*a*. We can see that the total voltmeter resistance equals 500,000 ohms. The equivalent resistance of R_2 is parallel with the meter is:

$$R_{eq} = \frac{500{,}000 \times 100{,}000}{500{,}000 + 100{,}000}$$

$$= \frac{5 \times 10^{10}}{6 \times 10^5}$$

$$= 83{,}300 \text{ ohms (approx)}$$

as shown in Fig. 8-5*b*. The potential across R_{eq} is:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 83{,}300}{183{,}300}$$

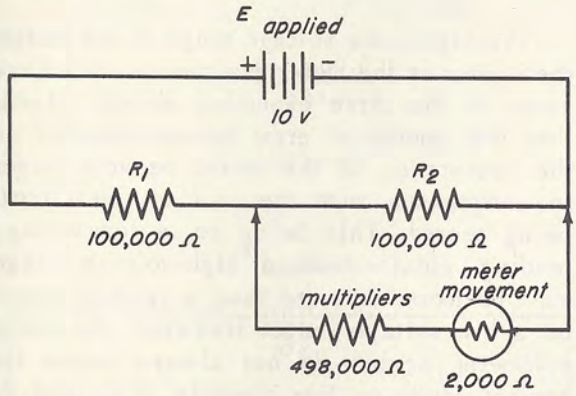
$$= 4.54 \text{ volts}$$

where:

E_{Req} is the potential across the parallel combination of R_2 and the voltmeter.

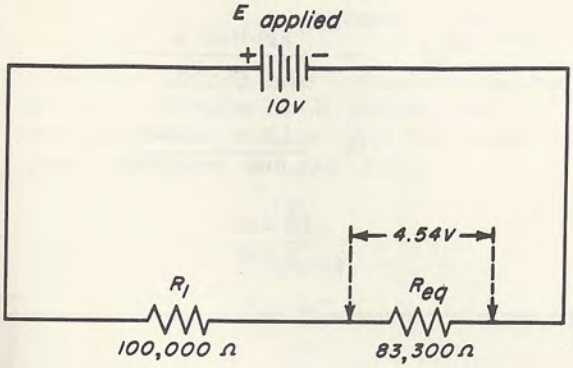
$E_{applied}$ is 10 volts

R_1 is the 100 k-ohm resistor



When the 500,000-ohm voltmeter resistance is in parallel with the 100,000-ohm resistance of R_2, the equivalent resistance is 83,300 ohms.

(a)



R_{eq} (R_2 in parallel with 25 v d-c voltmeter resistance) has a voltage of 4.54 volts across it.

(b)

Fig. 8-5

Suppose that you were to use the voltmeter with the RANGE selector switch in the 100 VDC position to indicate the voltage across R_2. Figure 8-6*a* shows that the resistance of the voltmeter circuit equals 2,000,000 ohms. When the test prods are connected to R_2, the shunting effect of the voltmeter causes the effective resistance of R_2 to be reduced from 100,000 ohms to:

$$R_{eq} = \frac{100{,}000 \times 2{,}000{,}000}{100{,}000 + 2{,}000{,}000}$$

$$= \frac{2 \times 10^{11}}{2.1 \times 10^{6}}$$

$$= \frac{2 \times 10^{5}}{2.1}$$

$$= 0.952 \times 10^{5}$$

$$= 95{,}200 \text{ ohms,}$$

as shown in Fig. 8-6*b*. The voltage across R_{eq} is:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 95{,}200}{100{,}000 + 95{,}200}$$

$$= \frac{952{,}000}{195{,}200}$$

$$= 4.88 \text{ volts}$$

where

E_{Req} is the voltage across the parallel combination of R_2 and the voltmeter.

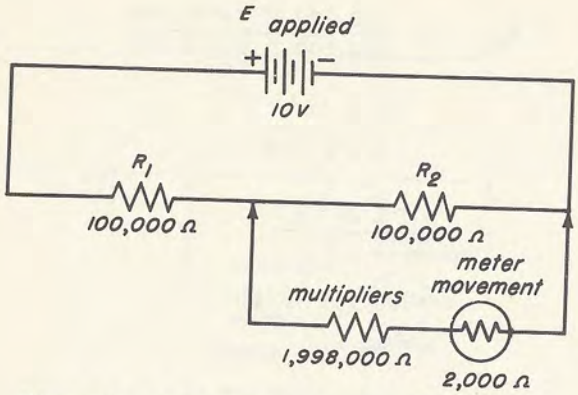
$E_{applied}$ is 10 volts

R_1 is the 100,000-ohm resistor.

Circuit Loading. If you compare the voltmeter readings obtained across R_2 when the RANGE selector knob was in the three different multiplier positions, you will learn that:

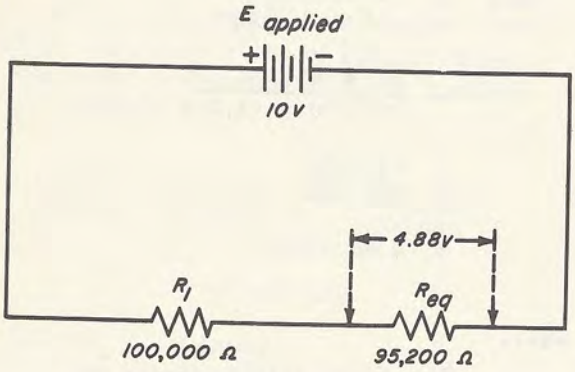
1. A voltmeter acts in parallel with the circuit being tested, and, therefore, lowers the resistance value of the circuit that it is used to test.

2. The lower voltmeter multiplier circuits have less resistance than the higher ranges. This causes the lower ranges, when used, to change and lower the resistance of the circuit being tested to a greater degree than when the higher ranges of the meter are used to make measurement of voltage.



When the 2,000,000-ohm voltmeter resistance is parallel with 100,000-ohm resistance of R_2, the equivalent resistance is 95,200 ohms.

(a)



R_{eq} (R_2 in parallel with 100-v d-c voltmeter resistance) has a voltage of 4.88 volts across it.

(b)

Fig. 8-6

When a voltmeter changes the resistance value of the circuit to which it is connected, we say that the meter loads the circuit. *Circuit loading* takes place whenever a meter such as yours is used to measure voltage. In many cases, the loading is so slight that it makes little or no difference in the voltage reading. However, under certain conditions, the loading is so great that the error in the voltage reading is very large. Voltmeters give accurate readings when:

1. The resistance of the voltmeter is much greater than the resistance being tested. (A rule of-thumb is that when the meter resistance is ten or more times the resistance of the part of the circuit being tested, the error is so small that it may be ignored.)

2. The equivalent resistance of the meter in parallel with the part of the circuit being tested is much greater than the sum of all other resistance values in series with the circuit being measured.

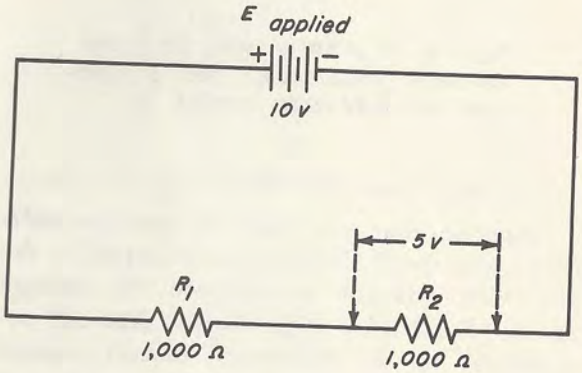
The higher the voltage range of the meter, the higher is the meter resistance. You have seen, in the three examples already given, that the amount of error became smaller as the resistance of the meter became larger in comparison with the part of the circuit being tested. This being so, a low-voltage reading obtained on a high-voltage range may be more accurate than a reading taken on a low-voltage range. However, the lower voltmeter scales do not always cause incorrect readings. For example, if R_1 and R_2 each had a resistance value of 1,000 ohms instead of 100,000 ohms, as shown in Fig. 8-7, the voltage across R_2 without the voltmeter connected would be:

$$E_{R2} = \frac{E_{applied} \times R_2}{R_1 + R_2}$$

$$= \frac{10 \times 1{,}000}{1{,}000 + 1{,}000}$$

$$= \frac{10{,}000}{2{,}000}$$

$$= 5 \text{ volts}$$



The voltage across R_2 is 5 volts.

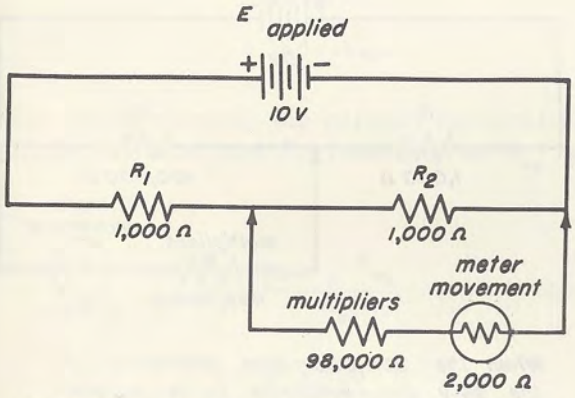
Fig. 8-7

When the voltmeter is connected to R_2 with the RANGE selector knob in the 5 VDC position, the parallel-resistance combination of the voltmeter resistance (100,000 ohms) in shunt with R_2 (1,000 ohms) shown in Fig. 8-8*a* is:

$$R_{eq} = \frac{1{,}000 \times 100{,}000}{1{,}000 + 100{,}000}$$

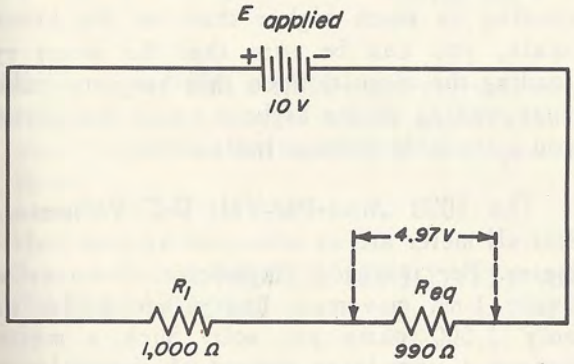
$$= \frac{100{,}000{,}000}{101{,}000}$$

$$= 990 \text{ ohms}$$



When the 100,000-ohm resistance of the 5-v d-c voltmeter is in parallel with the 1,000-ohm resistor R_2, the equivalent resistance is 990 ohms.

(a)



R_{eq} (R_2 in parallel with 5-v d-c voltmeter) has a voltage of 4.97 v across it.

(b)

Fig. 8-8

The required voltage across R_{eq}, shown in Fig. 8-8*b*, is:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 990}{1{,}000 + 990}$$

$$= \frac{9{,}900}{1{,}990}$$

$$= 4.97 \text{ volts}$$

As you can see the meter causes practically no error when its resistance is very much higher than the resistance of the part of the circuit being tested.

When the combination of the meter and the part being tested has much greater resistance than the rest of the series circuit, meter loading will affect the voltage reading very little. Figure 8-9*a* shows two resistors in series connected across ten volts. R_1 measures 1,000 ohms and R_2 is 100,000 ohms. The voltage across R_2 is:

$$E_{R2} = \frac{E_{applied} \times R_2}{R_1 + R_2}$$

$$= \frac{10 \times 100{,}000}{1{,}000 + 100{,}000}$$

$$= \frac{1{,}000{,}000}{101{,}000}$$

$$= 9.90 \text{ volts}$$

When the 25 VDC position is connected across R_2 (Fig. 8-9*b*), R_2 is in parallel with 500,000 ohms meter resistance. The equivalent circuit is:

$$R_{eq} = \frac{100{,}000 \times 500{,}000}{100{,}000 + 500{,}000}$$

$$= \frac{50 \times 10^9}{6 \times 10^5}$$

$$= \frac{50 \times 10^4}{6}$$

$$= 8.33 \times 10^4$$

$$= 83{,}300 \text{ ohms}$$

then:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 83{,}300}{1{,}000 + 83{,}300}$$

$$= \frac{8330}{843}$$

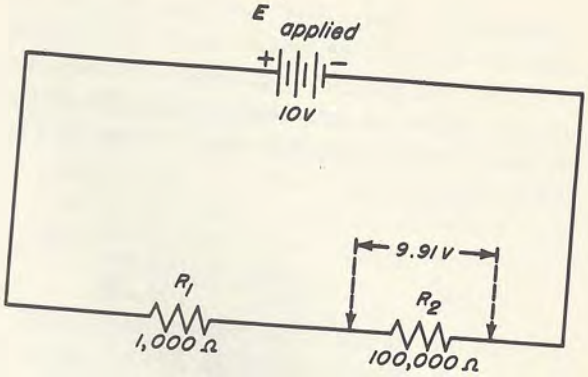
$$= 9.88 \text{ volts}$$

As you can see, meter loading has little effect on this voltage reading.

8-2 METER SENSITIVITY

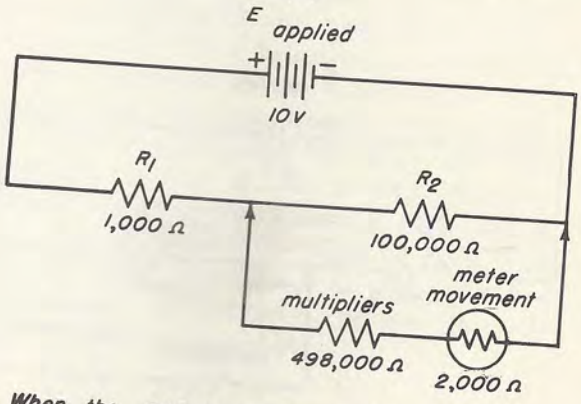
Meters are sometimes rated by the amount of current required to make the needle go to full scale. When so rated, the meter that requires the least amount of current is rated the most sensitive. For example, the basic meter movement used in your multimeter is a very sensitive instrument; it requires only 50 microamperes of current through the moving coil to force the needle to full scale. Another way uses an *ohms-per-volt* rating, which is used in rating voltmeters. The ohms-per-volt rating is found by dividing the meter resistance by the number of volts indicated when the needle goes to full scale for a particular voltage range. The meter resistance is the sum of the resistance of the basic meter movement and the multiplier resistance for the particular scale. For example, your multimeter has a resistance of 100,000 ohms on the 5 VDC range. The sensitivity is found by dividing 100,000 by 5 (the number of volts indicated by a full-scale deflection of the needle). We find that 20,000 ohms is the answer and that the sensitivity of your meter is 20,000 ohms per volt. You will find that you'll get the same answer no matter which scale you use.

In most cases, when using your voltmeter, you do not have to worry much about circuit loading and inaccurate readings. However, when you are in doubt about the accuracy of a voltage reading, due to what you may suspect to be circuit loading, take



The voltage across R_2 is 9.91 volts.

(a)



When the 500,000-ohm resistance of the 25-v d-c voltmeter is in parallel with the 100,000 ohms of R_2, the equivalent resistance is 83,300 ohms.

(b)

Fig. 8-9

a reading on the next higher scale. If the reading is much higher than on the lower scale, you can be sure that the meter is loading the circuit. When this happens, take your reading on the highest scale that gives you a readable voltage indication.

The 1000 Ohms-Per-Volt D-C Voltmeter. Not all meter are as sensitive as your multimeter. For instance, any meter that uses a basic 1-ma movement has a sensitivity of only 1,000 ohms per volt. Such a meter causes a very large amount of circuit loading when making d-c voltage measurements in modern radio, TV, or general electronic equipment. One milliampere (1,000 microamperes) of current is needed to deflect the needle to the full-scale position, while our meter requires only 50 microamperes. Therefore, our meter is $\frac{1000}{50} = 20$ times more sensitive to changes in current. The volt-

meter resistance of a 1000-ohms-per-volt d-c voltmeter is *only 5,000 ohms*, when used in the 5 VDC position. You can see that such a low-resistance voltmeter would cause a very large amount of circuit loading. For example, Fig. 8-10*a* shows that the voltage drop across R_2 is 5 volts. If a 1,000-ohms-per-volt d-c voltmeter is connected across R_2 with the RANGE selector knob in the 5 VDC position, the combined parallel resistance of the voltmeter and R_2 is:

$$R_{eq} = \frac{5{,}000 \times 100{,}000}{5{,}000 + 100{,}000}$$

$$= \frac{500{,}000{,}000}{105{,}000}$$

$$= 4{,}760 \text{ ohms}$$

The voltage across the parallel combination of the voltmeter and R_2, identified as R_{eq} is:

$$E_{Req} = \frac{E_{applied} \times R_{eq}}{R_1 + R_{eq}}$$

$$= \frac{10 \times 4{,}760}{100{,}000 + 4{,}760}$$

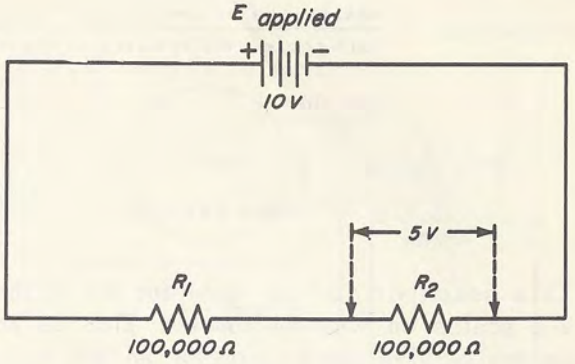
$$= \frac{47{,}600}{104{,}760}$$

$$= 0.45 \text{ volts, as shown in Fig. 8-10}b \text{ and } c.$$

You can see that a 1,000-ohms-per-volt meter is much more likely to load a circuit than is your highly sensitive 20,000 ohms-per-volt meter.

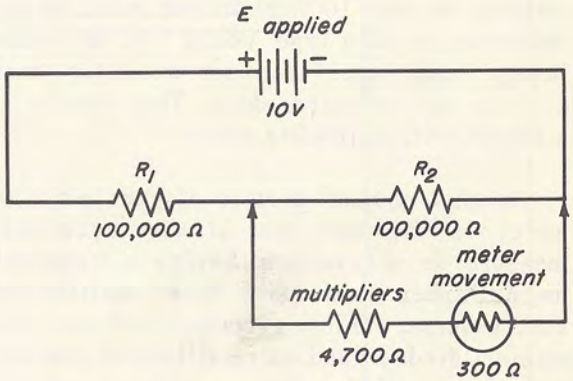
8-3. A-C VOLTMETER SENSITIVITY AND CIRCUIT LOADING

The a-c voltmeter is not used as often as the d-c voltmeter when troubleshooting and repairing radio receivers. However, when it is used, it is important to know what results to expect and under what conditions the meter will load the circuit. Earlier in this lesson, we learned that the sensitivity of a voltmeter in ohms per volt is equal to voltmeter resistance divided by



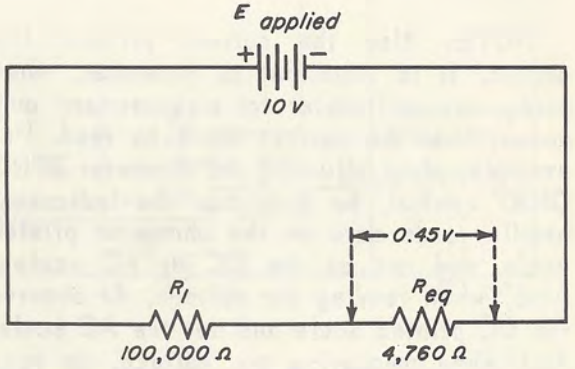
The voltage across R_2 is 5 volts.

(a)



When the 5,000 ohms of the voltmeter is in parallel with the 100,000 ohms of R_2, the equivalent resistance is 4.760 ohms.

(b)



R_{eq} (R_2 in parallel with the 5 VDC range of the 1,000-ohms-per-volt meter) has 0.45 volts across it.

(c)

Fig. 8-10

the full-scale voltage. For the 15-volt scale, our a-c voltmeter resistance is 100,000 ohms. Therefore:

$$\text{Sensitivity} = \frac{\text{resistance of meter}}{\text{full-scale volt reading of meter}}$$

$$= \frac{100{,}000}{15}$$

$$= 6{,}667 \text{ ohms per volt}$$

This sensitivity is the same for all of the a-c scales on your multimeter. This is an unusually high sensitivity for an a-c voltmeter compared with other a-c voltmeters used in multimeter circuits. Many types of a-c voltmeters on the market have a sensitivity of only 1000 ohms per volt. An a-c voltmeter of this type would load a circuit being tested more than six times as much as your a-c voltmeter does. This results in a larger voltage-reading error.

Another unusual feature of your a-c voltmeter is the fact that it can accurately measure an a-c voltage having a frequency much higher than most other multimeters can manage. This is because of the germanium diodes used as rectifiers in your a-c voltmeter. (Diodes and rectifiers are discussed fully in a Theory Lesson later in this course.) Many a-c voltmeters use copper-oxide rectifiers, which do not measure a-c voltages at higher a-c frequencies as accurately as do germanium diodes.

NOTE: Use the correct printed dial scales. It is important to remember, when using any multimeter for measurement purposes, that the correct scale be read. For example, when adjusting the ohmmeter ZERO OHMS control, be sure that the indicating needle reads zero on the ohmmeter printed scale and not on the DC or AC scales. Also, when reading d-c voltage, do observe the DC printed scale and not the AC scale. And when measuring a-c voltage, do read the AC scale and not the DC voltage scale.

PART TWO

8-4. POSSIBLE MULTIMETER TROUBLES

When you have completed the wiring of your multimeter, you may find that it does not work properly on one or more ranges. Or, after the multimeter has been in use for some time, you may discover that there is something wrong with it. In either case, it will save you a lot of time and effort if you know how to go about locating the trouble and correcting it. Most of the troubles that may affect your multimeter can be located by carefully following the troubleshooting instructions given in the following pages. Do not try any short cuts. Follow each step in the troubleshooting procedure in the order given and you will protect your meter from accidental damage while you make your tests.

If your meter does not work properly, there are many possible reasons. However, for your multimeter, there are six basic kinds of trouble

1. The meter does not work on any range in any function.

2. The meter does not work on one or more d-c voltmeter ranges.

3. The meter does not work on one or more a-c voltmeter ranges.

4. The meter does not work on one or more ohmmeter ranges.

5. The meter does not work on one or more current ranges.

6. The meter does not work on the output voltage ranges.

While the troubleshooting instructions that follow were written to help you troubleshoot your multimeter, the method and order of tests are basically the same for any multimeter that uses a D'Arsonval moving-coil movement. The system of multipliers and shunts for the voltage and current ranges of any multimeter are very much like those in your multimeter. When you study Theory Lesson 11, you will find that there are several different systems used in wiring ohmmeter circuits. For this reason, it is important to know what ohmmeter circuits are being used in any other multimeter so that you may trace them in troubleshooting.

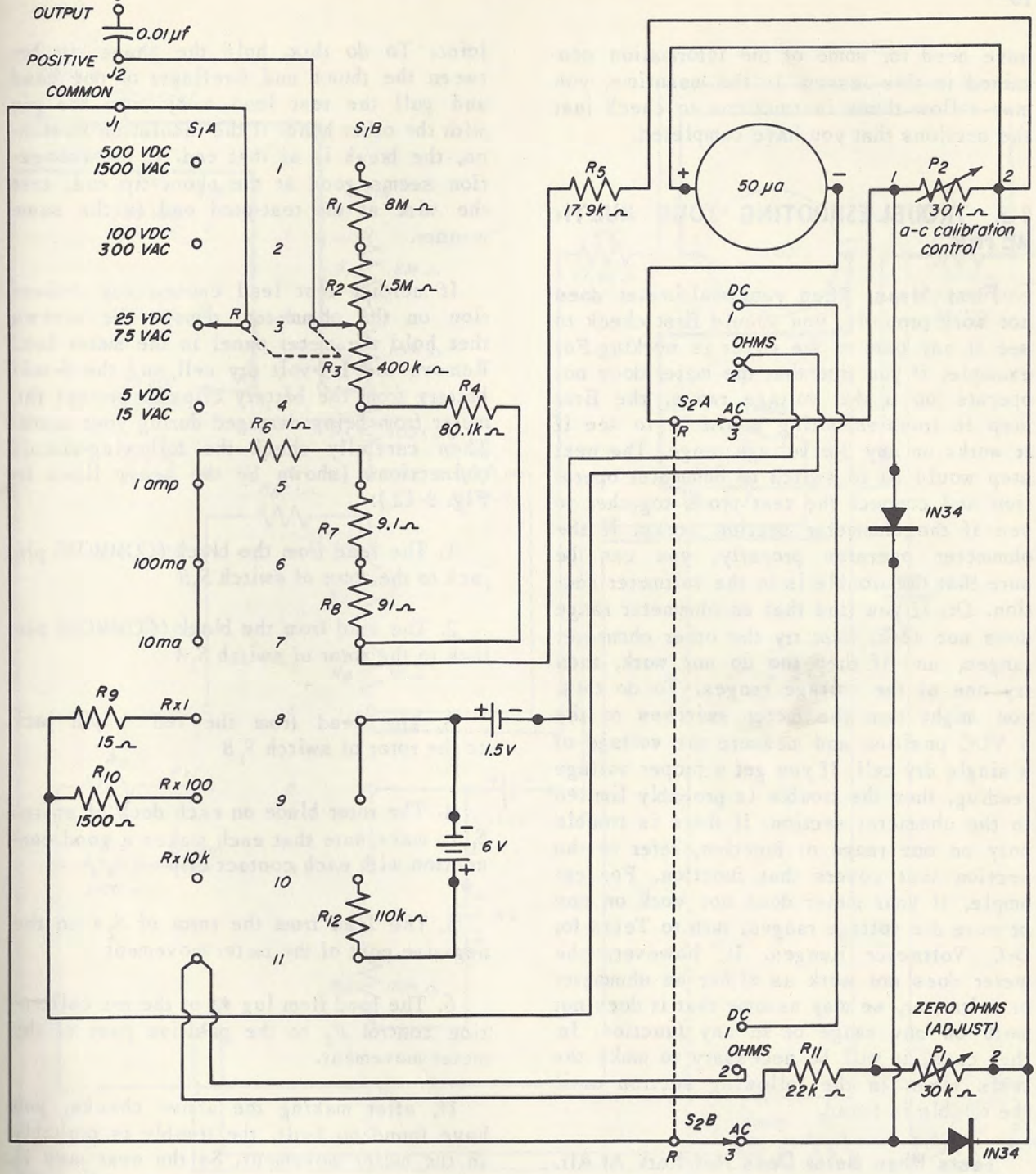


Fig. 8-11

Sometimes a schematic drawing may be obtained from the manufacturer of the multimeter or from one of the organizations that publish schematics and service data for servicemen.

Figure 8-11 shows the complete schematic diagram for your multimeter. At the time that you receive this booklet, you will not have wired the a-c section. However, as you know, these Service Practices booklets are designed to be kept handy for ready reference when needed, while you are taking the course and even long after you have finished the course. After you have completed wiring the a-c section of your multimeter, you may

have need for some of the information contained in this lesson. In the meantime, you may follow these instructions to check just the sections that you have completed.

8-5. TROUBLESHOOTING YOUR MULTIMETER

First Steps. When your multimeter does not work properly, you should first check to see if any part of the meter is working. For example, if you find that the meter does not operate on a d-c voltage range, the first step in troubleshooting would be to see if it works on any d-c voltage range. The next step would be to switch to ohmmeter operation and connect the test prods together to see if the ohmmeter section works. If the ohmmeter operates properly, you can be sure that the trouble is in the voltmeter section. Or, if you find that an ohmmeter range does not work, first try the other ohmmeter ranges, and if they too do not work, then try one of the voltage ranges. To do this, you might turn the meter switches to the 5 VDC position and measure the voltage of a single dry cell. If you get a proper voltage reading, then the trouble is probably limited to the ohmmeter section. If there is trouble only on one range or function, refer to the section that covers that function. For example, if your meter does not work on one or more d-c voltage ranges, turn to Tests for D-C Voltmeter Ranges. If, however, the meter does not work as either an ohmmeter or voltmeter, we may assume that it does not work on any range or in any function. In that case, it will be necessary to make the tests given in the following section until the trouble is found.

Tests When Meter Does Not Work At All. First check the test leads. To do this, set the meter up for operation on the R x 1 ohmmeter scale. Then remove the red test lead from the + pin jack. Connect one end of the black test lead to the COMMON pin jack and the other end to the + pin jack. If the ohmmeter works, test the red lead in the same way. If the meter needle deflects for one test lead and not the other, you can be sure that the lead that causes no deflection is defective. Then test each end of the defective test lead for a break or a poor joint. To do this, hold the phone tip between the thumb and forefinger of one hand and pull the test lead away from the pin with the other hand. If the insulation stretches, the break is at that end. If the connection seems good at the phone-tip end, test the wire at the test-prod end in the same manner.

If neither test lead causes any deflection on the ohmmeter, remove the screws that hold the meter panel in the meter box. Remove the 1.5-volt dry cell and the 6-volt battery from the battery clips to protect the meter from being damaged during your tests. Then carefully check the following-circuit connections (shown by the heavy lines in Fig. 8-12.):

1. The lead from the black (COMMON) pin jack to the rotor of switch S_2B

2. The lead from the black (COMMON) pin jack to the rotor of switch S_1A

3. The lead from the red + pin jack to the rotor of switch S_1B

4. The rotor blade on each deck of switch S_1 to make sure that each makes a good connection with each contact clip

5. The lead from the rotor of S_2A to the negative post of the meter movement

6. The lead from lug #2 of the a-c calibration control P_2 to the positive post of the meter movement.

If, after making the above checks, you have found no fault, the trouble is probably in the meter movement. So the next step is to check the movement. Of course, if either of the spiral springs or the moving coil is burned out because of meter overloading, it will be easy to see because the needle may be badly bent. However, it is possible for a meter movement to open up because of some defect in manufacture or because of rough handling. The meter movement may be checked in this manner:

1. Disconnect all wires from both terminals of the meter.

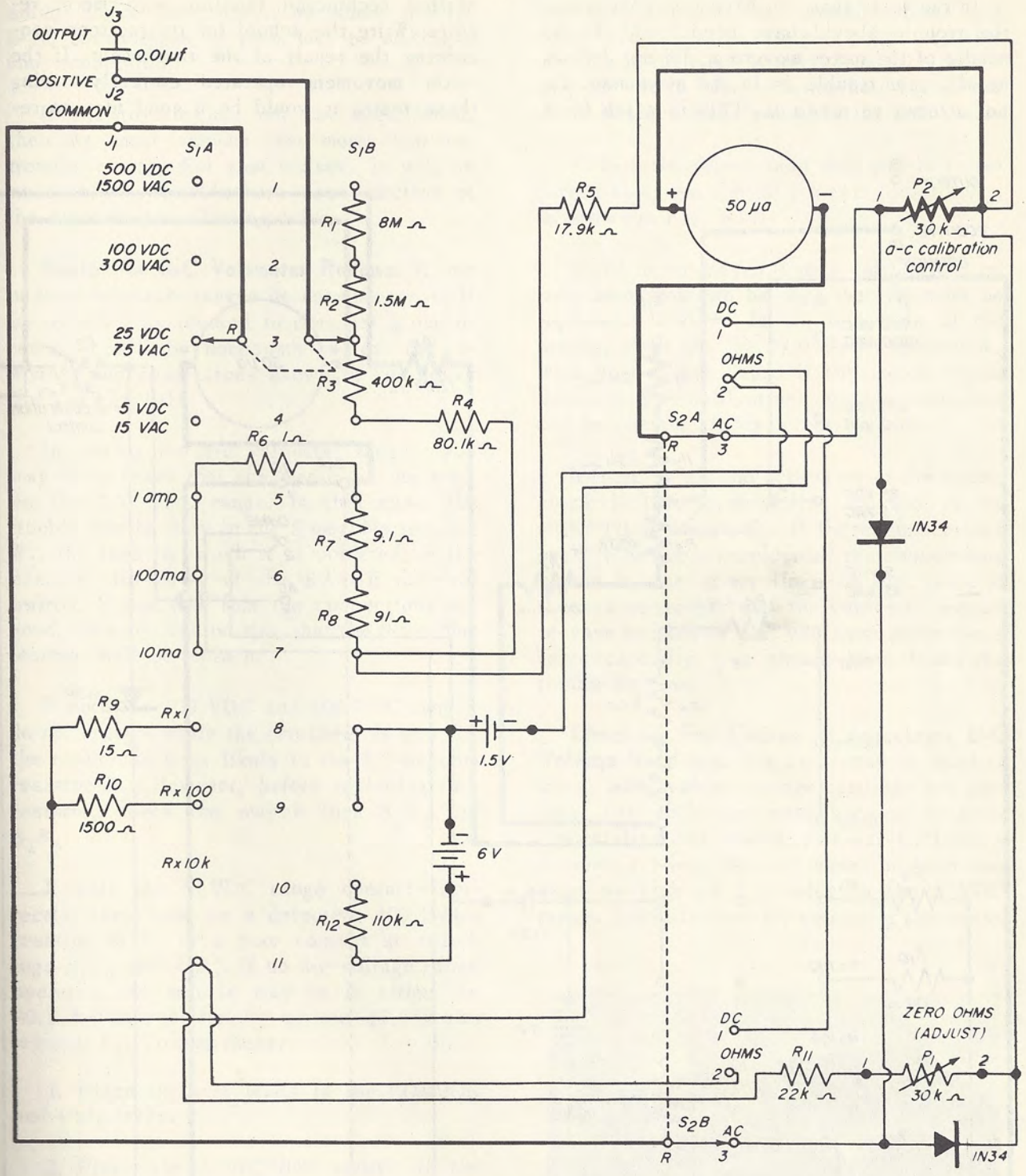


Fig. 8-12

2. Connect the negative terminal of the dry cell to the negative terminal of the meter, making sure that the positive terminal of the cell *does not touch* the positive terminal of the meter.

3. Moisten both forefingers; place one finger on the positive terminal of the cell and one finger on the positive meter terminal

4. Observe the meter needle; if there is even the slightest movement of the needle, it shows that the meter movement is operating in a normal manner.

In the tests that you have just completed, the trouble should have been found. If the needle of the meter movement did not deflect at all, your trouble is in the movement. Do not attempt to repair it. This is a job for a skilled technician familiar with meter repairs. Write the school for instructions concerning the repair of the instrument. If the meter movement operated correctly during these tests, it would be a good idea to re-

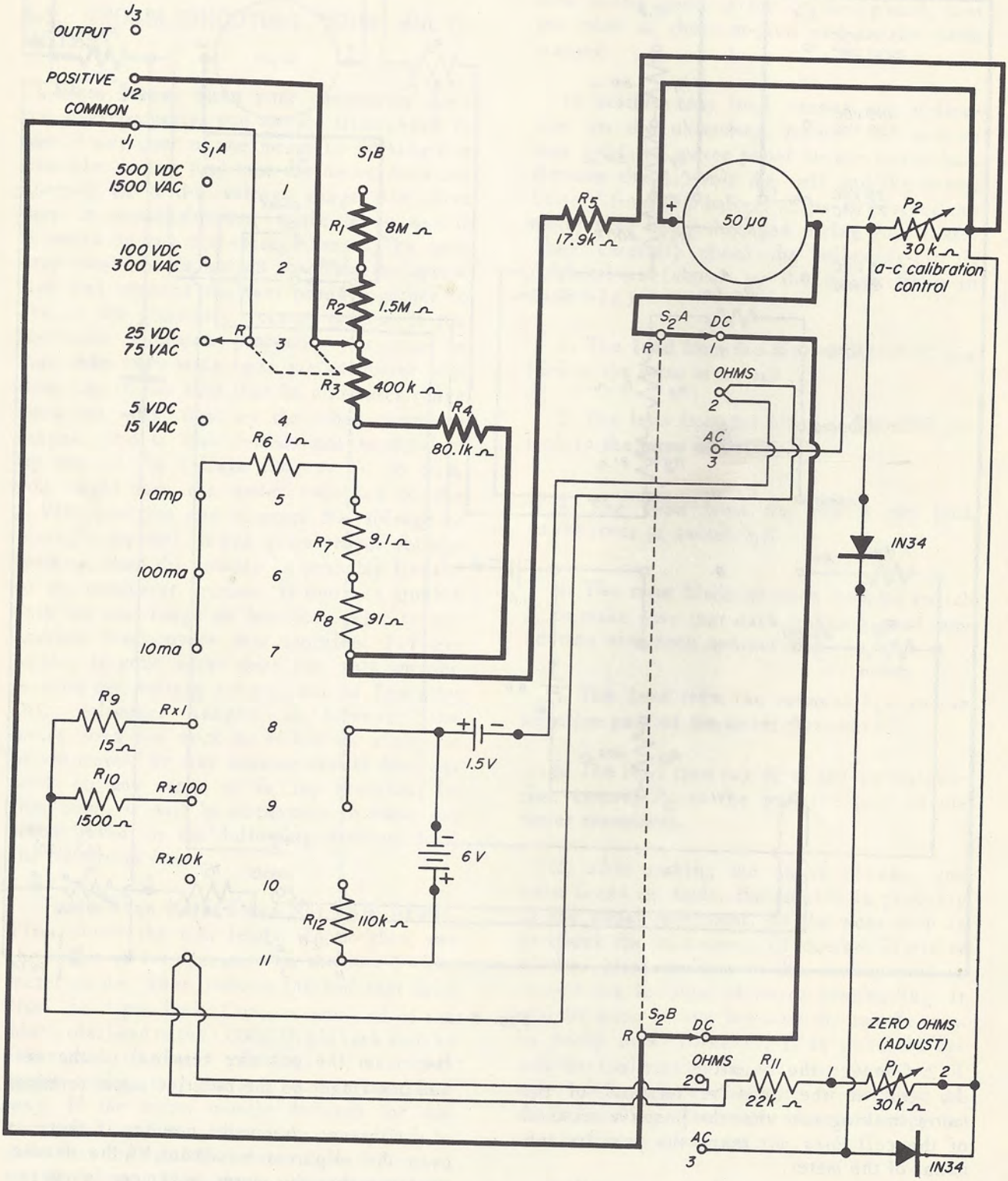


Fig. 8-13

solder all of the connections shown in Fig. 8-12, because one of them may be making a poor connection.

If the trouble has not yet been found, then we must assume that more than one trouble exists. For that reason, it will be necessary to troubleshoot each section of the meter in the following order.

Tests For D-C Voltmeter Ranges. If one or more voltmeter ranges do not operate, or if no trouble was located in the first group of tests, it will be necessary to test the resistors and connections shown by the heavy lines in Fig. 8-13.

In testing the d-c voltmeter ranges, you may have found that the meter did not work on the 500 VDC range. In this case, the trouble can be only in the 8-megohm resistor R_1, the lugs to which it is soldered, or the contact clip S_1B_1 of the RANGE selector switch. If you find that the connections are good, then you can be sure that the 8-megohm resistor must be replaced.

If both the 100 VDC and 500 VDC ranges do not operate while the two lower ranges do, the trouble is most likely in the 1.5-megohm resistor R_2. However, before replacing this resistor, check the switch lugs S_1B_2 and S_1B_3.

If only the 5 VDC range operates correctly, then look for a defective 400 k-ohm resistor in R_3 or a poor contact at switch lugs S_1B_3 and S_1B_4. If no d-c voltage range operates, the trouble may be in either the 80.1 k-ohm resistor R_4 or the 17.9 k-ohm resistor R_5. To test these:

1. Place the test leads in the COMMON and + pin jacks.

2. Place the FUNCTION switch in the DC position and the RANGE switch in the 25 VDC position.

3. Remove ¼-inch of insulation from each end of a 6-inch length of solid hook-up wire.

4. Connect the red test prod to the positive terminal of the 6-volt battery (which you removed from the meter battery clips), and connect the negative test prod to the negative terminal of the same battery. It may be necessary for you to have someone hold these test prods in place while you make the next tests.

5. With the 6-inch lead that you just prepared, short out the 80.1 k-ohm resistor R_4, as shown in Fig. 8-14.

If the meter moves 3 or 4 calibrations up from zero, you can be sure that R_4 must be replaced. If there is no deflection of the needle, short out the 17.9 k-ohm resistor R_5 with your 6-inch lead. If the meter needle moves 2 or 3 calibrations up from zero, you can be sure that R_5 is defective.

If there is still no deflection of the meter, check the lead between S_2B_1 and S_2A_1 on the FUNCTION switch S_2. If these connections seem to be good, resolder all the connections shown by the heavy lines in Fig. 8-13. If there is no trouble with the voltmeter section of your multimeter and you have made these tests carefully, you should have found the trouble by now.

Checking For Causes of Inaccurate D-C Voltage Readings. Dry cells may be used to check whether the voltage readings are correct. Dry cells are used because of their availability and known voltage. Ordinarily, a fresh 1.5-volt dry cell under no load may read as high as 1.7 volts on the 5 VDC range. Similarly, two 1.5-volt cells connected

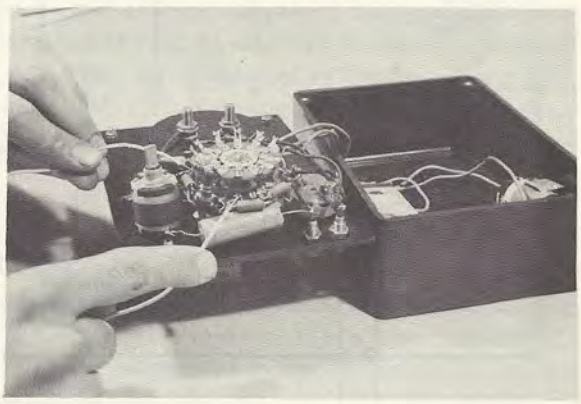


Fig. 8-14

in series may read as high as 3.4 volts. As the dry cells age and under loaded conditions, the voltage of a dry cell may become 1.5 volts and lower. A wrong indication of voltage as read on any or all of the four d-c scales may be a wrong or changed value of resistance. For example, if the 5 VDC-scale readings are accurate, the 80.1 k-ohm and 17.9 k-ohm resistors are normal. If the 25 VDC scale readings are accurate, the 80.1 k-ohm, 17.9 k-ohm, and 400 k-ohm resistors are normal. But if the 100 VDC scale readings are not accurate, the 1.5-megohm resistor should be replaced. If R_1 has changed value or has a value other than the 8-megohms, the accuracy of the 500 VDC scale will be affected. If all d-c voltage ranges read high or low, either the 80.1 k-ohm resistor R_4 or the 17.9 k-ohm resistor R_5 may have changed value or be of the wrong value.

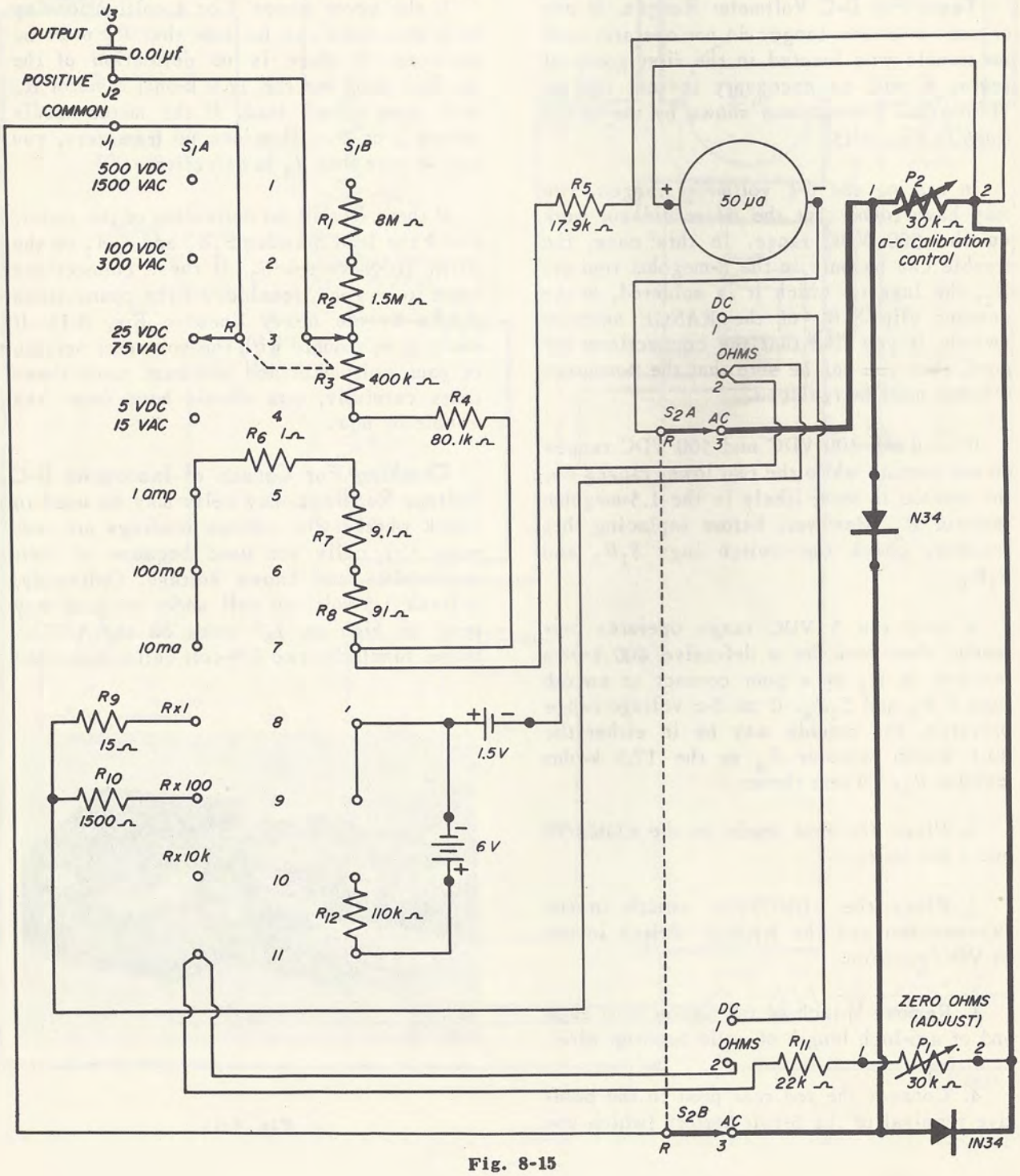


Fig. 8-15

Another cause of inaccurate d-c voltage readings may be loose or poorly soldered connections, especially at resistor and switch-lug connections. A poor solder joint may either cause the voltage reading to be inaccurate or cause the meter needle to waver and sway back and forth. Make sure that all connections are well-soldered.

If the d-c voltage readings are low on all ranges, it is possible that the 50-μa meter may be faulty. If you have reason to believe that this is so, please write the school, submitting voltage readings on the 5 VDC range of one, two, and three 1.5-volt dry cells connected in series along with any other pertinent information. You will be advised by the school as to what should be done.

Tests For A-C Voltmeter Ranges. These tests can be made only when you have already wired the a-c section of your multimeter. If this section has not been wired, go on to the next group of tests (Tests for Ohmmeter Ranges).

In these tests, it is assumed that the multimeter works on the d-c voltage ranges but does not work on the a-c voltage ranges. To test the a-c voltage ranges, it is necessary to test that part of the multimeter circuit shown by the heavy lines in Fig. 8-15.

1. Examine the connection between the FUNCTION switch lug S_2A_3 and terminal *1* on potentiometer P_2.

2. Examine the connection between the FUNCTION switch lug S_2B_3 and the common connection between the two 1*N*34 crystals.

3. Examine each of the other connections to the two 1*N*34 crystal-diode rectifiers.

4. Examine the connection between the centertap terminal *2* of the a-c calibration control P_2 and one of the 1*N*34 crystals.

If all of these connections are correct, the trouble may be in one or both of the 1*N*34 crystals. Test them as follows:

1. Set up the multimeter for service on the R x 100 scale. (This means that it will be necessary to replace the 1.5-volt dry cell in its clip in the meter case.)

2. Remove one of the crystals from its clip. Connect the black test lead to the cathode end of the crystal and the red test lead to the anode end. The resistance may be as high as 400 ohms. This is called measuring the forward resistance.

3. Set the multimeter for service on the R x 10 k scale. Reverse the leads to the crystal and measure the resistance again. The resistance reading should be at least 100,000 ohms. This is called measuring the backward resistance.

4. Test the other 1*N*34 crystal in the same manner. If you have made these and other tests carefully, any trouble in the a-c voltage section of your multimeter should have been located.

Tests For Ohmmeter Ranges. The heavy lines in Fig. 8-16 shows the parts and connections that are in the meter circuit when it is used as an ohmmeter. These consist of four fixed resistors (R_9, R_{10}, R_{11}, and R_{12}), the ZERO OHMS control (P_1), a 6-volt battery, and a 1.5-volt dry cell. The parts actually in the ohmmeter circuit when the RANGE selector switch is in the R x 1 position are shown in Fig. 8-17*a*. The 22 k-ohm resistor R_{11}, the ZERO OHMS control P_1, and the meter movement are in series with each other. This series circuit is in parallel with the 15-ohm resistor R_9. When the test leads are shorted together, this parallel combination is placed directly across the 1.5-volt cell. When the ohmmeter is working correctly, the ZERO OHMS control P_1 is used to adjust the ohmmeter to zero ohms. The only changes that take place in this circuit when the RANGE selector is turned to the R x 100 position, as shown in Fig. 8-17*b*, are that the 15-ohm resistor R_9 is cut out of the circuit and the 1,500-ohm resistor R_{10} is connected in its place. Figure 8-17*c* shows the circuit when the ohmmeter is set up in the R x 10 k position. As you can see, the 110 k-ohm resistor R_{12} and the 6-volt battery are placed in series with the 1.5-volt cell, and there is no parallel resistor in use.

Let us assume that the meter does not work on any ohmmeter range. The most probable fault will be that the 1.5-volt cell is defective or that it is not making good contact with the terminals of its battery clip. To test it, remove the cell from the clip and test it on the 5 VDC range. If it tests 1.3 volts or higher, replace it in its battery clip and make sure that it is making good contact with the clip terminals. Set up the meter for operation on the R x 1 ohmmeter range. If the ohmmeter still does not operate, the trouble is an open circuit. It will be necessary to check the following connections:

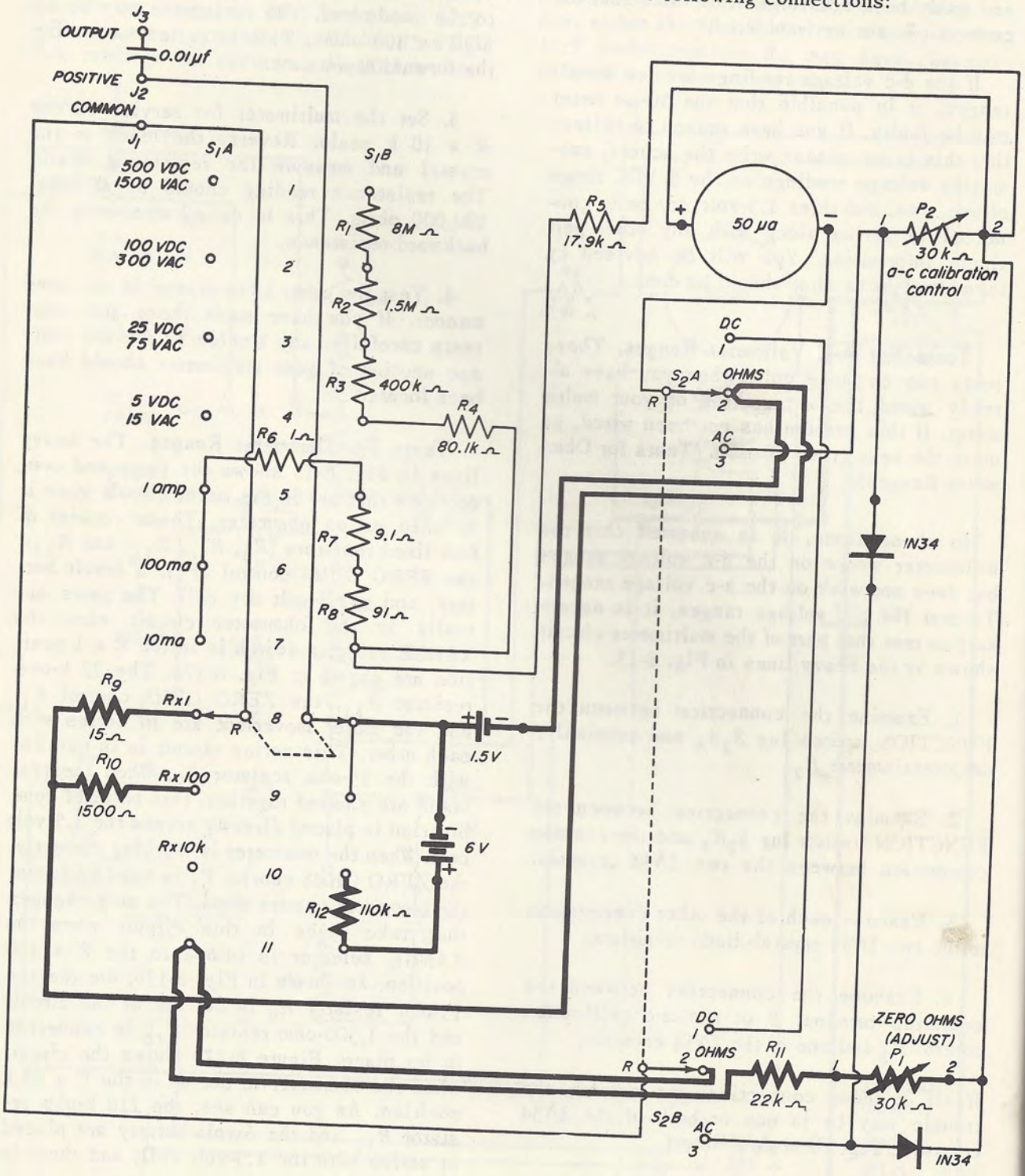
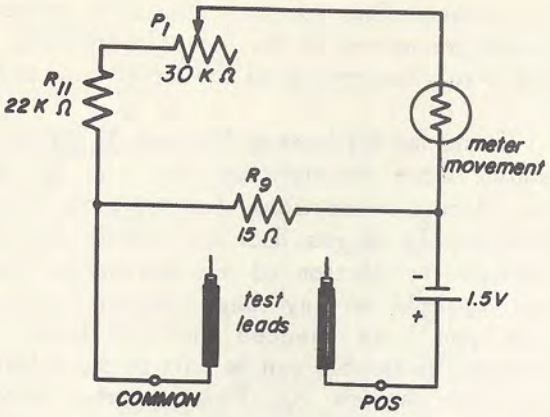
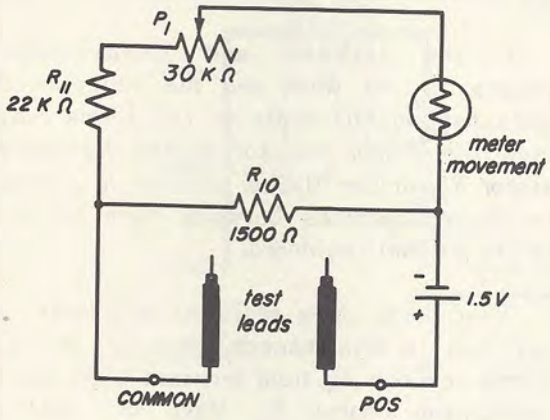


Fig. 8-16



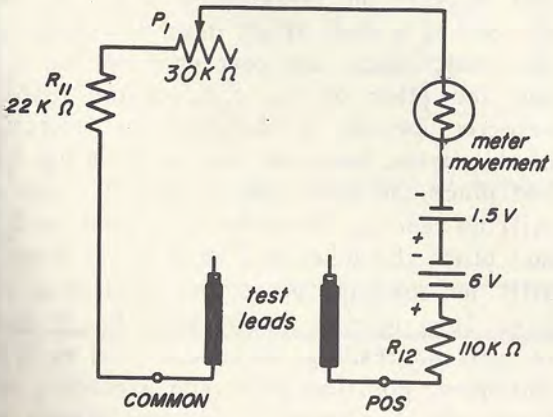
Ohmmeter circuit in R x 1 position.

(a)



Ohmmeter circuit in R x 100 position.

(b)



Ohmmeter circuit in R x 10 K position

(c)

Fig. 8-17

1. The connection between lug S_1B_8 of the RANGE selector switch and the positive lug of the 1.5-volt battery clip

2. The connection between the negative lug of the 1.5-volt battery clip to lug S_2A_2 on the FUNCTION switch

3. The connections of the 22 k-ohm resistor R_{11} to lug S_2B_2 of the FUNCTION switch and to terminal *1* of the 30 k-ohm ZERO OHMS control P_1

4. The connection between terminal *2* of the ZERO OHMS control and terminal *2* of the a-c calibration control P_2

If all of these connections are in good order, it would appear that either the 22 k-ohm resistor R_{11} or the 30 k-ohm ZERO OHMS control P_1 is open. To check these:

Step 1. Remove the positive test lead from its pin jack on the meter panel and connect the negative test lead between the + and COMMON pin jacks, as you did when you checked the test leads.

Step 2. Moisten the forefinger of each hand and place one finger of each hand on each lead of the 22 k-ohm resistor.

If there is a deflection of the meter needle, you may be sure that R_{11} is defective. If there is still no deflection, test the ZERO OHMS control in the same manner — place one moistened finger on terminal *1* and the other on terminal *2*. If there is a deflection of the meter needle, P_1 is defective. If there is no deflection, carefully resolder all of the connections that you have tested in the ohmmeter circuit.

Let us assume that the ohmmeter does not work on the R x 1 position and that it does on each of the other two ohmmeter ranges. A possible defect is that the S_1B rotor blade does not make contact with the S_1B_8 contact clip on the RANGE selector switch.

Let us assume that the ohmmeter works on the R x 1 and R x 10 K ranges and does not work on the R x 100 range. A possible defect is in the connection between lugs S_1B_8 and S_1B_9 of the RANGE selector switch.

Let us assume that the meter works on the two lower ohmmeter ranges but does not work on the R x 10 K range. The trouble then

is in either the 110 K-ohm resistor R_{12}, the 6-volt battery, the connection between them, or the connection between the negative lug of the 6-volt battery clip and the positive lug of the 1.5-volt battery clip. The most probable trouble is that the battery is defective or that it is not making good contact with the terminals of its clip. You can test the battery by measuring its voltage on the 25 VDC range. The connections should be carefully inspected, and if the ohmmeter still does not work on the R x 10 K range, the trouble must be in the 110 k-ohm resistor R_{12}.

Other Causes And Cures For Improper Ohmmeter Operation. We will now assume that the meter needle responds and indicates for all three ranges when the two test prods are joined. However, it is possible, due to incorrect wiring or a defective part, for one or more of the ranges to operate improperly. Some of the symptoms of improper operation on the R x 1 and R x 100 scales are:

1. Meter needle does not advance all the way to the zero-ohms position with the prods joined, no matter how the ZERO OHMS knob is adjusted. The trouble may be a weak 1.5-volt dry cell, the value of R_{11} may be too high, or a resistor of very low value may have been mistakenly used for the 15-ohm or 1,500-ohm resistor. On the R x 10 K scale, either the 6-volt battery may be weak or R_{12} may be too high.

2. The meter needle forcefully goes beyond full scale when test prods are joined, and cannot be adjusted to zero with the ZERO OHMS control. The trouble may be incorrect wiring of both the 1.5-volt dry cell and 6-volt battery, or the values of R_{11} may be too low.

3. The ohmmeter does not accurately indicate resistance values within the normal combined tolerance of both the resistor being tested and the ohmmeter. The trouble may be that the 15-ohm resistor is not wired into the circuit or that the 15-ohm resistance has changed value.

4. Meter needle deflects toward the left instead of toward the right when the prods are joined. This may be caused by reversed leads connected to the 1.5-volt dry cell, to the 6-volt battery, or to the meter movement.

Tests for Milliameter Ranges. Figure 8-18 shows three resistors (R_6, R_7, and R_8) and the circuit connections that are used in the milliampere ranges. Let us assume that the milliameter section of the multimeter does not operate on any range. We will assume that you have checked the test leads already. The trouble can be only in the RANGE selector switch S_1. Examine the switch carefully to make sure that the rotor blade on each deck is making contact with the 5th, 6th, and 7th lugs of each deck and that the connections to lug S_1B_7 are well-soldered.

If the 1-ampere and 100-milliampere ranges do not work and the meter needle goes beyond full scale on the 10-ma range, then the 1-ohm resistor R_6, the 9.1-ohm resistor R_7, or the 91-ohm resistor R_8 is open or the connections between them are open or are not well-soldered.

Test these three resistors and their connections in this manner. Unsolder the 17.9 k-ohm resistor R_5 from terminal 2 on the a-c calibration control P_2. Make sure that the free end of the resistor does not in any way touch any other lug, wire, or resistor. Set the ohmmeter for service on the R x 1 scale and measure the resistances of R_6, R_7, and R_8, one at a time. If all three resistors test correctly, place one test prod on lug S_1B_7 and the other on lug S_1A_7 of the RANGE selector switch. If there is no deflection of the meter, keep one test prod on lug S_1B_7 and place the other one on S_1A_6. If there is still no reading, keep one test prod on S_1B_7 and place the other one on S_1A_5. If there is still no reading, place the prod that you have been moving around on S_1B_5. If there is still no reading, move the prod to S_1B_6. Whichever position gives you a reading will show you that there is an open circuit between it and the last position from which you measured. If you have located the defect, resolder the free end of the 17.9 k-ohm resistor R_5 to terminal 2 of the a-c calibration control P_2.

Checking For Causes of Inaccurate D-C Readings. In some cases, when your multi-

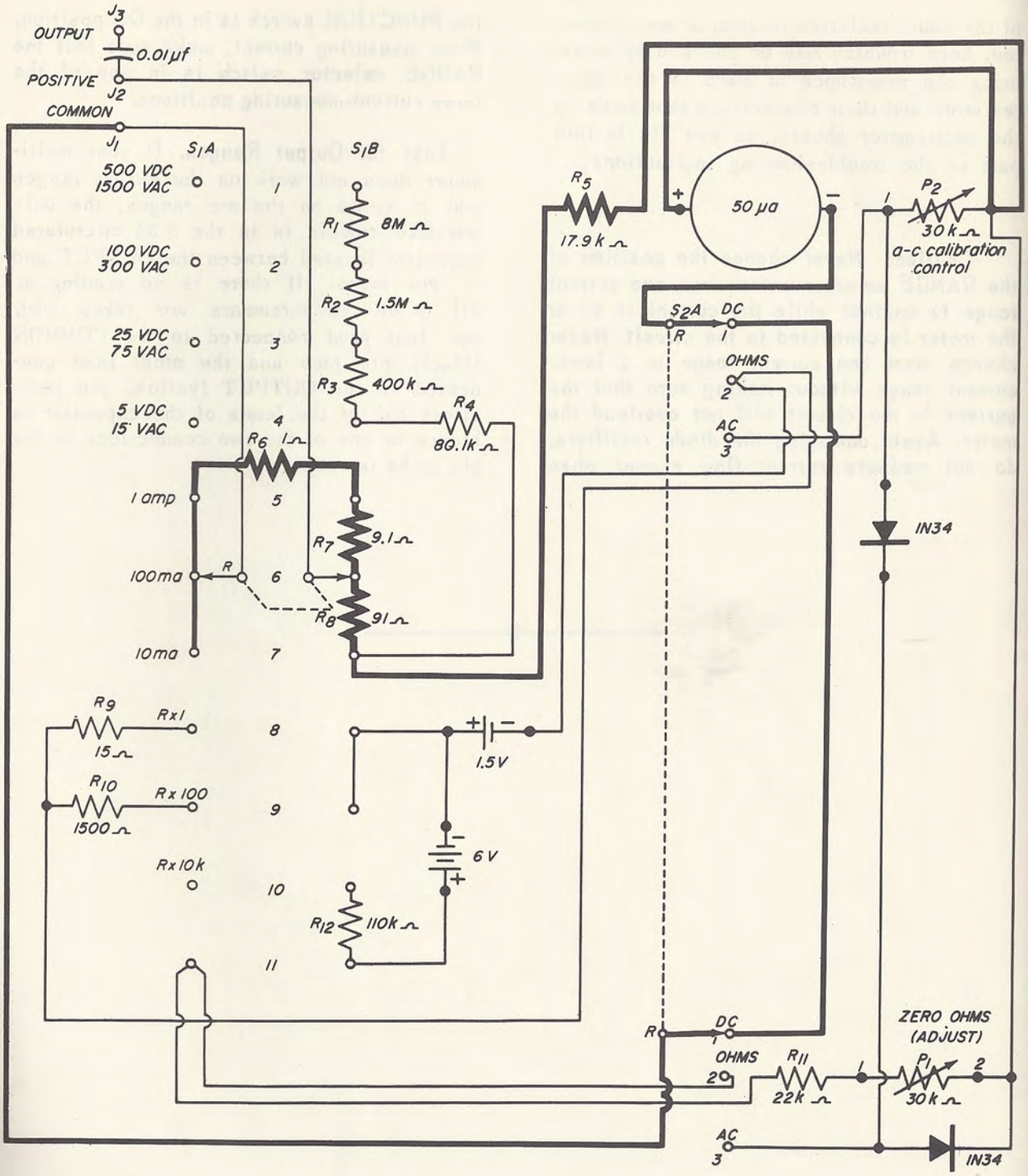


Fig. 8-18

meter is used to measure current, the current ranges may operate and still give you faulty readings on one or more ranges — readings that are too high or too low. When the position of the meter needle indicates an amount of current that is less than the actual current in the circuit, it will be because one or more of the shunt resistors is of too low a value. If the position of the meter needle indicates a current that is more than the current actually flowing in the circuit, or if the needle goes beyond full scale or bangs against the needle bumper on the right side of the meter movement, then one of the shunt resistors is either too high in value, the circuit has high resistance connection, or one or more

of the shunt resistors is open or not connected. Such troubles may be checked by measuring the resistance of each of the three resistors and their connections that make up the milliameter shunts, as you did in this part of the troubleshooting instructions.

Caution: Never change the position of the RANGE selector switch from one current range to another while the current is on or the meter is connected to the circuit. Never change from one current range to a lower current range without making sure that the current in the circuit will not overload the meter. Avoid damaging the diode rectifiers; do not measure current flow except when the FUNCTION switch is in the DC position. When measuring current, make sure that the RANGE selector switch is in one of the three current-measuring positions.

Test for Output Ranges. If your multimeter does not work on the output ranges and it works on the a-c ranges, the only possible trouble is in the 0.01 microfarad capacitor located between the OUTPUT and + pin jacks. If there is no reading at all when measurements are taken with one test prod connected to the COMMON (black) pin jack and the other lead connected to the OUTPUT (yellow) pin jack, either one of the leads of the capacitor is broken or one of the two connections to the pin jacks is open.