SUBCOURSE
SS0602

EDITION
6

APPLICATION OF TV TEST EQUIPMENT
DEVELOPMENTAL DATE; SEPTEMBER 1986)

PRO PATRIA VIGILANS

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

A I P D

READINESS / PROFESSIONALISM THRU GROWTH

U.S. ARMY RADIO/TELEVISION SYSTEMS SPECIALIST
MOS 26T SKILL LEVEL 1

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APPLICATION OF TV TEST EQUIPMENT

SUBCOURSE NO. SS0602-6

(Developmental Date: 30 Sep 86)

U.S. ARMY SIGNAL CENTER
Fort Gordon, Georgia

Six Credit Hours

GENERAL

The Application of TV Test Equipment block is a major part of the Radio/Television System Specialist, MOS 26T Skill Level 1 course. This subcourse is designed to teach the knowledge necessary to perform tasks related to maintenance and repair of television system equipment. Information is provided on several tasks which are performed at increasing levels of difficulty at Skill Levels 1 and 2. The subcourse is presented in three lessons, each lesson corresponding to a terminal objective as indicated below. This subcourse will assist personnel in MOS 41E to merge into MOS 26T30 as prescribed by AR 611-201.

Lesson 1: APPLICATION OF TEST METERS

TASK: Describe and identify theory and terminology used in the application of test meters.

CONDITIONS: Given the information and illustrations about terms and theory relating to application of volt/ohmmeter for TV maintenance.

STANDARDS: Demonstrate competency of the task skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of the application of test meters.

Lesson 2: DEFINE THE THEORY AND APPLICATION OF AN OSCILLOSCOPE

TASK: Describe the theory and terminology related to maintenance procedures for the oscilloscope.

CONDITIONS: Given the information and illustrations about terms and theory relating to application of the oscilloscope.

STANDARDS: Demonstrate competency of the task skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of using an oscilloscope.

Lesson 3: DESCRIBE THE APPLICATION OF GRATING GENERATOR, DOT BAR GENERATOR, AND VIDEO SWEEP MARKER GENERATOR

TASK: Describe the theory and terminology of maintenance with the application of video sweep marker generator, grating generator, and dot bar generator.

CONDITIONS: Given information and illustrations about terms and theory relating to the application of video sweep generator, grating generator and dot bar generator.

STANDARDS: Demonstrate competency of the task skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of the application of video sweep marker generator, grating generator, and dot bar generator.

This subcourse supports the following MOS 26T tasks:

113-575-0021	Troubleshoot and Repair a Television Receiver
113-575-0038	Troubleshoot and Repair Video Pulse Distribution Amplifier
113-575-0040	Troubleshoot and Repair a Sync Generator
113-575-0041	Troubleshoot and Repair a Character Generator
113-575-0042	Troubleshoot a Reel-to-reel Audio Tape Recorder/Reproducer
113-575-0043	Troubleshoot a Color Television (TV) Camera
113-575-0044	Troubleshoot a 3/4-inch Video Cassette Recorder/Reproducer (VCR)
113-575-0045	Troubleshoot a Television Transmitter
113-575-0046	Troubleshoot a Television (TV) Video Switcher
113-575-0049	Troubleshoot a Time Base Corrector
113-575-2040	Perform Functional Check of a Color Television (TV) Film Chain Camera
113-575-2041	Perform Functional Check of a Color Television (TV) Camera System
113-575-2042	Perform Functional Check of a Color Television (TV) Studio Camera Colorplexer
113-575-2043	Perform Functional Check of a Color Television (TV) Studio Camera
113-575-2044	Perform Functional Check of a Small Format Television (TV) Recording System, Using a 3/4-inch Video Cassette Recorder/Reproducer (VCR)
113-575-2045	Perform Functional Check of a Time Base Corrector (TBC)
113-575-2047	Perform Functional Check of a Television (TV) Transmitter
113-575-3029	Perform Daily Maintenance on a 3/4-inch Video Cassette Recorder/Reproducer (VCR)
113-575-3031	Perform a Complete Color Convergence of a Color Television (TV) Receiver
113-575-3033	Perform Measurement of the Visual and Audio Transmitter Carrier Frequency

113-575-3035	Perform Daily Maintenance of a Television (TV) Video Switcher
113-575-3036	Perform Preventive Maintenance of a Character Generator
113-575-4010	Replace a Color Picture Tube (CRT)
113-575-4011	Replace Faulty Television (TV) Studio Camera Cable
113-575-4012	Replace RF Transmission Lines Between Antenna and RF Modulators
113-575-8017	Perform Alignment Check of a Wave Form Monitor

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Whenever pronouns or other references denoting gender appear in this document, they are written to refer to either male or female unless otherwise indicated.

INTRODUCTION TO APPLICATION OF TV TEST EQUIPMENT

The complexity of today's electronic technology requires that a technician become as knowledgeable and experienced in as many facets of his/her career field as possible. The purpose of this subcourse is to provide the technician, MOS 26T soldier, with an overall view of some of the test equipment used in this field with some guidelines on how to use it to troubleshoot any equipment, including what to look for, how to check it out, and a few procedures to be followed. It is also meant to assist MOS 41E personnel to merge into MOS 26T30, as prescribed by AR 611-201, and to help anyone cross-train into the 26T career field.

LESSON 1
APPLICATION OF TEST METERS

TASK

Describe and identify theory and terminology used in the application of test meters.

CONDITIONS

Given the information and illustration about terms and theory relating to application of volt/ohmmeter for TV maintenance.

STANDARDS

Demonstrate competency of the task, skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of the application of test meters.

REFERENCES
None

Learning Event 1:
DETERMINE WHAT A MEASURING INSTRUMENT IS

1. Measuring Instruments. The primary measuring instrument that you use in performing maintenance tasks are the ammeter, the voltmeter, and the ohmmeter. These three instruments are basically current measuring devices. The main difference in construction is that an external resistance is connected with respect to the moving element in different ways.

2. Ammeter. The electrical instrument used to measure the current in an electrical circuit is called an ammeter. It is connected to measure the current passing a given point. Figure 11b illustrates how you connect an ammeter into the circuit to measure the current passing point P of Figure 1-1a. When you connect an ammeter between the source and the load shown in Figure 11b, it is in a series.

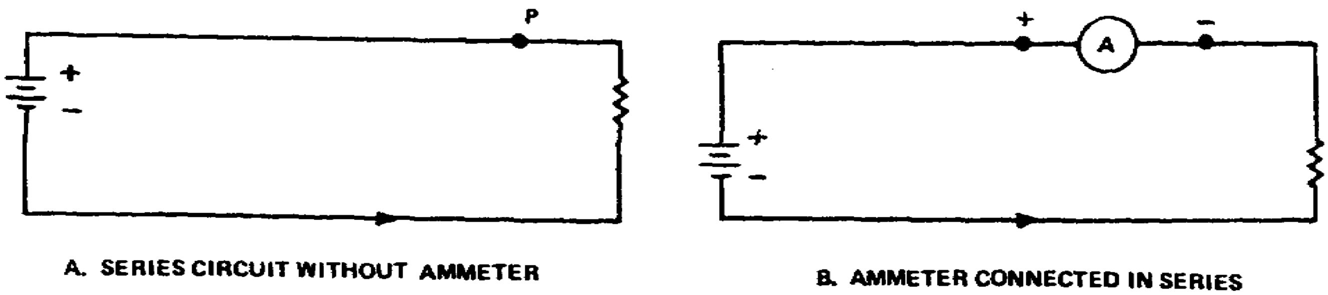


Figure 1-1. Connection of an ammeter in a circuit

a. You must observe polarity when connecting an ammeter into an electrical circuit. To do this properly, you must trace electron flow from the negative (-) side of the battery through the circuit and back to the positive (+) side of the battery.

b. Then break the circuit and connect the ammeter so that electrons enter the negative side and exit through the positive side into the load (fig. 1-1b).

c. An ammeter that measures smaller amounts of current is called either a milliammeter or a microammeter, depending upon the amounts of current to be measured.

3. Voltmeter. The electrical instrument used to measure difference of potential, or voltage, is a voltmeter. It is connected so it measures the difference of potential between two points. Figure 1-2b illustrates the proper connection of a voltmeter.

a. To measure the electromotive force of the battery, you must connect voltmeter V1 (fig 1-2b), while observing polarity. To measure the potential difference between points X and Y of the circuit (fig 1-2a), it is necessary to trace the electron flow and observe the polarity between points X and Y.

b. Note that the side of the resistor that the electrons enter is the negative side. A meter that is connected across a difference of potential (fig 1-2b), is in parallel.

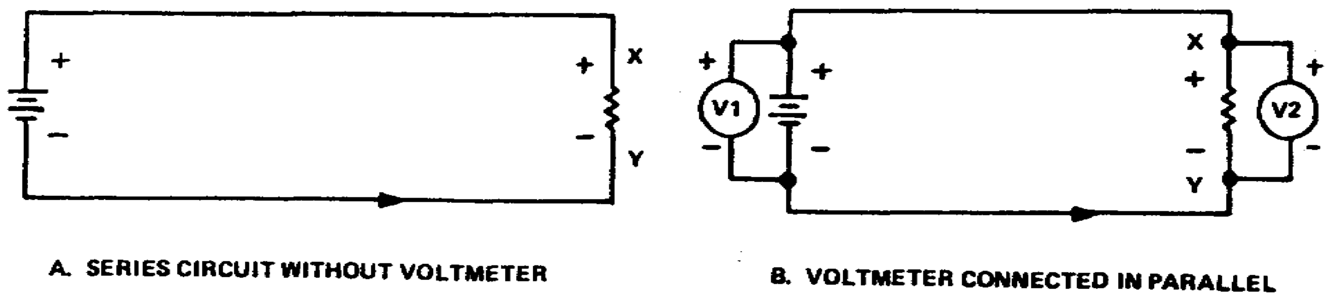


Figure 1-2. Connection of a voltmeter in a circuit

4. Ohmmeter. An electrical instrument which is used to measure resistance is an ohmmeter. Figure 1-3b illustrates the connection of an ohmmeter to measure resistance.

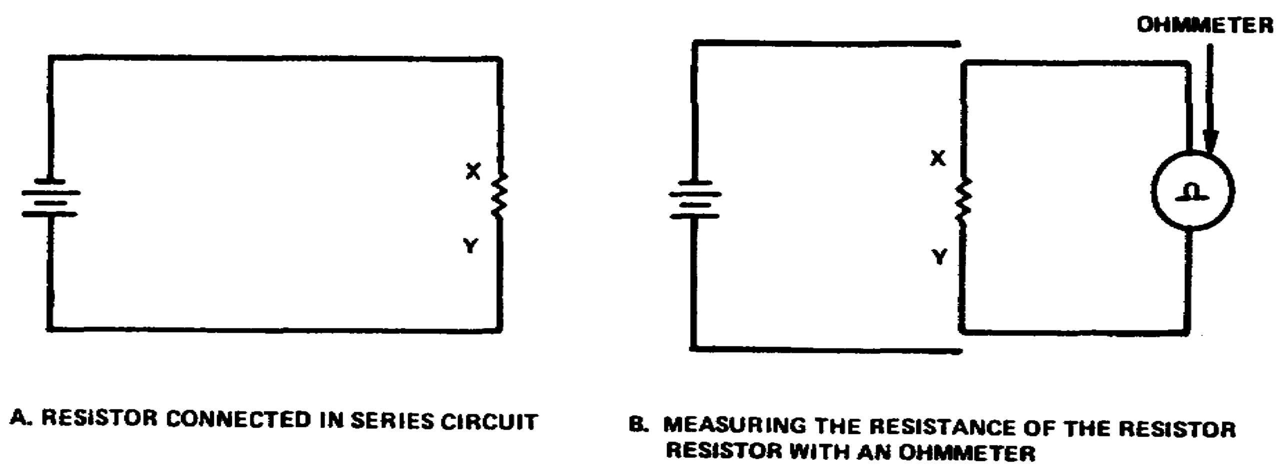


Figure 1-3. Connection of a ohmmeter in a circuit

a. In order to measure the resistance of resistor XY in Figure 1-3a, the resistor XY must be disconnected from the remainder of the circuit.

b. Then the ohmmeter is placed across the resistor as shown in Figure 1-3b.

5. For convenience, more than one electrical measuring device may be combined in one instrument. An instrument of this type is variously called a multimeter, a multitester, a voltohmmeter, etc. The term meter is frequently used in scientific literature and may designate any of the above.

NOTE: The combination meter will be discussed later in this section.

6. Meter Circuitry. You may recall that you connect ammeters in series in that part of the circuit where the current is to be measured. The voltmeter must be connected in parallel with the component between the two points where a potential difference is to be measured. The ohmmeter must not be connected into a hot (power-source-applied) circuit.

a. Ammeter. If you connect a 0-to 10-milliampere meter coil in a circuit carrying 10 amperes, not only is the meter coil incapable of measuring such large values of current, but it will be severely damaged.

(1) To measure larger amounts of current than the coil itself can safely carry, you connect a resistance in parallel with the coil, as shown in Figure 1-4a. The current being measured divides between the coil and resistor, with a small portion flowing through the coil (Rm) and the remainder through the parallel resistor, called the meter shunt (Rs). The shunt may be built into the meter or it may be mounted externally.

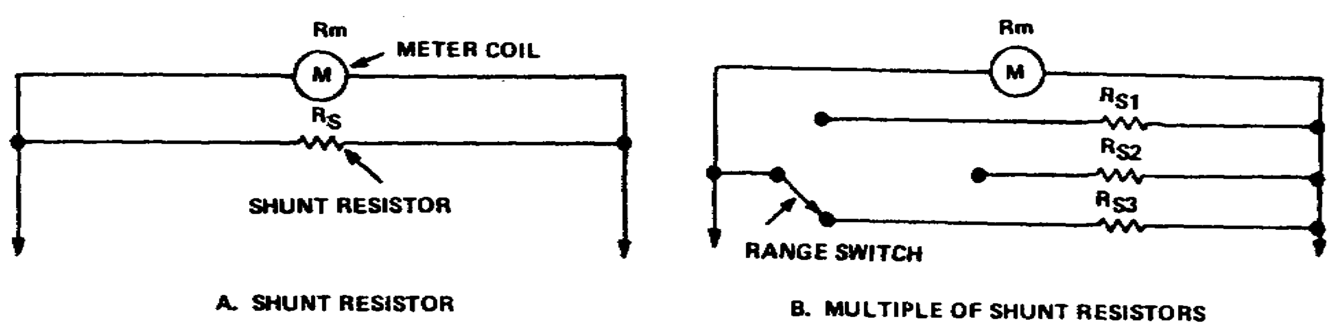


Figure 1-4. Typical ammeter circuit

(2) Ammeters which are designed to measure several ranges of current use a shunt for each range. The shunts are mounted on a common terminal board and are connected to a multiple switch, as shown in Figure 1-4b. Setting the switch to the desired range connects the proper shunt into the meter circuit. Shunts usually contain only a fraction of an ohm of resistance and consist of a few inches of a metal alloy having a low temperature coefficient. The alloy is drawn into a wire and is wound around a piece of mica or fiber and mounted on a terminal board.

(3) The accuracy of an ammeter reading depends upon the relative magnitudes of the meter resistance and the circuit load resistance (resistance of the circuit into which the meter is connected). For example: if the meter resistance (Rx) equals the circuit load resistance (RL), as shown in Figure 1-5a, the value of actual circuit current is twice that of the measured current, representing an error of 50 percent. If you decrease the meter resistance as shown in Figure 1-5b, you also decrease the percentage of error. If the meter resistance is considerably smaller than the load resistance, the percentage of error becomes so small that for practical measurements it can be disregarded. Thus, for any given circuit conditions, the accuracy of the ammeter reading is greater if the total meter resistance is much less than the ohmic resistance of the load.

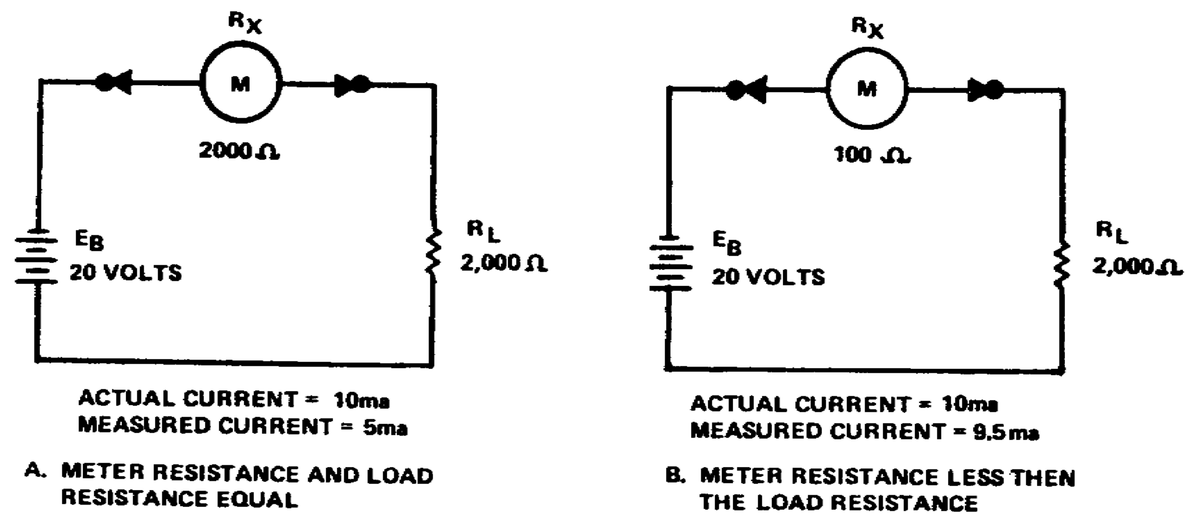


Figure 1-5. Error in ammeter readings

b. Voltmeter. The meter movement discussed above can be used either as an ammeter or a voltmeter. How is this possible? You can measure voltage with the ammeter just described by placing resistance in series (not parallel) with the meter coil and measure the current flowing through the coil. In other words, a voltmeter is a current-measuring instrument designed to indicate voltage by measuring the current through a resistance of known value.

(1) A typical voltmeter circuit, shown in Figure 1-6a, is a simple-series circuit. As with the ammeter, it is possible to obtain various voltage ranges with a voltmeter. To obtain more than one range, various sized resistors, called "multipliers," are added in series with the coil, as shown in Figure 1-6b.

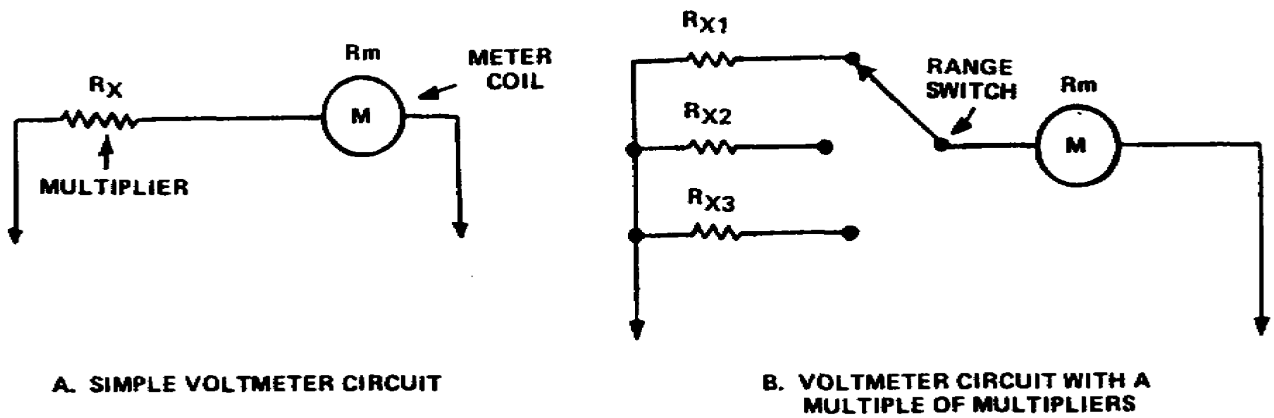


Figure 1-6. Typical voltmeter circuit

(2) The accuracy of any measurement made with a voltmeter depends, for the most part, upon the relationship between the total resistance in the meter circuit and the value of resistance across which the voltage is measured. This fact can be seen from a study of the circuit in Figure 1-7, showing both the actual voltage and the measured voltage as well as percentage of error. Observe that the voltage measured is two-thirds the actual voltage across RM, an error of 33.3 percent, since the meter resistance is only one-half the value of the total resistance in the circuit.

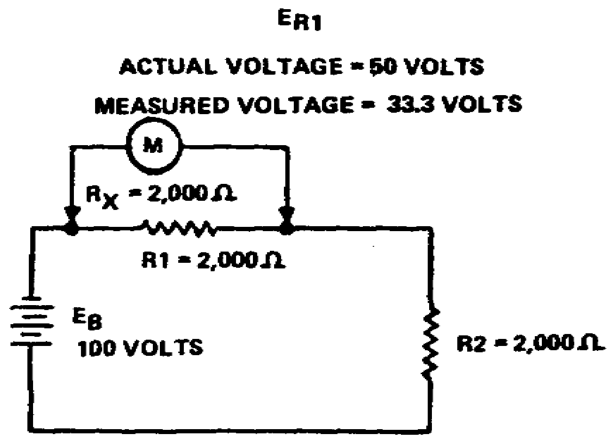


Figure 1-7. Error in voltmeter readings

(3) If you double the meter resistance (increase to 4000 ohms), the error in the voltage reading diminishes to 30 percent (40 volts across R1). If you increase the ratio between the meter resistance and load resistance even more by increasing the meter resistance you obtain a point where the voltmeter error can be tolerated.

(4) For practical purposes, the voltmeter error can be tolerated when the voltmeter resistance is ten times as great as the resistance across which the voltage is measured.

c. Ohmmeter. The ohmmeter is a device that uses a current-actuated meter and a fixed source of voltage for measurement of resistance (refer to Figure 1-8). It is used for practical work where simplicity, portability, and ease of operation are more important than a high degree of precision. There are two types of ohmmeters, the series type and the shunt type. The series type has the resistance to be measured connected in series with the meter movement. The shunt type has the resistance to be measured connected in parallel with the meter movement.

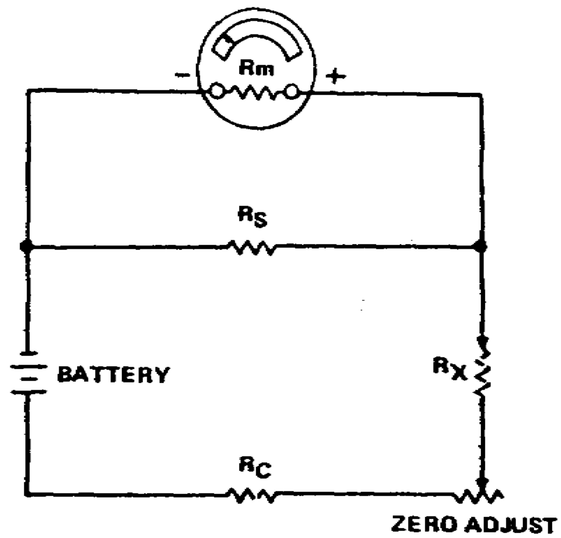


Figure 1-8. Typical ohmmeter circuit

(1) For any given ohmmeter, mid-scale deflection (one-half the maximum defection distance) is obtained when the current through the meter is one-half the value of the current at full-scale (zero ohms) deflection. This condition exists when the resistance being measured is equal to the total meter circuit resistance. Analysis of the series-type ohmmeter circuit in Figure 1-9 shows that full-scale deflection is obtained when the meter test probe are shorted, and that less than full-scale deflection is obtained when the resistance to be measured is connected into the circuit.

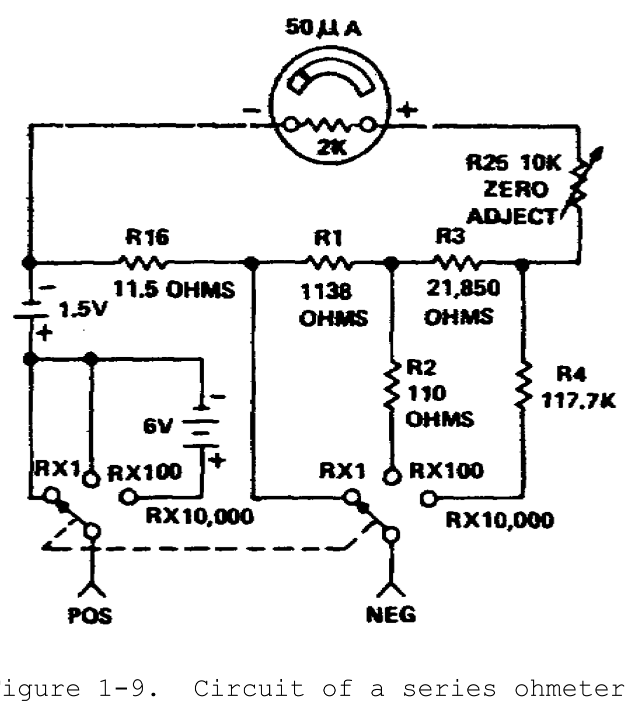


Figure 1-9. Circuit of a series ohmeter

(2) Since the ohmmeter is calibrated at mid-scale, the mid-scale portion represents the most accurate portion of the scale. However, the usable range extends, with reasonable accuracy, on the high end to 10 times the mid-scale indication, and on the low end to 1/10th of the mid-scale indication.

(3) To extend the usable high range of the series-type ohmmeter, shunt Rs (fig 1-8), can be removed from the circuit, and the value of the series-dropping resistor Rc increased 10 times. This permits a mid-scale reading with a resistance of 10 times Rx. The limitations which prevent a further increase in the usable high range of the ohmmeter are fixed voltage (battery) and the sensitivity (current necessary for full-scale deflection) of the meter mechanism. You can obtain a higher range by increasing the battery voltage or by using a more sensitive meter mechanism. The former method is practical, and is used in some commercial test equipment.

(4) You can extend the usable low range of the ohmmeter by installing meter shunt Rs and decreasing Rc until the current in the circuit and the internal resistance of the battery limit any further extension of the range. Excessive current can extend the low range by decreasing the battery voltage, but this method is not feasible. Instead, a shunt-type ohmmeter is used.

d. The shunt-type ohmmeter (fig 1-10), measures low and medium values of resistance. The shunt-type ohmmeter scale is calibrated in the reverse direction from the series type because full-scale deflection is obtained with test probes open.

(1) Mid-scale deflection occurs when the combination of the meter resistance and the shunt Rs is equal to Rx, the resistance to be measured.

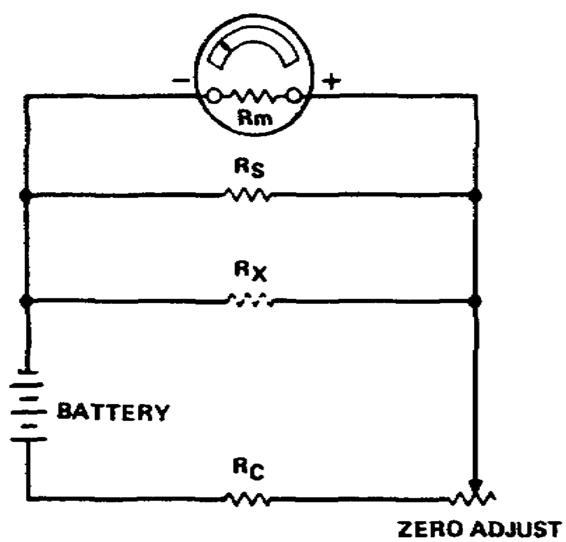


Figure 1-10. A shunt ohmmeter

(2) Limitations which prevent a further decrease in the range are:

(a) Internal resistance of the battery which becomes an appreciable part of the total circuit resistance, causing errors in readings to increase with battery age.

(b) Excessive current drain which decreases the life of the battery, and which could in some cases cause damage to the components under test.

(3) It is impractical to measure very low values of resistance with an ohmmeter. The ohmmeter, in itself, is only a means of approximating resistance values, where practical electronic work requires a convenient and speedy method of checking resistances.

Learning Event 2:
DETERMINE WHEN AND HOW TO USE METERS

1. When using a voltmeter or an ohmmeter you must use a range that is high enough to keep the deflection less than full scale. Before measuring a current or voltage, you should have some idea of its magnitude. Then switch to a large enough range or start with the highest range.

> NOTE: Many voltmeters or ohmmeters have been ruined by attempting to measure amperes. Therefore, be sure to read the lettering either on the dial or on the switch positions, and choose the proper range before connecting the ammeter in the circuit.

2. When connecting the voltmeter (or ammeter) in the circuit, you must observe proper polarity. Current must flow through the coil in a definite direction in order to move the indicator needle up-scale. Wrong polarity (or reversal of current) results in a bent meter needle. You can avoid improper meter connections by remembering that the black meter leads are the negative leads and the red meter leads are the positive leads.

3. There are other precautions to observe with both the ammeter and the voltmeter. When using an ammeter, you must observe two important precautions.

a. Always connect an ammeter in series with the element through which the current is to be measured.

b. Never connect an ammeter across a source of voltage, such as a battery or a generator.

c. Remember that the resistance of an ammeter, particularly on the higher ranges, is extremely low and that any voltage, even a volt or less, may cause very high current through the meter, and severely damage the meter.

4. When using a voltmeter you must observe one additional precaution along with those already mentioned. Always connect a voltmeter in parallel across

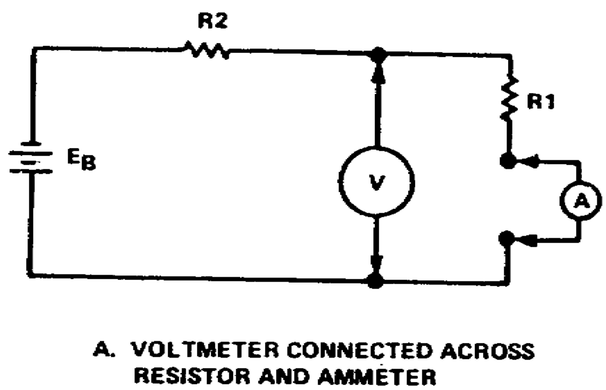
the portion of the circuit in which voltage is being measured. If you observe these precautions when using an ammeter or voltmeter, you can obtain reliable results from these instruments.

5. If you wish to use a voltmeter and an ammeter in the circuit at the same time, there are two possible ways to connect them, but each produces an error.

a. If the meters are connected as shown in Figure 1-11a, the voltmeter reads the voltage across the resistor and the ammeter.

b. If the meters are connected as shown in Figure 1-11b, the ammeter reads the current through the resistor R1 and the voltmeter.

c. Both methods further emphasize the fact that the resistance of the ammeter must be very low to keep the voltage across it small, and that the resistance of a voltmeter must be large enough to keep the current through it small.



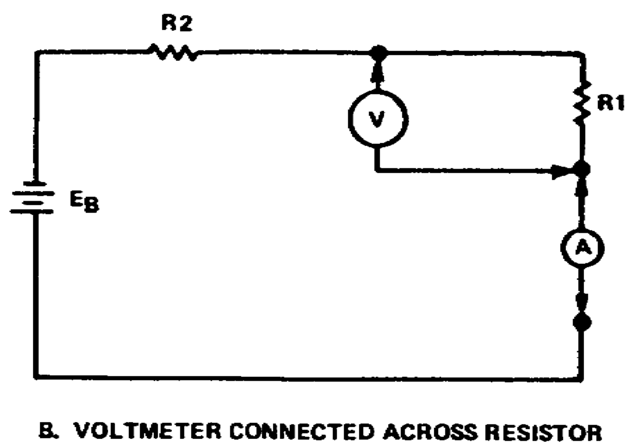


Figure 1-11. Measuring current and voltage simultaneously

6. In either of the above cases, the correct connection to use is the one leading to the least error and that depends on the relative values of resistance. If the resistance of the circuit is small (approaching the resistance of the ammeter), use the second circuit (fig -1-11b). If the resistance of the circuit is large compared to the voltmeter resistance, use the first circuit (fig 1-11a). For intermediate values of circuit resistance, either circuit connection is satisfactory.

7. You can determine the resistance of a circuit element by first measuring the current through it with an ammeter, then the voltage across it with a voltmeter, and finally apply Ohm's law. It is much more practical, however, to use an ohmmeter from which you can read resistance directly from a scale.

8. When using an ohmmeter to measure resistance, proceed as follows:

a. Choose a range which you think contains the resistance of the element that you are measuring or use a range in which the reading falls in the upper half of the scale.

b. Short the leads together and zero the meter, using the zero adjustments. If you change ranges at any time, remember to readjust to zero ohms.

c. Never attempt to measure resistance in a circuit while it is connected to a source of voltage.

d. Connect the unknown resistance between the test leads and read its resistance from the scale. When applicable, disconnect at least one end of the element being measured to avoid reading the resistance of parallel paths.

9. In addition to measuring resistance, the ohmmeter is very useful for checking continuity in a circuit. Often when troubleshooting electronic circuits or wiring a circuit, you cannot visually inspect all parts of the current path. Therefore, it is not always apparent whether a circuit is complete or whether current may be flowing in the wrong part of the circuit because of contact with adjacent circuits. The best method of checking a circuit under these conditions is to send a current through it.

a. If the conductor makes a complete circuit, current flows through the circuit. The ohmmeter is ideal for checking circuits. It provides the power to cause the current and it provides the meter to indicate the amount. To check, first study the circuit diagram, then check the corresponding parts of the circuit itself with the ohmmeter. The ohmmeter should indicate perfect conduction, partial conduction (resistance), or no conduction at all.

b. Ohmmeters are not always available, and even when they are, they are often of little value. The most common cause of a useless ohmmeter is a dead battery, which is usually caused by leaving an ohmmeter on the low-ohms scale. On this scale the meter draws current continuously. Another common carelessness is to leave a multimeter on the "ohmmeter" position and to permit the test leads to short circuit.

10. Since an ohmmeter may not be available, you must understand another way of determining resistance. There are two procedures you can use for measuring resistance without an ohmmeter.

a. One is the voltmeter-ammeter method. Connect the voltmeter and ammeter (fig 1-11(a)). After connecting the meters, use the voltmeter and ammeter reading to calculate resistance by Ohm's law.

$$R1 = \frac{\text{voltmeter reading (volts)}}{\text{ammeter reading (amperes)}}$$

b. If the resistance is high, the voltmeter method can be used. With the voltmeter method, a voltmeter with known resistance is connected in series with the unknown resistance (fig 1-12).

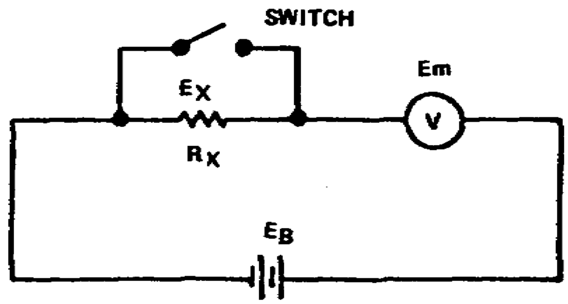


Figure 1-12. Determining value of unknown resistance of voltmeter

When power is applied, the voltage (Em) across the meter can be read on the voltmeter. Then by shorting out resistor Rx (fig 1-11), the voltmeter indicates the applied voltage (Eb). Thus the voltage (Ex) across the unknown resistor is equal to the difference between the two measured voltages.

$$Ex = Eb=-Em$$

c. The voltages across the resistor and the meter are

$$Ex = IRx \text{ and } Em=IRm$$

d. By dividing the first equation by the second equation, the currents cancel out:

$$\frac{Ex}{Em}=\frac{Rx}{Rm} \text{ or } Rx=Rm\frac{Ex}{Em}$$

e. But since Ex is equal to the difference between Em and Eb (Eb-Em) the unknown resistance is

$$Rx = Rm\frac{Eb-Em}{Em}$$

f. Since Eb, Em, and Rm are unknown, the above equation can be solved for the value of the resistance Rx.

Learning Event 3:
DETERMINE METER SENSITIVITY

1. We have said that the voltmeter and ammeter have various ranges and also that you determine the resistance of the meter to decrease errors in readings. This points to the conclusion that meters are delicate devices which can respond to small forces.

2. The resistance of a meter movement and the maximum current permitted to flow through it are so small that the use of an unshunted meter movement as a measuring device is very limited. A typical meter movement has 50 ohms of resistance and gives full-scale deflection with 1 milliampere of current through the meter coil. Such a meter movement has a 50 millivolt voltage across it at full-scale deflection as shown by the formula:

$$E = 1 \times R = 0.001 \times 50 = 50 \text{ millivolts}$$

The above meter movement is limited to measuring current values from 0 to 1 milliampere and voltage from 0 to 50 millivolts.

3. How is it possible to have sensitive ammeters and voltmeters that can measure much larger values of current and voltage? Let's discuss sensitivity in more detail and see how it is possible to measure large values of current, voltage, and resistance with the applicable meters.

a. Ammeters. The sensitivity of a meter movement is inversely proportional to the amount of current that causes the indicator to deflect full scale. The smaller the current required for full-scale deflection, the more sensitive the meter movement. For measuring current in electronic equipment, ammeters with a sensitivity of 0.1 ampere or even 1 milliamperes are used. Meters with a sensitivity of 100 microamperes are common.

(1) To understand how to determine applicable shunt resistors for an ammeter, let's study the circuit in Figure 1-13. Since current through the two parallel branches divides in a ratio inversely proportional to the branch resistances, it is possible to calculate the current through the coil as well as the total current in the circuit in which current is being measured.

(2) In the circuit shown in Figure 1-12 you can find the current in the shunt (Is) and the total current (It) in the circuit. For example, if the shunt resistance (Rs) is equal to 1/5th the value of the resistance of the coil (Rc), and current through the coil (Ic) is 0.5 milliampere, there is 5 times as much current through the shunt (Is) as through the coil (Ic), because the current divides in inverse proportion to the resistance; therefore, the current through the shunt is 2.5(5x0.5) milliamperes. The total current in the circuit is 3 (0.5-2.5) milliamperes. The total current in the circuit is 3 (0.5+2.5) milliamperes.

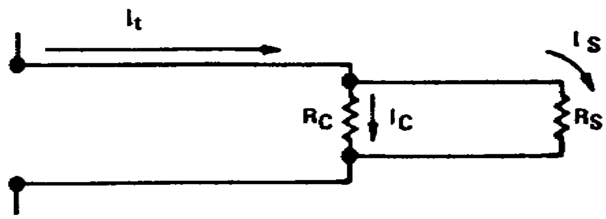


Figure 1-13. Shunt resistor current range

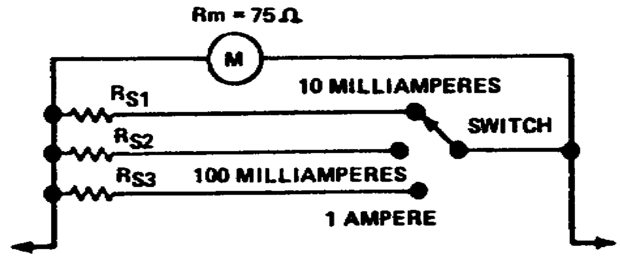


Figure 1-14. Determining shunt resistors

(3) Calculations such as those involved in this example enable you to determine the size of the shunt required to extend the range of an ammeter. Although in actual practice you seldom make these calculations, you must know how meters having the same movement are constructed with different ranges, and how a range switch on the same meter changes the current range of the meter.

(4) Assume that you want to make an ammeter with the ranges of 0 to 10 milliamperes, 0 to 100 milliamperes, and 0 to 1.0 ampere, as shown in Figure 1-14. Also assume that the meter sensitivity is 1 milliampere and the coil resistance is 75 ohms.

(5) You can determine the values for Rs1, Rs2, and Rs3 since the shunt and meter form a simple parallel circuit. As you know, the voltages across the shunt and meter are equal, as in the following formulas:

$$Es = Em$$

or

$$IsRs = ImRm$$

or

$$Rs = \frac{ImRm}{Is}$$

(6) Where Rs is the shunt resistance, "Is" is the current through the shunt at full-scale deflection, Rm is the coil resistance, and Im is the current through the coil for full-scale deflection. Thus, the shunt resistance required to produce the ammeter shown in Figure 1-14 are 8.33 ohms, 0.758 ohm, and 0.0751 ohm respectively.

4. Voltmeter. In constructing a voltmeter with various ranges, you must determine the size of the multiplier to place in series with the meter coil.

a. For this discussion, we can use the same meter as used for the ammeter. The meter sensitivity is 1 milliampere and coil resistance is 75 ohms. Assume we need to determine the correct multipliers for ranges of 0 to 10 volts, 0 to 100 volts, and 0 to 500 volts (fig 1-15). Since 1 milliampere causes a full-scale deflection, the total resistance of the meter (R1+75) must be such that the voltage across it is 10 volts (0-to 10-volt range) when 1 milliampere current is flowing. Thus:

$$R1 = \frac{E}{I} \quad \text{or} \quad R1+75 = \frac{10}{0.0001}$$

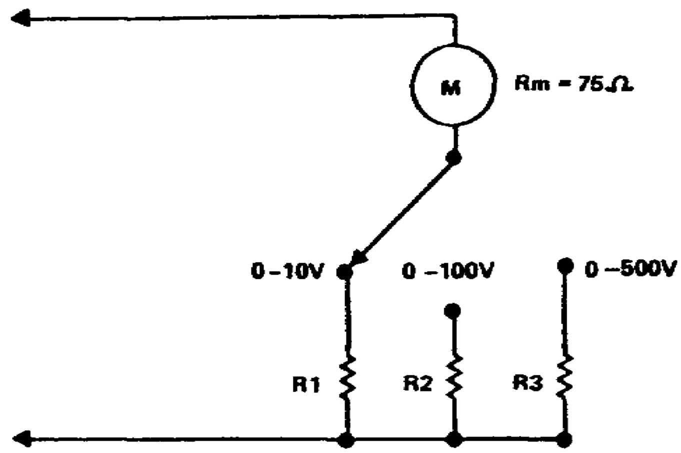


Figure 1-15. Determining multipliers

b. The total resistance is 10,000 ohms and the resistance of the multiplier (R1) is 9925 ohms. The resistance of the other two multipliers (R2 and R3) can be determined in a similar manner.

c. A term which you frequently encounter while troubleshooting television systems is voltmeter sensitivity. The sensitivity of a voltmeter is expressed in ohms per volt and is determined by dividing the resistance of the meter and the multiplier by the full-scale reading in volts. It is just another way of stating what current can cause full-scale deflection.

d. A voltmeter should have very high resistance so it draws very little current and affects the circuit as little as possible during voltage measurements. Sensitivity, therefore, is an indication of the measuring quality of a voltmeter. Generally, a meter with a 100-ohms-per-volt sensitivity is satisfactory. However, for good accuracy in circuits with high resistance, you must use a meter with a sensitivity of 20,000 (or more) ohms per volt.

e. To extend the range of a voltmeter, add a series resistor (multiplier). Normally this requires you to calculate the resistance of the multiplier. Then you merely add the required resistance in series so that the total resistance of the meter is satisfactory for the new range. You may wonder why you need to know how to increase the range of a voltmeter. In some cases you are required to measure extremely high voltages with a meter that does not have the required range. By determining the multiplier resistance and adding this resistance in series with the meter movement, you can measure these voltages.

f. As we have stated, the voltage indicated by the meter is somewhat in error, depending on the meter sensitivity. This error is due to the loading effect which the meter has on the circuit in which the voltage is being measured. To understand just how a meter affects (or loads) a circuit, observe the circuit shown in Figure 1-16. According to the values indicated, the total current in the circuit is 0.001 ampere.

$$It = \frac{120}{50,000 + 70,000} = 0.001 \text{ ampere}$$

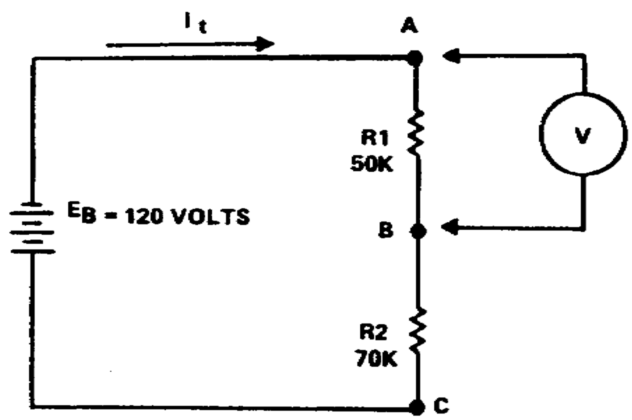


Figure 1-16. Leading effect

g. The applied voltage divides across the two resistors--50 volts across R1 and 70 volts across R2.

h. When you connect a voltmeter across (from point A to point B) the resistor R1, you naturally expect the meter to read 50 volts. However, depending upon the sensitivity of the meter, it may indicate less than the 50 volts you expect. For example, suppose you are using a voltmeter with a sensitivity rating of 1000 ohms x 100, or 100,000 ohms. To find the resistance of a voltmeter, multiply the sensitivity rating by the full-scale voltage.

i. When you connect this voltmeter across the 5000-ohm resistor in the circuit, you put the meter in parallel with this resistor. The total resistance of the circuit effectively becomes 103,333 ohms. Thus the total current increases to approximately 1.16 milliamperes, the voltage across R2 increases to approximately 81.2 volts, and the voltage reading on the meter is approximately 38.8 volts.

j. You can avoid loading a circuit by using a voltmeter in which the resistance is large compared with that of the circuit element across which you are measuring voltage. If a voltmeter with such high sensitivity is not available, you can improve accuracy by using a higher range on the voltmeter. For example, if you used the 0-to 500-voltage range on the meter, the voltage across the resistor R1 would read approximately 47.2 volts.

5. Ohmmeter. Despite its usefulness as a resistance-measuring device, the ohmmeter is comparatively inaccurate. It is used only where resistance measurements need not be extremely accurate. A good rule to remember when you are using an ohmmeter, such as shown in Figure 1-17, is that the highest reading that can be obtained with acceptable accuracy is approximately ten times the mid-scale reading, and the lowest reading is approximately one-tenth of the mid-scale reading.

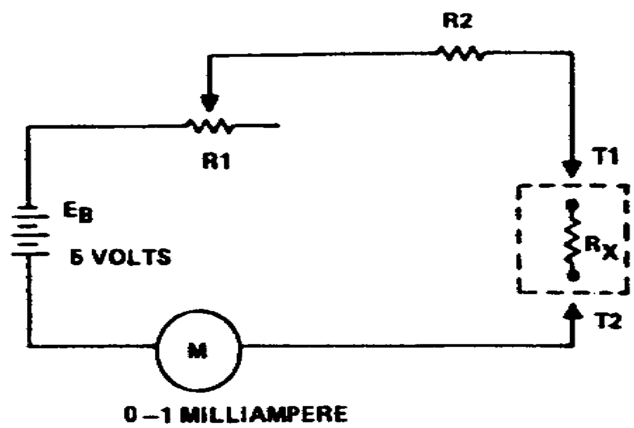


Figure 1-17. Typical ohmmeter scale

a. To determine the range of resistance within the above limits, you must determine what the total resistance of the meter circuit is to limit the current to 1 milliampere (full-scale deflection) when points T1 and T2 are connected together (short-circuited). Full-scale deflection is obtained when R1 is 5000 ohms.

$$R1 = \frac{Eb}{It} = \frac{5.0}{0.001} = 5000 \text{ ohms}$$

b. Where Eb is the battery voltage and it is 1 milliampere (meter sensitivity), the above calculation reveals that the sum of the adjustable and limiting resistor must be 5000 ohms if we are to obtain full-scale deflection. Full-scale deflection indicates zero resistance, and the meter scale is marked "0" ohms at 1 milliampere point (fig 1-10). When a resistor (Rs) is placed between terminals T1 and T2, the total resistance of the circuit is increased, and a smaller current flows through the meter.

c. For mid-scale reading, the size of Rx (fig 1-17) between terminals T1 and T2 must be of a value to limit current to 0.5 milliampere. Thus the total resistance of the circuit of half-scale deflection is 10,000 ohms.

$$R_t = \frac{E_t}{I_t} = \frac{5.0}{0.0005} = 10{,}000 \text{ ohms}$$

d. Therefore, Rx must be 5000 ohms for mid-scale reading when Rx is placed between T1 and T2. This leads to an interesting conclusion. The midscale resistance reading of an ohmmeter is equal to the internal resistance of the meter, and the scale may be so calibrated.

Learning Event 4:
DETERMINE VOLTS AND OHMS READING ON THE PSM-6

1. Multimeter PSM-6. As an aid to our discussion and for simplification, we will use the ME-70 PSM-6 multimeter illustrated in Figure 1-18.

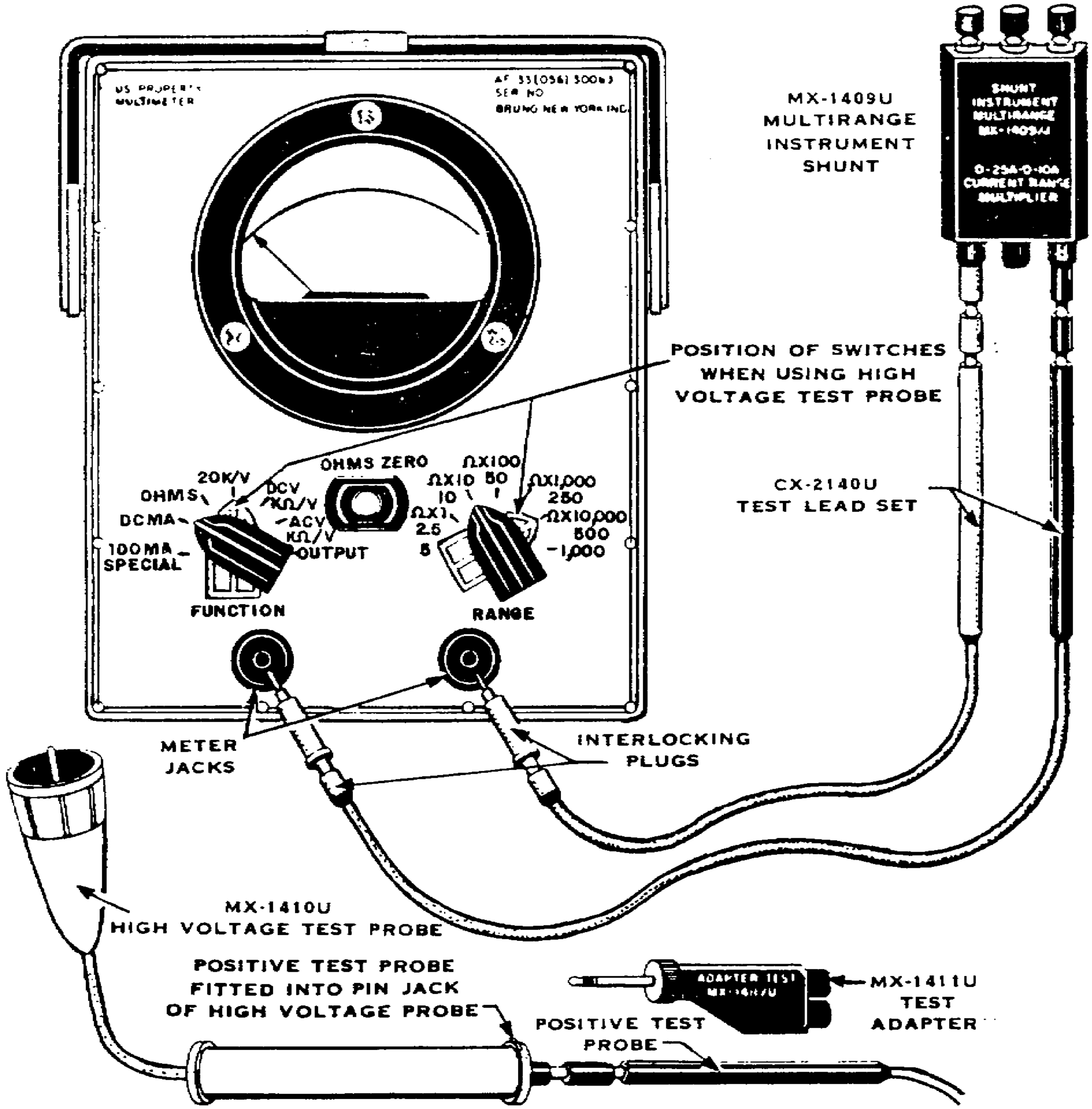
2. The sensitivity of the PSM-6 voltmeter is the ohms-per-volt rating of the meter circuit, either 1000 ohms per volt or 20,000 ohms per volt. Ordinary voltmeters are not extra-sensitive, since the energy they use is only a very small percent of the energy produced by the current of the circuit being tested. For accurate readings of delicate network circuits where normal current is small, the current which energizes the meter becomes such a large percentage of the total current that erroneous readings and circuit malfunctions occur when you use a common voltmeter.

3. Reading the multimeter. Look at the dotted line shown on the meter face in the illustration in Figure 1-18. It shows an imaginary line where the pointer of the meter comes to reset. Suppose the function switch is turned to the direct-current voltage position, 20,000 ohms per volt (20K). This indicates that the middle scale (black) is to be read. Now suppose that the range switch is on the 50 volts position. This indicates that the maximum deflection of the meter needle represents 50 volts. Therefore, make your reading on the 5 scale, since there is no 50 scale, and 50 is a multiple of 5. The multiple selected is always 1/10th, 10, 100, etc. However, instead of the indicated numbers 1, 2, 3, 4, and 5, visualize this scale as reading 10, 20, 30, 40, and 50 volts respectively. Each numbered segment of the arc has a value of 10 volts. Therefore, each small division of the scale has a value of 1 volt. Thus the reading is one increment past the number 2 (visualized 20). It, therefore, represents a value of 21 volts direct current.

a. Suppose that we turn the range switch to 250 and, checking a circuit, we notice that the needle again comes to rest as shown. There is no maximum reading of 250 on the direct-current scale, but we can use the 2.5 scale. This time we visualize the indicated numbers 0.5, 1, 1.5, 2, and 2.5 as readings of 50, 100, 150, 200, and 250 volts respectively. Each number segment of the scale has a value of 50 volts; therefore, each small increment has a value of one-tenth of 50, or 5 volts.

b. Turn the function switch to the 1000 ohms per volt, alternating-current voltage position and make the reading on the AC scale, which is the lower one and is red. Take the reading with the range switch on the 500 position (fig. 1-18) making it on the 5 scale. The numbered positions of the scale are visualized as representing 100, 200, 300, 400, and 500 volts. Then with each increment of the scale representing 10 volts, you are reading 240 volts.

4. The dual external shunt shown in Figure 1-18 extends the direct current range of the instrument from its normal range (0.5 to 1000 milliamperes----1000 milliamperes equal 1 ampere) to provide either a 0-to 2.5-ampere range or a 0-to 10-ampere range. Three terminals provided at each end of the molded plastic are standard pin jacks which accommodate the test lead



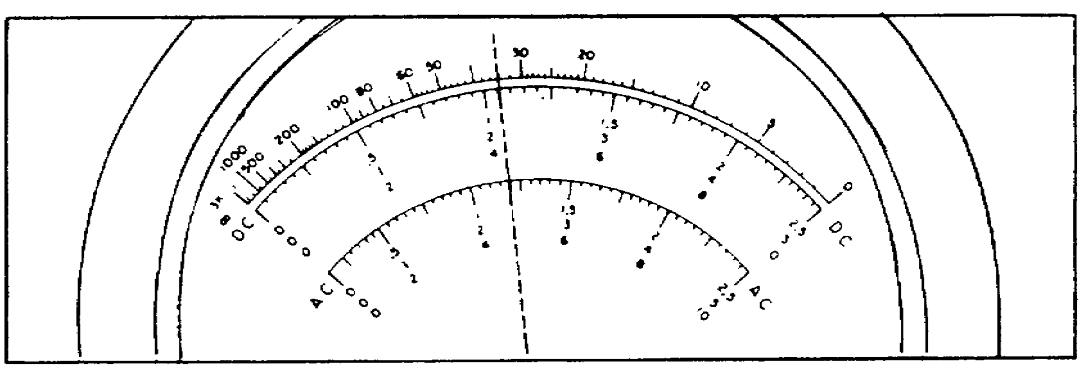


Figure 1-18. ME-70 PSM-6 multimeter

probe. The two lead wires are shown attached to correctly measure the current of a circuit. Make all connections with voltage not applied. After checking all connections, turn the circuit on and read the meter.

5. MX-1410U, the high-voltage test probe (fig 1-18), extends the DC voltage range to 5000 volts. Notice that the function switch is in the 20K position, the range switch must be set at 500, and the high voltage test probe is connected to the positive test lead.

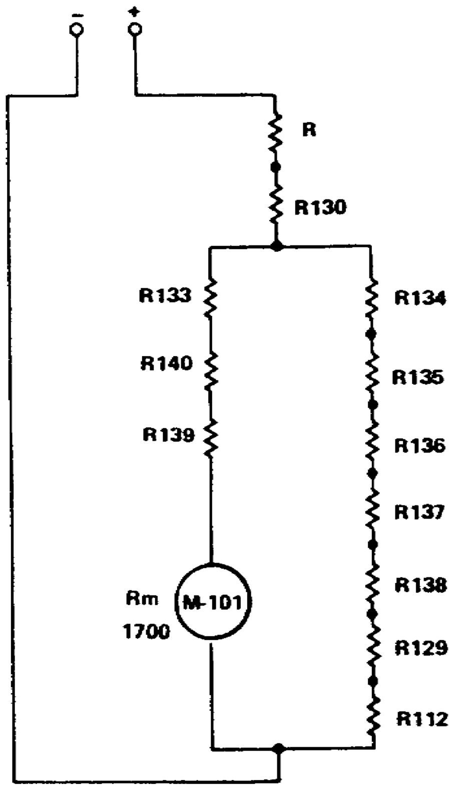
6. The MX-1441U test adapter (fig 1-18) is used to make crystal current measurements requiring a 1000-ohm load as seen from the plug end of the adapter.

7. The CX-2140U test Lead set (fig 1-18) includes a pair of four-foot test leads. These test leads have interlocking plugs installed at their set ends and test probe tips at the other end. Detachable alligator clips are also provided to fit over the test probe, to hold a component or clip on to a part of the circuit.

Learning Event 5:
DETERMINE THE VALUE OF R IN FUNCTION AND RANGE SETTINGS

1. The PSM-6 has a range switch allowing you to select DC voltage ranges of 0.5, 2.5, 10, 50, 250, 500, and 1000 volts. Further, since DC voltage may be checked at a sensitivity of either 1000 ohms/volts or 20,000 ohms/volts as selected by the function switch on the panel of the instrument operation (primarily the same regardless of whether the 20,000-ohms/volt or the 1000-ohms/volt function is selected), we will only discuss the 1000 ohms/volt operation. Figures 1-19 and 1-20 illustrate and identify both simplified circuits; if you know the operation of one, you can easily understand the other.

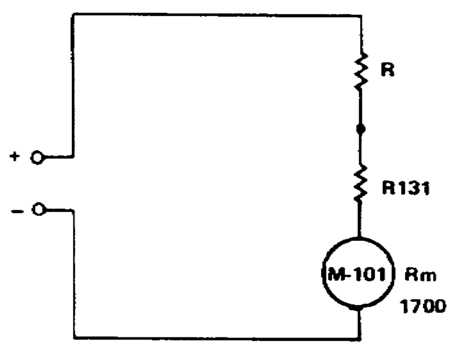
2. With the function switch set at the DCV Kohm/V position and the range switch at any position, the simplified circuit in Figure 1-19 shows the basic circuit configuration used to check DC voltages. Note in the diagram the range settings are obtained by the selection of resistors of various sizes. For example, when the range switch is in the 50 position, the value of R is such that 50 volts applied across the meter provides full-scale deflection. If the range switch is changed to position 10, then the value of R is such that 10 volts applied across the meter causes full-scale deflection, etc.



RANGE SETTING	VALUE OF R
.5	0
2.5	2,000
10	9,500
50	49,500
250	249,500
500	499,000
1,000	999,500

1,000 OMS /VOLT

Figure 1-19. 1000-ohms/volt simplified circuit



RANGE SETTING	VALUE OF R
.5	0
2.5	40,000
10	190,000
50	990,000
250	4,990,000
500	9,990,000
1,000	19,990,000

20,000 OHMS / VOLT

Figure 1-20. 20,000-ohms/volt simplified circuit

3. The circuit illustrated in Figure 1-20 is, for all practical purposes, identical to that in Figure 1-19 except for the resistance values used. For instance, when the function switch is set at 20K ohm/V and the range switch at any position, the circuit reduces to the simplified diagram illustrated it Figure 1-20. Again, the value of R depends upon the position of the range switch, as shown in the accompanying table. The total resistance, including the 1700 ohmmeter resistance, provides a 20,000 ohms-per-volt sensitivity for all ranges selected.

4. While we are talking briefly about DC voltage measurements, note two simple things that can cause damage to the meter movement. Refer to Figure 1-21 and note what happens when the meter leads are connected backwards in the circuit. The meter needle deflects in the opposite direction and is damaged because it is driven into the stop, or, forced off scale.

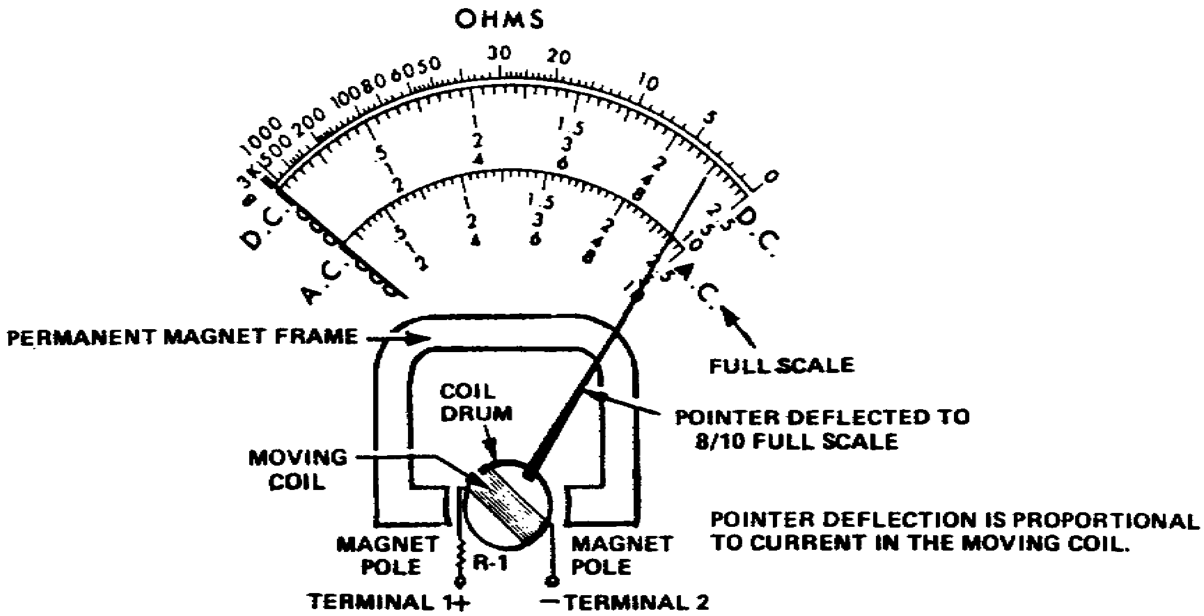
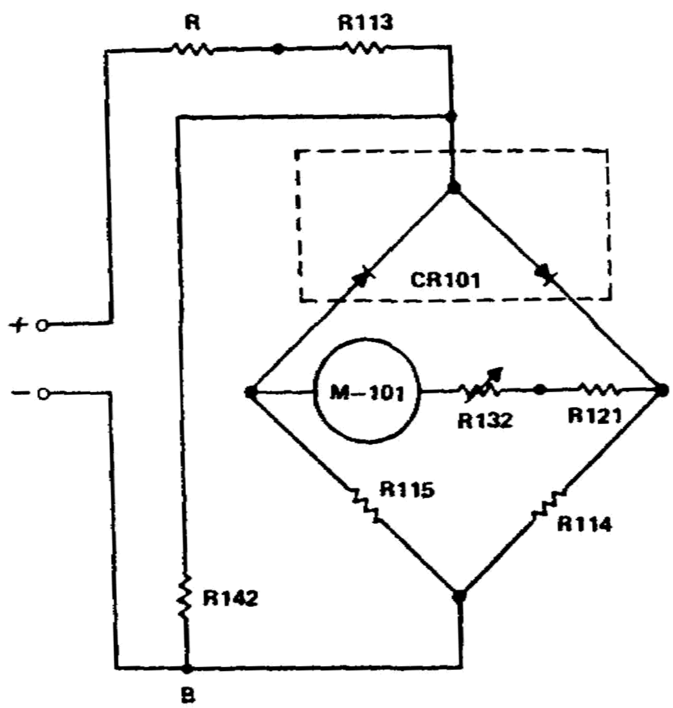


Figure 1-21. Meter damage

5. Suppose the meter is connected to a source of voltage greater than that which produces full-scale deflection. In this case the current through the movable coil exceeds the 1mA for which the coil is designed and forces the meter needle off the scale and may burn out the meter coil.

Learning Event 6:
DETERMINE THE VALUE OF R FOR AC VOLTAGE MEASUREMENTS

1. The measurement of AC voltage is a procedure very similar to the DC voltage measurement procedure just discussed. Again, the controls on the front panel of the PSM-6 are the function and range switches. With the function switch set at ACV and the range switch at any position, the circuit is basically the one shown in Figure 1-22, with the values of R as shown in the accompanying table. The ACV ranges are also designed for a sensitivity of 1000 ohms/volts, and the total resistance between points A and B should therefore be 450 ohms. The two rectifier sections of CR101 rectify the incoming AC voltage, and the resulting pulsating DC is read on the meter. Resistor R132 is a variable resistance, set at the factory, to provide compensations for variations in rectifier characteristics and temperature correction.



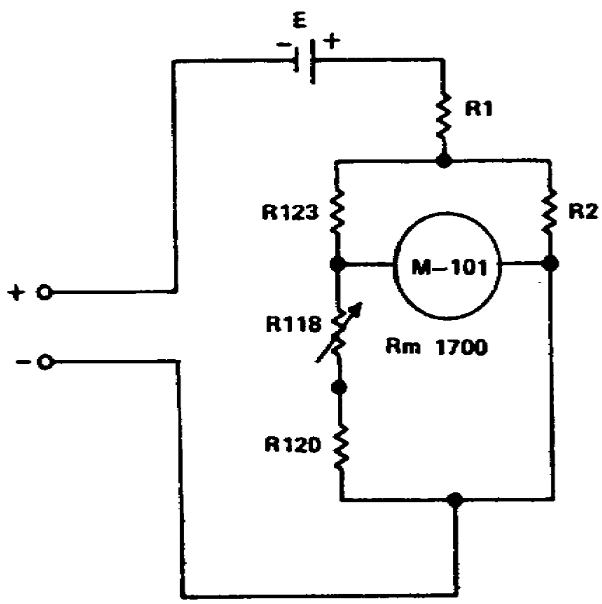
RANGE SETTING	VALUE OF R
.5	0
2.5	2,000
10	9,500
50	49,500
250	249,500
500	499,500
1000	999,500

Figure 1-22. AC voltage measurement circuit

2. The same basic precautions applying to AC voltage measurements apply to DC measurements except that it is not necessary to observe polarities. One additional precaution that should be observed, however, is one not necessarily related to safety but one which results in proper use of the meter in AC voltage measurements. The AC voltmeter section of the PSM-6 is designed to handle frequencies up to about 1000 hz. Above this frequency the voltage readings are subject to inaccuracies due to inductive reactance.

Learning Event 7:
DETERMINE THE RANGE SELECTION USED IN RESISTANCE MEASUREMENT

1. Although it uses the same basic meter movement, as shown in Figure 1-21, the circuitry is quite different. The circuit contains a battery in series with the meter, as shown in Figure 1-23. The ohms zero control R118 allows you to zero the meter for considerable drops in battery voltage. With the meter leads shorted together, adjust the variable resistor to produce a full-scale reading on the meters.



RANGE SETTING	VALUE OF R1 (Ω)	VALUE OF R2 (Ω)	E (VOLTS)
X1	54	23.75	1.34
X10	17.5	234.8	1.34
X100	175	2,583	1.34
X1000	1,750	OPEN	1.34
X10,000	226,750	OPEN	13.4

Figure 1-23. Resistance measurement circuit

a. The full-scale reading indicates zero resistance. When you insert a 50-ohm resistor between the leads, the current in the circuit is reduced and the meter no longer reads full scale. In other words, the size of the resistor inserted between the leads determines the current through the meter and the amount of meter deflection.

b. The scale is calibrated to read directly in ohms. A range switch allows you to select ranges of x1, x10, x100, or x10,000. For example, a direct reading of 67 on the scale with the range switch at x100 means that the circuit has a resistance of 67 x 100 or 6700 ohms.

2. Look at Figure 1-24 and see what else we should recall about measuring resistance with the meter. This figure shows a portion of the synchronizing circuit located in a typical modulator. Notice that the ohmmeter is connected across R630. Should you expect to get a reading of 100 on the meter? No, you should not! If you analyze Figure 1-24 more closely, you will see that the current from the meter has two paths. One path is from point A to terminal 7 to T603, through the transformer winding to terminal 8, and return to point B.

Therefore, the current from the meter is flowing through two parallel paths, and the resistance measured by the meter is the less than total resistance of R630. To prevent this situation you must disconnect one end of R630 and then measure its resistance. In this way you can measure the true value of R630. Remember that when you measure a specific resistance, you should eliminate any parallel paths in order for the reading to be accurate.

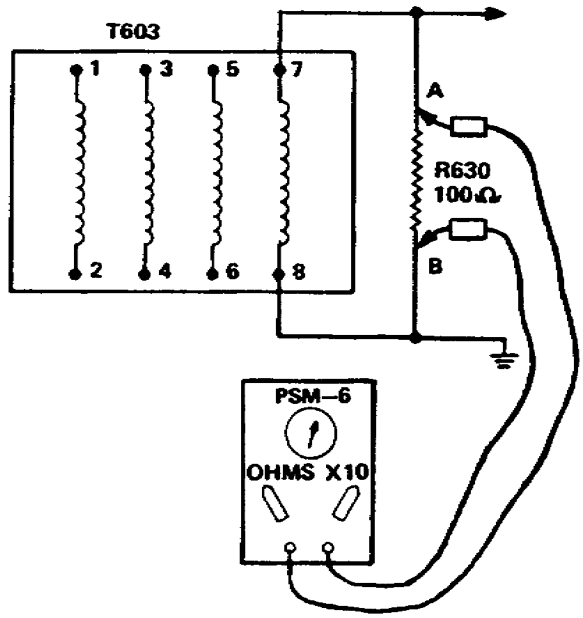


Figure 1-24. Resistance measurement proper circuit conditions

3. Another point you should remember when measuring resistance with an ohmmeter is illustrated in Figure 1-25, which shows a portion of a typical voltage regulator circuit. Suppose that you want to measure the resistance of potentiometer R1. Of course the circuit power is turned off, and parallel paths have been eliminated by disconnecting leads X and Y. Now all you have to do is measure the resistance of RI. However, in this case the terminals of R1 are hard to reach; so you place your fingers on the metal tips of the meter leads in order to hold the leads on the potentiometer terminals. The meter has only about a 1.34-volt or 13.4-volt battery, so you will not get a shock. You have overlooked one little detail. You have placed yourself in parallel with R1. You will probably obtain a resistance reading of 150,000 to 200,000 ohms, which is the sum of a parallel circuit made up of you and R1. Although there is no safety factor involved in this example, you have obtained an erroneous meter reading which would probably lead you down the wrong trail when troubleshooting a circuit of this type. This in turn wastes time and can cause unnecessary replacement of components or parts.

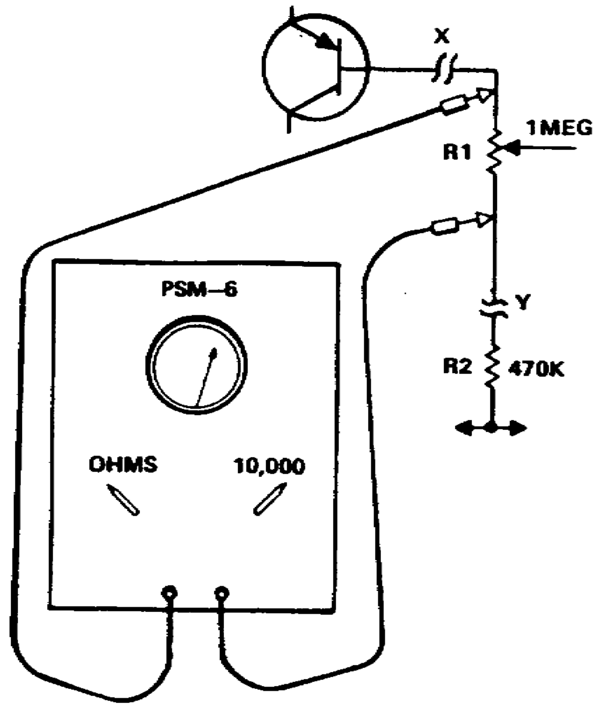


Figure 1-25. Ohmmeter connection

Learning Event 8:
ANALYZE METER OPERATIONS

1. The remaining major capability of the meter is, of course, the current measurement function. When using the PSM-6, direct current up to 1 ampere may be measured. To do this, set the function switch to the DC MA position and set the range switch at one of its positions.

2. Refer again to Figure 1-22, the basic meter movement. As discussed earlier, the amount of current through the movable coil determines the amount of meter deflection. In the case of PSM-6, 50 microamperes of current through the coil is necessary to cause full-scale deflection. What would happen if we put 100 microamperes through the coil? This would damage or burn: out the coil. The resistance allows only 50 microamperes through the coil if the range switch is set for higher than the total current in the circuit. For example, when the range switch is set at 50 and a current of 50 milliamperes are measured, 49.95 milliamperes flow through the resistor and 50 microamperes flow through the coil. This condition produces a full-scale deflection for that range setting and reads 50 milliamperes on the scale. In the actual circuit of the meter, different values of shunt resistors are used for each setting of the range switch.

3. Here, as with voltage measurements, be extremely careful to ensure that a range setting of sufficient amplitude is obtained so that the meter needle will not be pegged. If the needle does not deflect far enough to obtain an accurate reading, the range setting can always be decreased.

Learning Event 9:
MATCH OHMMETER READINGS TO CAPACITOR OR INDUCTOR CONDITIONS

1. Reactive components can become open or shorted. In either case the component is useless because it cannot store energy. Coils and capacitors can also become only partially efficient because of partial shorting or leaking.

2. Capacitor troubles. A leaky capacitor is equivalent to a partial short. The dielectric gradually loses its insulating properties under the stress of applied voltages. A good capacitor has very high resistance (in the megohms). A shorted capacitor shows zero resistance, while a leaky capacitor indicates less than normal resistance.

a. When the ohmmeter is initially connected, its battery charges the capacitor. Maximum current flows at the first instant of charge and the meter indicates low resistance. As the capacitor charge slows, less current flows, and the meter indicates more resistance. When the capacitor has charged to the meter potential, the charging current is zero, and the ohmmeter reads only a small leakage current through the dielectric. This capacitor action is normal.

b. Troubles in a capacitor are indicated as follows:

(1) When the ohmmeter reading is immediately zero and stays there, the capacitor is shorted.

(2) When the capacitor shows a charging action but the final ohmmeter reading is less than normal, the capacitor is leaking.

(3) The electrolytic capacitor must be checked by taking a normal reading, then reversing the ohmmeter leads and taking another reading. The higher reading indicates the true condition of the component.

(4) If the capacitor shows no charging action and immediately indicates a high resistance, it is open.

3. Inductor checks should be made with the component disconnected from the circuit if we are to set a true indication. The most common trouble in coils is an open, which is indicated by an infinite reading on the ohmmeter.

a. Less common troubles are a short between turns, a short between primary and secondary turns in a transformer, and a short to an iron core.

b. A coil has a DC resistance equal to the resistance of the wire used in the winding. For RF coils with inductance values up to several millihenrys, the 10 to 100 turns in the coil have a DC resistance of 1 to 20 ohms. Inductors for lower frequencies have several hundred turns and a range in resistance from 10 to 500 ohms, depending on the wire size.

4. When checking a transformer with four or more leads, check the resistance across the two primary leads, and across any other pairs of leads for additional secondary windings.

a. For an autotransformer with three leads, check the one lead to each of the other two. When an open is indicated in a coil, the connection from the external terminals to the coil should be checked. Often these can be re-soldered to make the coil reusable.

b. Shorted turns cannot be definitely checked with the ohmmeter because a few shorted turns will only slightly reduce the DC resistance. When shorted turns are suspected because of a reduced resistance, the unit should be replaced. Excess heat across the short can eventually create an open in the coil.

5. The resistance between separate windings in a transformer is normally infinite. If the ohmmeter is connected between the primary and secondary windings and reads a low resistance, this indicates a short between the primary and the secondary. Similarly, the resistance between the winding and the core or frame should be infinite. If a low reading is shown between these points, this indicates a short.

Learning Event 10:
IDENTIFY DIODES, CATHODES, AND ANODES, TO DETERMINE SERVICEABILITY

1. The solid-state diode may be thought of as a resistor that has a high resistance in one direction and a very low resistance in the other direction. As you remember, the end of a diode which current can easily enter is the cathode, while the end through which current leaves is the anode. A diode may become open or shorted. In either case, the diode is useless. We will discuss some of the common procedures for checking a diode.

2. There are several physical differences in diodes, but even if we know these differences, we may still be unable to discern between a diode and a resistor. One sure way to tell the difference is to check with an ohmmeter. A resistor has the same resistance to current in both directions. As shown in Figure 1-26, a diode exhibits a different resistance when reversing lead positions.

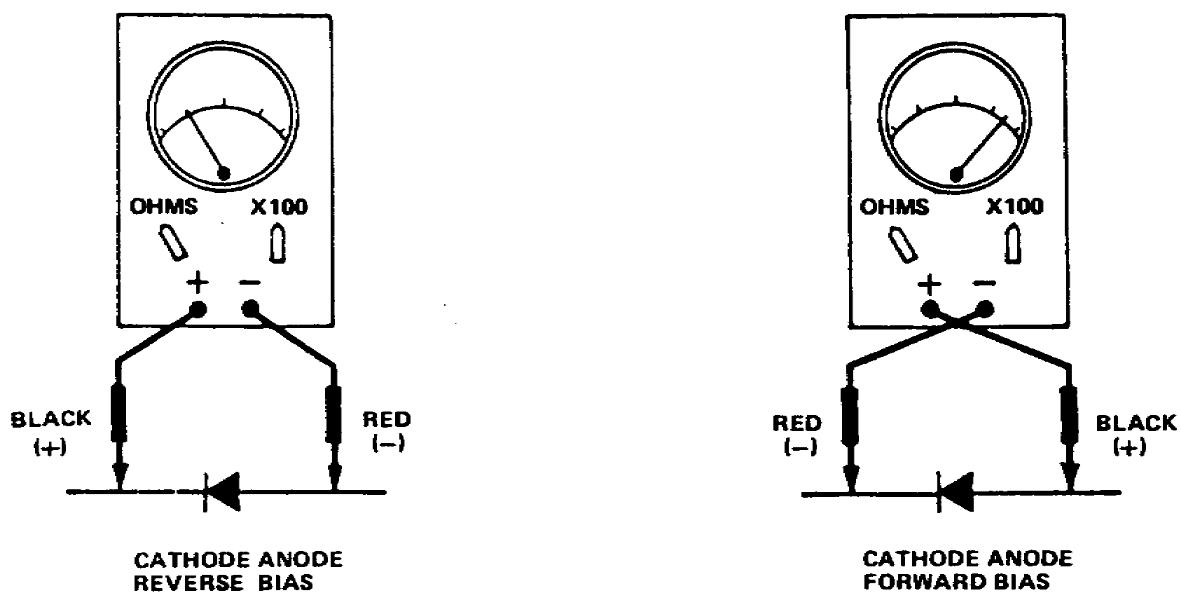


Figure 1-26. Forward-bias and reverse-bias diode

a. When the ohmmeter function on the PSM-6 is selected, the polarity of its leads reverses. The black lead becomes positive and the red lead becomes negative. In order to make the meter deflect in the proper direction, current must enter the meter through the black lead. To accomplish this on the ohms function, the internal battery is connected with its negative terminal to the red lead, and its positive terminal to the black lead.

b. The markings on a diode case often become illegible, and it is impossible to tell from visual inspection which lead is the cathode and which is the anode. In a situation such as this, it is possible to determine the cathode and anode of a diode by using an ohmmeter such as the PSM-6. To forward bias a diode, you must place a negative potential on the cathode. Therefore, when checking a diode for resistance ratio, if you know which lead is negative and which is positive, you can determine which lead is the cathode and which is the anode.

Learning Event 11
IDENTIFY SOME COMMON PROCEDURES FOR CHECKING TRANSISTORS

1. Transistors may be thought of essentially as two diodes mounted back to back. In this project you will use the PSM-6 to check the condition of transistors and determine their types. A transistor may become open or shorted. In either case, it is useless. The PSM-6 may be used to check the condition of the transistor. The following discussion will acquaint you with some of the common procedures for checking a transistor.

2. While using an ohmmeter to check the condition of a transistor, it is also possible to determine its type (PNP or NPN). Since a transistor is essentially two diodes mounted back to back, to check its condition you must measure the resistance ratio (about 10 to 1) of each junction emitter to base and collector to base, then measure the resistance between the emitter and the collector. Remember, when using the PSM-6 as an ohmmeter, the meter leads reverse polarity according to the way the internal power source is connected. The red lead becomes the negative lead, and the black lead becomes the positive lead.

a. Also, a transistor must be isolated from its related circuit before you can check its type or condition with an ohmmeter. In many cases this requires the transistor to be desoldered from the circuit and it is possible to obtain an erroneous ohmmeter indication. One example is shown in Figure 1-27.

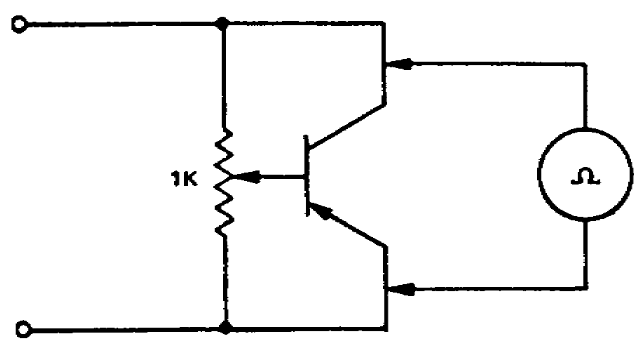


Figure 1-27. False ohmmeter reading

b. With the meter connected across the emitter-collector circuit with an open condition, the meter measures 1K since the current flows out the negative lead through the 1K resistor to the positive meter lead. For this reason, whenever you check a transistor, two of the three leads must be disconnected from the circuit.

c. A transistor, like a diode, has a low-resistance junction when it is forward-biased and a high resistance when it is reverse-biased. When the meter leads are connected red to base and black to emitter, the lowest value of resistance is measured. This indicates a forward-biased condition.

d. When the E-B junction is forward-biased, a negative potential is applied to the base. You remember from your study of diode testing, this indicates that the base is constructed of N-type material and that the emitter is constructed of P-type material. Once you know the type of material that the base and the emitter, or collector, are made of, you can determine the type of transistor. Since we know the emitter is P-type material and the base is N-type, this must be a PNP-type transistor.

Lesson 1
PRACTICE EXERCISE

1. What are two of the three principal measuring instruments used to perform maintenance?

   a. Voltmeter and frequency counter
   b. Ammeter and ohmmeter
   c. Voltmeter and oscilloscope
   d. Oscilloscope and frequency counter

2. To measure large amounts of current you must put what in the circuit?

   a. Impedance matching device
   b. Shunt device
   c. Temperature coefficient
   d. Capacitance device

3. What must you observe when connecting a meter in circuit?

   a. The current
   b. Voltage
   c. Impedance
   d. Polarity

4. To determine full-scale deflection for a voltmeter, you use what formula?

   a. $Rx = Rm \frac{Eb - Em}{Em}$

   b. E = 1 xR = 0.001 x 50

   c. $Rs = \frac{Im\ Rm}{Is}$

   d. I = R + E

5. What must you do to extend the range of a voltmeter?

   a. Add a shunt device
   b. Add a parallel resistor
   c. Add an impedance device
   d. Add a series resistor

6. What are the two sensitivity settings of a PSM-6 voltmeter?

   a. 500 ohms per volt and 20,000 ohms per volt
   b. 1000 ohms per volt and 20,000 ohms per volt
   c. 1000 ohms per volt and 10,000 ohm per volt
   d. 500 ohms per volt and 10,000 ohms per volt

7. If your meter is set at 10 volts DC and you read across a 50-volt line, what happens to the meter?

   a. Coil may burn out
   b. Nothing will happen
   c. Waveform is all right
   d. Syn lock is all right

8. The maximum frequency the PSM-6 can handle to measure AC voltage is how many Hz?

   a. 400 Hz
   b. 800 Hz
   c. 1000 Hz
   d. 1400 Hz

9. What should you expect to read on your meter if your leads are as shown in Figure 1-24?

   a. 100 ohms
   b. Nothing
   c. Parallel path
   d. Correct waveform

10. To determine what type of transistor you are checking you do what first?

   a. Check emitter to base
   b. Check collector to base
   c. Check emitter to collector
   d. Remove from the circuit

LESSON 2
DEFINE THE THEORY AND APPLICATION OF AN OSCILLOSCOPE

TASK

Describe the theory and terminology related to maintenance procedures for the oscilloscope.

CONDITIONS

Given the information and illustrations about terms and theory relating to application of the oscilloscope.

STANDARDS

Demonstrate competency of the task skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of using an oscilloscope.

REFERENCE

None

Learning Event 1:
DESCRIBE THE PRINCIPLES OF OPERATION OF AN OSCILLOSCOPE

1. The cathode-ray oscilloscope is a test instrument using a cathode-ray tube (CRT). It is one of the most important units of test equipment in maintenance and service. It is used to give a visual presentation of circuit waveforms which, by comparison, show the operation efficiency level of a portion of a circuit or a complete circuit contained in the system being tested.

2. When using the oscilloscope, you compare actual waveforms against optimum-efficiency waveforms which are permanently printed and located either at the equipment test points or on schematic diagrams in the applicable technical manuals. Scope patterns periodically taken at the test points are compared with those printed waveforms. Differences between the optimum waveform and the scope pattern indicate that the circuit (and the equipment) is below the optimum performance level and that corrective action should be applied.

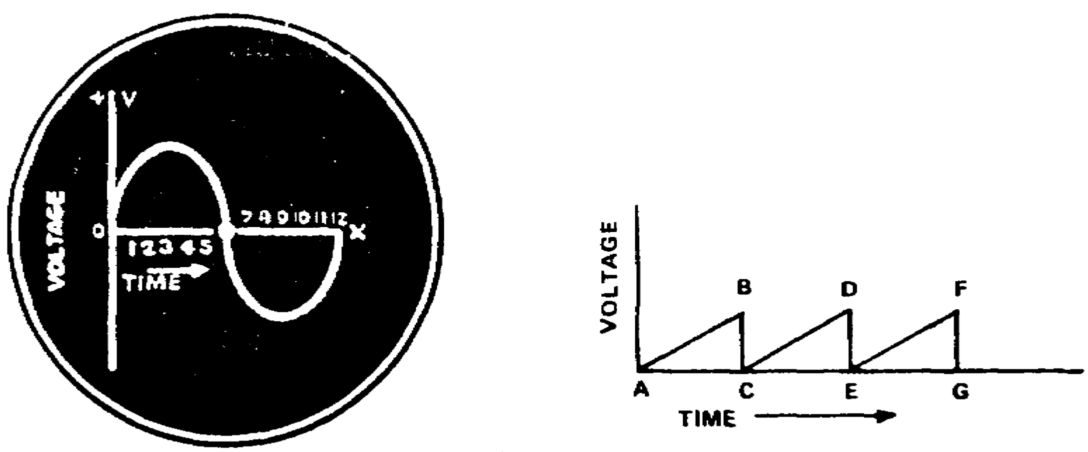
3. The beam of electrons from a cathode-ray tube follows a straight line unless deflected by an electric or a magnetic field. Cathode-ray tubes are of two types according to the method used to deflect the electron beam. These types are electrostatic and electromagnetic. The electrostatic type of CRT is used in practically all cathode-ray oscilloscopes operating at test instruments. In the electrostatic type, the beam is deflected by an electric field

set up across the deflection plates by a deflection voltage. The progressive deflection of the beam paints the picture of the waveform on the face of the cathode-ray tube.

a. The inner face of the CRT is coated with a material which fluoresces when it is struck by the beam of electrical energy. In the CRT the beam is repeatedly swept across the screen. With the waveform, an alternating-current voltage can be observed on the screen when it is applied to one pair of deflection plates and when a second voltage of appropriate characteristics is simultaneously applied to the other pair of plates.

b. The conventional way of representing voltage or current of a sine waveform is shown in Figure 2-1. The voltage to be observed is applied between the vertical deflection plates; simultaneously, a sawtooth voltage is applied between the horizontal deflection plates. The sawtooth voltage moves the beam from left to right at a constant speed to form the time scale along line OX (fig 2-1). Then it returns the beam rapidly to the starting position at the left, and repeats the operation. The sawtooth voltage is so named because it resembles a sawtooth. As the voltage increases from A to B, the beam is swept from 0 to 12. As the voltage falls from B to C, the beam is quickly returned to its starting position (zero), and the process is repeated.

c. If an AC voltage of sine waveform is applied between the vertical deflection plates with no horizontal deflection, a single vertical line appears on the screen. The varying rate of change of the voltage is hidden because the vertical movements retrace themselves repeatedly on the same vertical line. Similarly, if a sweep voltage of sawtooth waveform is applied to the horizontal deflection plates in the absence of vertical deflection, a horizontal line is formed, and the rate of change of the voltage is obscured. However, when both voltage are introduced at the same time, the vertical motion of the beam is spread out across the screen to form a sine curve, such as the one shown in Figure 2-1.



A. SINE WAVEFORM PLOTTED AGAINST TIME

B. SAWTOOTH WAVEFORM PLOTTED AGAINST TIME

Figure 2-1. Sinewave and sawtooth voltage waveforms

4. A block diagram of a representative cathode-ray oscilloscope is shown in Figure 2-2. The horizontal deflection amplifier is a high-gain resistor-capacitor-coupled class A wideband voltage amplifier that increases the amplitude of the horizontal input voltages and applies it to the horizontal deflection plates. The sweep generator supplies a sawtooth voltage to the input of the horizontal amplifier through a switch that provides an optional external connection.

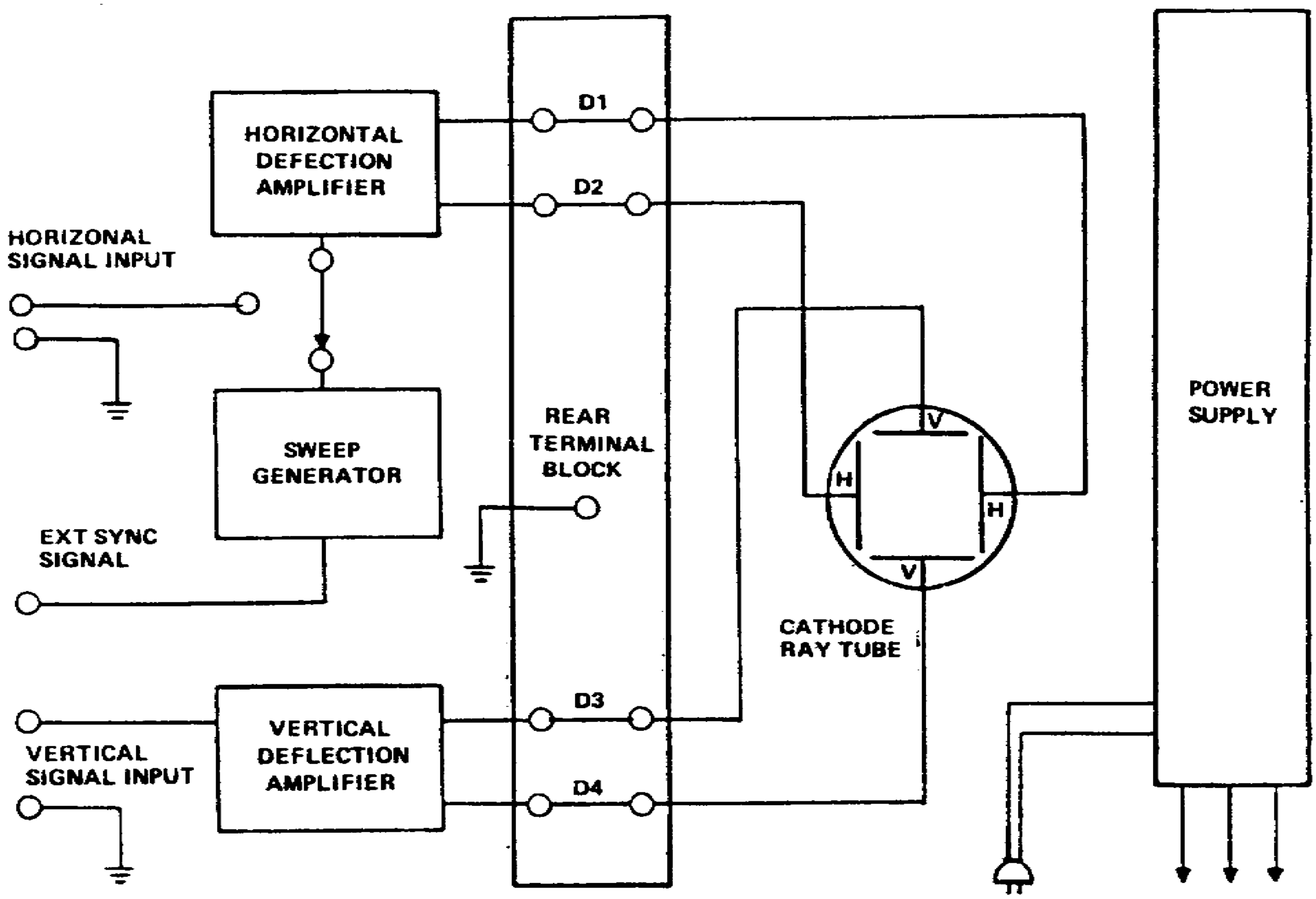


Figure 2-2. Block diagram of a typical cathode-ray oscilloscope

5. The vertical deflection amplifier increases the amplitude of the vertical input voltage before applying it to the vertical deflection plates. The input to the vertical amplifier appears in magnified form on the viewing screen as a graph of the current or voltage waveform being examined. A rear terminal block provides direct electrical connections to the deflection plates. These connections are used, for example, when one is examining direct-current potentials or high-frequency signals that would be attenuated excessively by the amplifier circuits. The power supply provides all DC voltages for the tubes, including a high DC voltage for the CRT.

a. You should consult the applicable technical manual for specific operating instruction covering your particular instrument. For proper use of any oscilloscope, you must consult the instruction regarding turn on and operation. Improper operation of the oscilloscope may cause damage to the instrument.

b. After the oscilloscope is properly set up, allow time for the instrument to warm up before you start to use it for checking waveforms. Make certain there is a good reference signal on the screen.

c. A couple of examples of a good signal, which you should be able to obtain at this point, are shown in Figure 2-3. If any other picture is obtained, adjust the appropriate scope controls until the proper picture is shown on the screen.

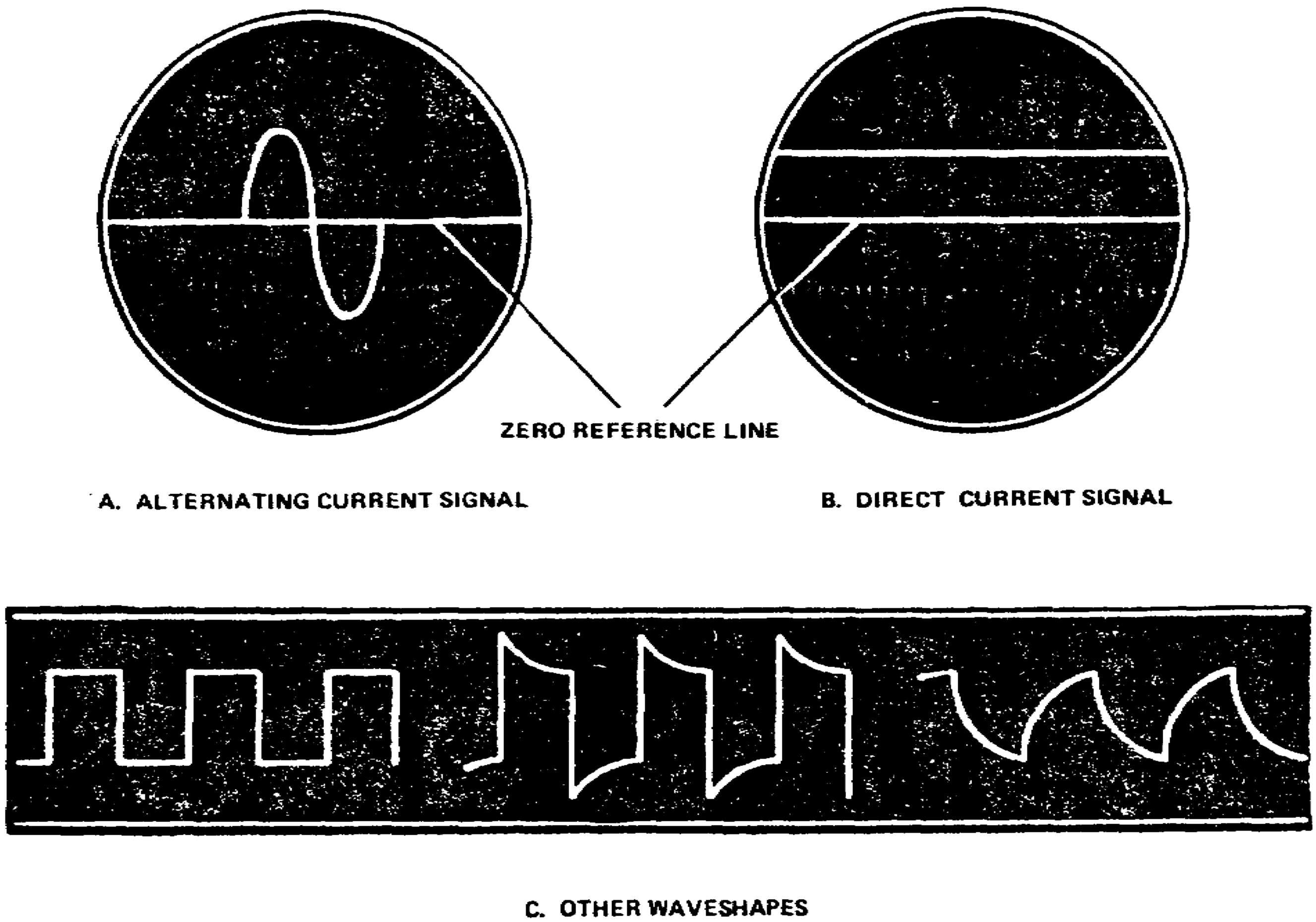


Figure 2-3. Checking waveforms

Learning Event 2:
DESCRIBE THE VARIOUS CONTROLS ON AN OSCILLOSCOPE

1. If you understand the principle of operation of one oscilloscope you can apply the same techniques to other oscilloscopes, since all scopes operate on the same principle and have about the same controls. By discussing the controls in general you will have sufficient information to operate most types of oscilloscopes.

a. The two basic controls affecting the readability of the scope display are the beam intensity and focusing controls. These two controls are considered together because they interact to an extent that adjusting one requires adjusting the other.

b. The intensity control is used to adjust the spot to the brightness desired. When the spot is still, it becomes brighter, larger, and out of focus as the intensity control is rotated toward maximum intensity. Further rotation of this control produces secondary emission, causing a halo around the spot. When the halo appears, the intensity control must be immediately decreased to eliminate the halo before the screen is burned.

(1) The halo from an excessively bright spot disappears to some extent when the electron beam is subjected to the deflection fields because the energy in the electron beam is distributed over a much greater area.

(2) However, the spot will produce a wide trace, tending to obliterate any available fine detail.

c. The focus control is used to produce a round spot with a clearly defined edge. A stationary spot becomes smaller and sharper when you rotate the focus control from minimum toward maximum value. As you rotate this control beyond the focal point, an out-of-focus spot is again produced.

d. A poorly focused spot can appear elliptical instead of round. When the elliptical spot is set into motion under the influence of deflecting fields, it is noticeable as a line of variable thickness. The spot in motion produces a thin line only at the peaks of sine wave, while the positive and negative-going portions of the sine wave are considerably thickened.

e. Depending upon the velocity of the spot, an increase in spot intensity may be required because the rapidly moving spot does not remain in one position long enough to fully excite the phosphor screen of the cathode-ray tube. You may observe this effect in Figure 2-4, when viewing square waves with extremely rapid rise and decay times.

Figure 2-4. Beam intensity affected by spot velocity

f. The basic controls that determine the size of the display are potentiometers used as horizontal and vertical gain controls. Adjustment of the horizontal gain control increases or decreases the height of the display.

(1) An attenuator (occasionally referred to as a multiplier) is sometimes used prior to adjusting the gain control. It is associated with the vertical amplifier and is calibrated in steps of 1x, 3x, 10x, 30x, and 100x. The attenuation at each step is expressed with respect to the attenuation range at step 1x. Operation of this control results in abrupt changes in the scope display because of step attenuation of the input signal level.

(2) The attenuator is called a multiplier because the attenuator output is usually larger than the vertical amplifier input. The scope can be used as a direct-reading, peak-to-peak voltmeter once the vertical amplifier is calibrated. Calibrate the amplifier by setting the attenuator to 1x, inject a signal of known amplitude, and adjust the display to vertical dimensions of convenient known height. Advancing the gain control too far for a given signal, or applying a signal that exceeds the amplification capabilities of the horizontal or vertical amplifiers, results in overloading.

g. Interpretation of an observed waveform depends greatly upon proper proportioning of the horizontal and vertical dimensions of the scope display. Uncertainty or lack of knowledge concerning the signal that an amplifier is processing, together with improper display proportioning, can lead to an erroneous conclusion concerning the test circuit. Figure 2-5b shows the display of a trapezoidal waveform where the horizontal and vertical dimensions are acceptable.

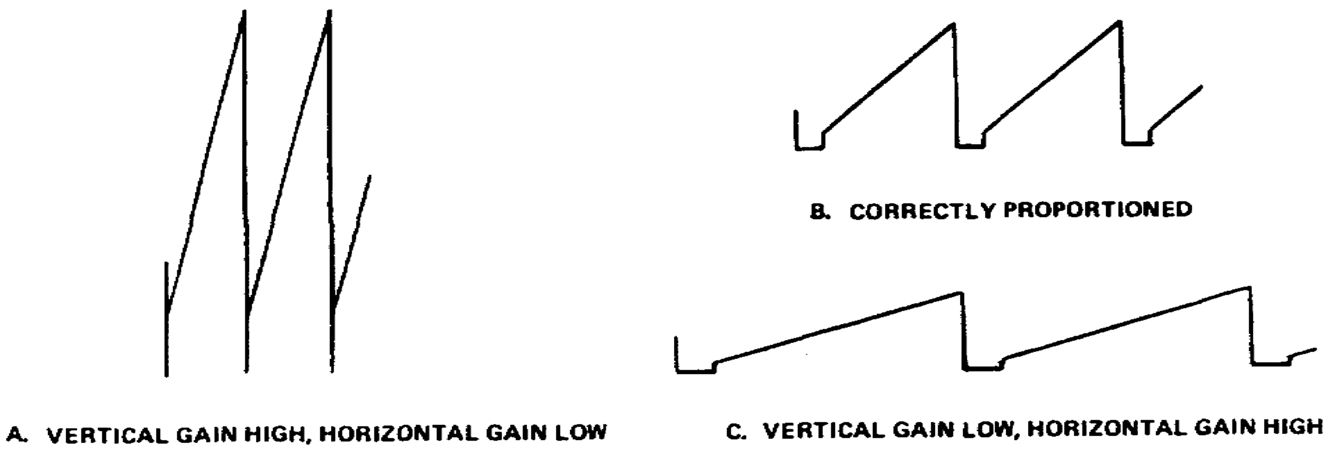


Figure 2-5a, b, and c. Apparent changes in waveform with changes in vertical to horizontal proportioning

(1) By contrast, if both the horizontal and vertical gain controls are changed randomly so the change in the vertical direction predominates, the characteristics of the trapezoidal waveform become masked.

(2) If you were inexperienced in the use of a scope, or if you had no previous knowledge that the waveform was supposed to be a trapezoid, you could reach the erroneous conclusion that the display was a sawtooth waveform. On the other hand, if you know that the circuit produces a trapezoidal wave and wish to closely inspect the waveform for any irregularities, such proportioning of the display is entirely acceptable and advisable.

(3) By changing the horizontal and vertical gain controls once more to the opposite extreme so the display is exaggerated predominantly in the horizontal direction, you produce a waveform like that shown in Figure 2-5c. Under these conditions, the trapezoidal waveform viewed on the scope screen could be interpreted as a sawtooth waveform with excessive retrace time.

h. A height-to-width ratio of approximately 2 to 3 or 4 to 5 provides optimum display proportions for general purpose waveform examinations. Once you are certain of the waveform you are inspecting, expansion or exaggeration of the waveform in the vertical or horizontal direction to observe waveform irregularities may be very advantageous.

i. Sometimes the signal at the point under examination is so small that a display of more than a half-inch in the vertical dimension cannot be obtained. The horizontal dimension of the display must also be reduced so that the display is correctly proportioned. A reduction in beam intensity, followed by a refocusing of the spot, generally produces a display which is easier to view.

2. The vertical and horizontal positioning controls permit you to shift the position of the entire display to any portion of the viewing area desired. The vertical positioning control is a continuously variable potentiometer that permits the display to be moved up and down by any amount, including those positions away from the viewing area. Similarly, the horizontal positioning permits the side-to-side movement of the entire display.

3. Occasionally, while examining a waveform, you may notice irregularities at or near some extremity of the display. You can enlarge the display using other scope controls, and then position it by using the horizontal and vertical position controls, so the irregularity appears within the viewing area. The remainder of the signal, of which the irregularity is only a small part, is then deflected off the screen toward the neck of the cathode-ray tube, where it cannot be viewed. At the edges of the tube, the display being deflected off the screen widens and becomes considerably blurred at the rim of the tube. This distortion is caused by the curvature and the reinforcing thickness of the glass.

4. The coarse and fine sweep frequency controls of a scope provide for changing the frequency of the sawtooth sweep generator output (fig 2-2). The coarse frequency control is generally a multiposition rotary switch used to select the desired range of sawtooth frequency by changing the forward sweep time charging capacitor. The fine frequency control is a potentiometer used to adjust the sweep time constant (TC) to obtain the exact frequency needed for suitable display.

a. Selecting different shapes of the horizontal amplifier signals is also determined by the setting of the coarse frequency control. Five or six positions of the coarse frequency control are used to cover the full frequency range of the internal sawtooth sweep generator.

b. Sinewave signals are widely used for time base sweep applications. Such signals are easily obtained from the 60-Hz power source within the scope. The sawtooth sweep generator is disabled by the coarse frequency control when either the line sweep function or the direct function is selected.

5. With the fine frequency control and the coarse frequency control, you can select the time base required to display as many cycles or pulses as desired to view the waveform. Except for markings which aid in estimating some previous position, the fine frequency control is not calibrated because the time base frequency is only used as a means of obtaining a convenient display.

6. You can easily determine the frequency of the time base generator by injecting a known frequency into the vertical amplifier and manipulating the coarse and fine frequency controls for a stationary pattern of one cycle. If the injected signal is a 60-Hz sinewave, one sinewave lasting 1/60 of a second is displayed by one sawtooth lasting for 1/60 of a second. Therefore, the frequency of the time base generator is also 60 Hz and is a 1-to-1 frequency ratio, as shown in Figure 2-6.

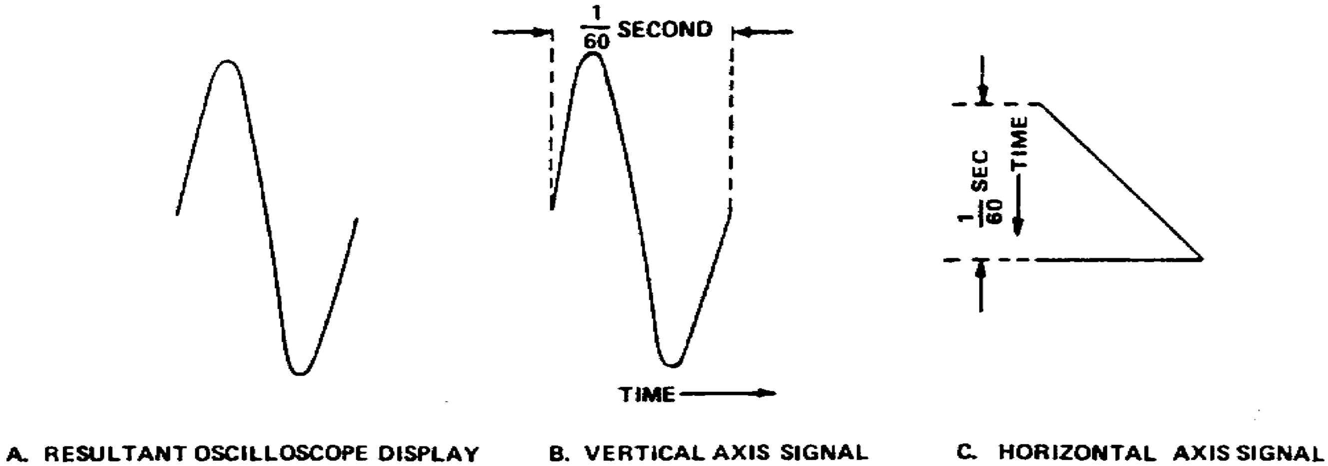


Figure 2-6. Sweep frequency equals test signal frequency

7. If the pattern is not stationary, the method described is not valid and cannot be used with accuracy. It is easy to stop a scope waveform display by using these controls if the frequency of the waveform under investigation is within the frequency limits of the scope.

8. Now let's consider a couple of sawtooth sweep frequencies that are lower than the frequency of the waveform applied to the vertical input terminals.

a. Consider an input sinewave signal with a frequency of 60 Hz, and the resultant stationary display on the scope showing two complete cycles of the input waveform for one sweep of the time base generator. In this case the time base sweep is slow enough to display two cycles of the input wave, each one lasting 1/60th of a second. The sweep time is now a total of 2/60 second (30 Hz)(fig 2-7).

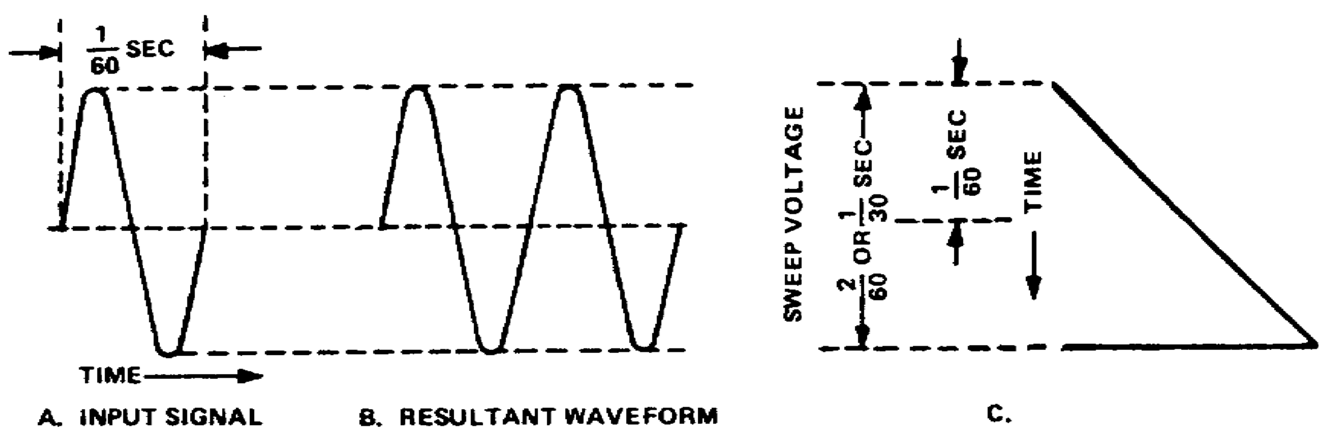


Figure 2-7. Sweep frequency lower than test signal frequency

b. Consider a sinewave input signal of 1500 Hz. The resultant scope display is adjusted until a stationary pattern of three complete cycles is observed for one sweep of the time base generator. The sweep is now displaying three cycles, with each cycle lasting 1/1500 second, and there are 500 sweeps per second.

c. When the display includes one or more complete cycles of an input waveform, whether completely stationary or not, the frequency of the time base generator is equal to or lower than that of the input waveform. In these cases where the display is adjusted for a stationary pattern, the frequency of the time base generator may be calculated by dividing the input frequency by the number of complete cycles displayed.

9. The synchronizing control provides for injecting a portion of the signal being amplified in the vertical section into the time base generator to produce a stationary waveform display. Throughout this discussion about time base sweep controls, we have emphasized the stationary display. To obtain a stationary display, the vertical amplifier input and the horizontal amplifier output have a whole-number frequency ratio and an in-phase relationship.

10. The synchronizing control potentiometer is used to inject as much of the synchronizing signal as needed to produce a stationary display pattern. The adjustment of this control is not critical, but an excessive synchronizing signal can severely distort the observed signal due to erratic functioning of the time base generator.

a. When there is no synchronizing waveform injected into the time base generator, the generator initiates a sweep when the potential on the plate is equal to the ionizing potential of the generator tube. The resulting sweep is free running under these conditions because the sweep rate is governed by the frequency-determining network of the generator. The display obtained may appear as a variety of constantly changing patterns, depending upon the frequency of the generator with respect to the waveform present in the vertical amplifier.

b. If the synchronizing control is advanced too far, the amplitude of the synchronizing signal produces a distorted sweep signal. The display obtained is undesirable because it is difficult to visualize the type of signal applied at the vertical input terminal. However, the pattern remains stationary, being continuously displayed as a single trace until corrective action is taken.

c. The synchronizing signal is often injected directly into the time base generator from a source external to the scope. Its use is dependent chiefly upon the type of signal undergoing observation and is especially useful for initiating triggered sweeps.

Learning Event 3:
DESCRIBE THE CHARACTERISTICS OF THE 453 OSCILLOSCOPE

1. One of the first things to observe concerning the 453 oscilloscope is its dual-channel capability. That is, you can apply two signals to the scope and can present the two signals at the same time or separately.

2. The vertical deflection system has a frequency response from DC to 50 MHz. Frequency response means the frequency over which the scope amplifies all frequencies uniformly. Another characteristic of the vertical deflection system is the deflection factor, expressed as the voltage required to produce a unit deflection on the CRT screen. The deflection accuracy of this scope is -+ .3 percent of the indicated deflection. When channel 1 and channel 2 are cascaded by using an external cable, they can provide a 1-millivolt deflection factor, the volts/div switch on both channels must be set to 5 mV.

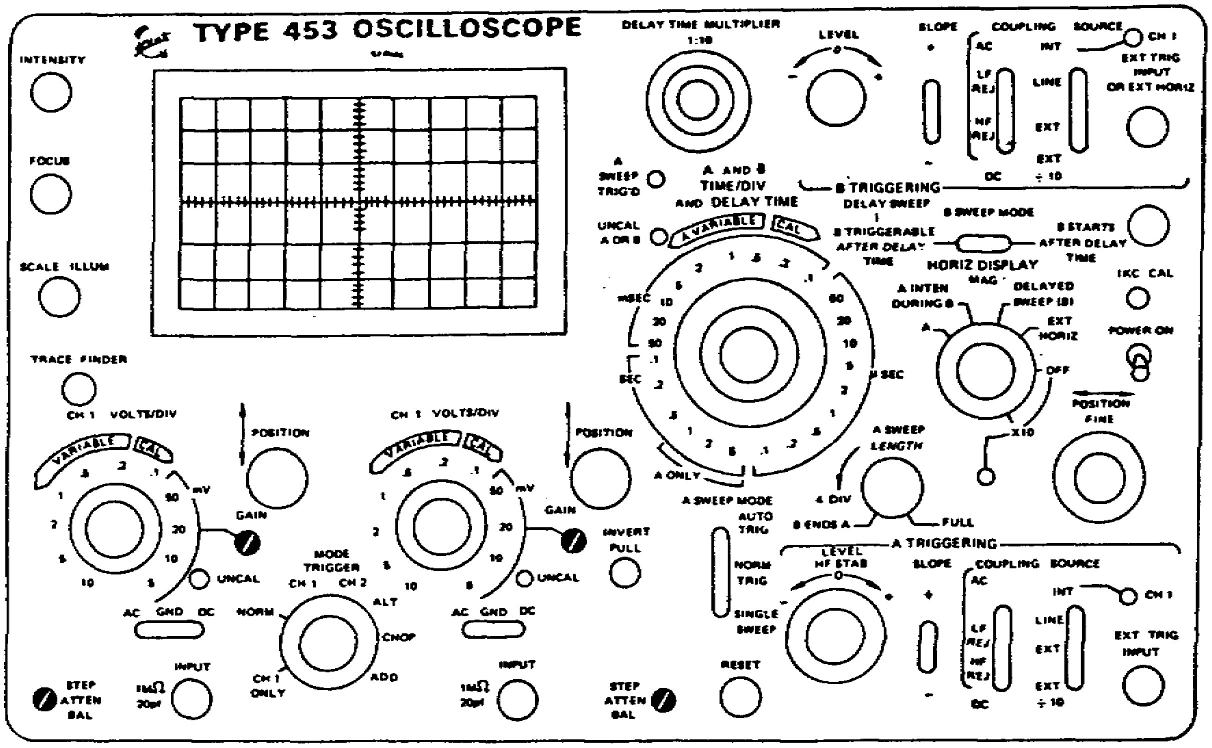
3. The 453 scope can also measure risetime accurately. By properly using the 20-mV to 10-V per division switches, you can measure risetime with accuracy to within 6.7 nanoseconds on each channel. Stable triggering is provided over the full range of vertical frequency response by the trigger circuits. Triggers are used to start the sweep generator.

4. The horizontal sweep system provides sweep rates from 0.1 microsecond per division to 5 seconds per division in 24 calibrated steps. Under normal operating conditions, the sweep accuracy is +/-3 percent of the indicated sweep rate. Using the sweep magnified characteristics, each sweep rate can be increased to 10 times the indicated sweep rate by expanding the center division of display. The calibrated delay time characteristic gives a sweep delay that is continuous from 50 seconds to 1 microsecond.

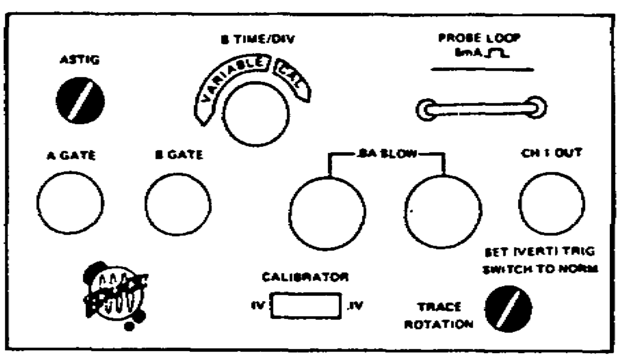
5. As we have already pointed out, this scope performs in a variety of environmental conditions. The instrument performs satisfactorily over a temperature range of -15 C to +55 C degrees. A fan in the rear of the scope blows air through the instrument. If the internal temperature exceeds a safe operating level, an automatic resetting thermal cutoff cuts off the instrument power. The power automatically comes back on when the temperature returns to a safe level. The warmup time for a given accuracy is 20 minutes. All of the characteristics of this instrument are listed in the applicable technical manual or technical order.

6. Front panel, left side controls for the 453 scope. The controls located to the left of the screen in Figure 2-8 control the signal display on the screen. Keep in mind the purpose of intensity, focus, scale illumination, trace finder, mode, trigger, volts/division, step attenuator balance, vertical position, and AC-GND-DC controls.

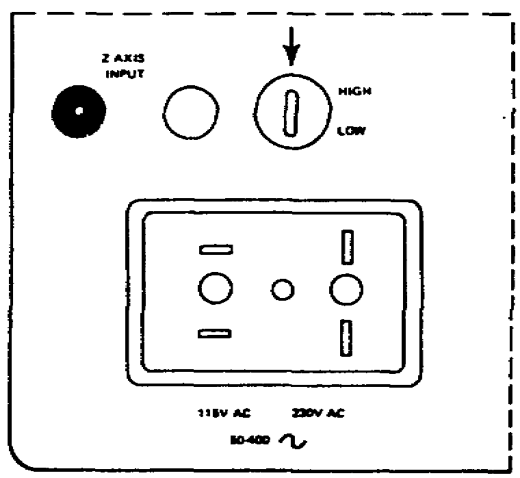
7. The intensity control (fig 2-8a) controls the brightness of the display. When setting the intensity control, do not set the control for more brightness than is necessary to provide a satisfactory display. Too much intensity can damage the CRT phosphor.



a. Front panel



b. Side panel



c. Rear panel

Figure 2-8. Type 453 oscilloscope

8. Adjust the focus control (fig 2-8a) to obtain a clear, well-defined image on the screen. The focus of the display may be affected by setting the intensity control. Therefore, it may be necessary to adjust the focus control a small amount when the intensity control is changed.

9. The scale illumination control (fig 2-8a) is directly under the focus control. Adjust the scale illumination control so that the graticule lines are illuminated to desired brightness.

10. The trace finder control (fig 2-8a) is used to locate a display which exceeds the scan of the display area. When you press the trace finder button, the horizontal and vertical deflection is reduced, and the display is compressed within the graticule area. After locating the display, center it by adjusting the position controls.

11. There are five modes of operation that can be selected by the mode switch. They are channel 1, channel 2, alternate, chopped, and algebraic addition (fig 2-8a). When either channel 1 or channel 2 is selected, only the signal that is applied to the respective channel is displayed. The other three modes are for dual-trace operations.

a. When the alternate position is selected, the signal applied to one channel is presented for one cycle of the horizontal sweep voltage. Then the signal applied to the other channel is presented for the next cycle of the sweep voltage. The scope CRT coating retains the image of the first channel's presentation during the time the second channel makes its presentation when the sweep rates are sufficient. Although all sweep rates can be used in the alternate mode, alternate mode switching becomes visually perceptible at slower sweep speeds. The chopped mode is preferred at sweep rates below about 0.5 millisecond per division.

b. In the chopped mode the signals applied to the two channels are electronically switched on and off to produce a display. The switching rate is about 500Hz. A segment of the signal displayed from channel 1 is displayed for about one microsecond; then a segment of the next signal from channel 2 is displayed for the next microsecond. For most applications the chopped mode provides the best display at sweep rates slower than about 0.5 millisecond or when dual-trace single-shot phenomena are to be displayed. At faster sweep rates the chopped switching becomes obvious and interferes with the display.

c. The third dual-trace operation is the algebraic addition mode. When the algebraic addition mode is selected, the signals from channel 1 and channel 2 are algebraically added, and the algebraic sum is displayed on the CRT. If you want to improve the signal-to-noise ratio, you can eliminate part of the noise by using this mode to display the difference of two signals. You can do this in the algebraic addition mode by following these steps.

(1) Apply the signal that contains the desired and undesired signals to channel 1 input and apply the signal containing only the undesired signal to channel 2.

(2) Invert the signal applied to channel 2 by pulling the invert switch located with vertical channel 2 controls.

(3) When the undesired components of both signals, opposite in polarity, are added algebraically, adjust the channel 2 volts-per-division switch and variable control to reduce the undesired signal.

12. The trigger control is a dial concentric with the mode switch (fig 2-8a). The trigger control selects the source of internal triggering signal from the vertical system. When the trigger control is set to normal, the sweep circuits are triggered from the displayed channel(s). Also, the channel 1 signal is available at channel 1 output connector, which is located on the side panel (fig 2-8b). If the trigger control is set to the channel 1 only position, the sweep circuits are triggered only from a signal on channel 1. No signal is available at the channel 1 output connector.

13. Since the vertical controls of channel 1 (fig 2-8a) are duplicated in channel 2, we will cover only the vertical controls of channel 1. Keep in mind that channel 2 controls perform the same function.

a. Locate the channel 1 volts-per-division switch on the left side of the front panel under the trace finder button. When you select a position on the volts/division control, you select a specific combination of frequency-compensated attenuator networks through which the applied signal must pass.

b. Notice that a smaller variable control is concentric with the volts/division control. To be specific, the variable control provides a continuously variable deflection factor to at least 2.5 times the setting of the volts/division switch. Always turn the variable control clockwise to the calibrated position when you adjust the vertical gain of that channel.

c. To check the vertical gain of the channel, the volts/division switch is set to 20 mV, and a 0.1-volt signal from the calibrator is connected to the channel’s input jack. If the vertical deflection does not measure exactly 5 divisions, turn the gain adjustment to obtain exactly 5 divisions of deflection. The gain should be set with the volts/division switch set to 20 mV.

14. The step attenuator balance control (fig 2-8a). You should make the gain adjustment before making the step attenuator check.

a. To check the step attenuator balance, set the AC-GND-DC switch to GND, and set the A sweep mode switch to automatic trigger to produce a free-running sweep.

b. When a vertical shift in the trace occurs as you change the volts/division switch from 20 mV to 4 mV, an adjustment is required.

c. To make the step attenuator balance adjustment, position the trace to the graticule centerline when the volts/division switch is set to 20 mV. Then rotate the volts/division switch to 5 mV and adjust the step attenuator balance to return the trace to the graticule centerline. When the step attenuator balance is properly adjusted, the trace does not shift when the volts/division switch is changed from 20mV to 5mV.

15. The vertical positioning control, which is located to the right of the volts/division switch (fig 2-8a), controls the vertical position of the trace.

16. The AC-GND-DC switch (fig 2-8a) is located below the volts/division control. It is used to select the method of coupling the input signal to the grid of the input amplifier. When DC position is selected, all components of the input signal are passed to the input amplifier. DC coupling can be used for most applications. However, with the DC component, it is better to select the AC position.

a. In the AC position the DC component of the input signal is blocked by a capacitor in the input circuit. The low frequency limit in the AC position is about 1.6 Hz. Although you can use the AC position for frequencies between 1.6 Hz and 16 Hz, use the DC position for signals below 16 Hz because they are attenuated by AC coupling. Also, you can expect some low frequency distortion at these low frequencies in the AC position.

b. When you select the GND position, a DC ground reference is established at the input circuit. The grid of the input tube is at ground potential. However, the input signal is not grounded. You may obtain a reference without removing the applied signal from the input connector (fig 2-8b).

Lesson 2
PRACTICE EXERCISE

1. What class of operation does the horizontal deflection amplifier operate under?

   a. Class A
   b. Class A & B
   c. Class B
   d. Class C

2. What can you use the oscilloscope for other than reading waveforms?

   a. Waveform monitor
   b. Peak to peak voltmeter
   c. Vector scope
   d. Ohmmeter

3. What must you adjust to obtain the exact frequency for a sweep time constant?

   a. Course frequency adjust
   b. Sawtooth sweep generator
   c. Fine frequency adjust
   d. Base frequency

4. For the 453 oscilloscope, how closely can the risetime of a signal be measured?

   a. +/- 3 percent
   b. 6.7 nanoseconds
   c. One millivolt
   d. 15.5 nanoseconds

5. How many modes of operation does the 453 oscilloscope have?

   a. 3 modes
   b. 4 modes
   c. 5 modes
   d. 7 modes

LESSON 3
DESCRIBE THE APPLICATION OF GRATING GENERATOR, DOT BAR GENERATOR, AND VIDEO SWEEP MARKER GENERATOR

TASK

Describe the theory and terminology of maintenance with the application of video sweep marker generator, grating generator, and dot bar generator.

CONDITIONS: Given information and illustrations about terms and theory relating to the application of video sweep marker generator, grating generator, and dot bar generator.

STANDARDS

Demonstrate competency of the task, skills and knowledge by correctly responding to 80 percent of the multiple-choice test covering theory and terminology of the application of video sweep marker generator, grating generator, and dot bar generator.

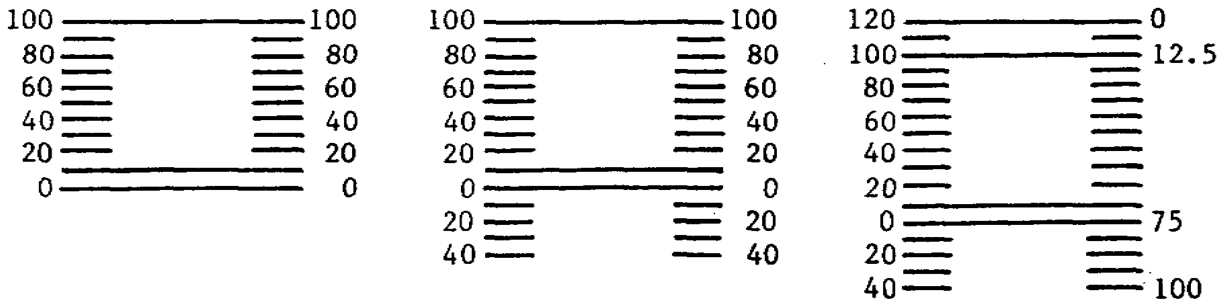
REFERENCES

None

Learning Event 1:
DESCRIBE THE USE AND PURPOSE OF A WAVEFORM MONITOR

1. The waveform monitor is a specialized oscilloscope which provides detailed or varied video information. It can present many video combinations from a complete television frame to a single segment of a desired line or even a single pulse shape or edge. Consequently, the waveform monitor is much more adaptable to television testing than the average scope. Its uses are much more suitable for system tests than for individual circuit or circuit component troubleshooting.

2. The major difference between the waveform monitor and the oscilloscope is the measuring scale. Examples of three of the scales for waveform monitors are shown in Figure 3-1.



No. 1	No. 2	No. 3
For use at camera control unit when sync is not inserted in this unit	Monitoring scale for use on any waveform monitor where sync is present in the signal	Used where desired to relate levels to depth of modulation of video carrier
Reference White - 100 Reference Black - 10 Blanking Level - 0 (Setup Value 10%)	Reference White - 100 Reference Black - 10 Blanking Level - 0 Sync Peaks - 40	Reference White - 12.5% Reference Black - 67.5% Blanking Level - 75% Sync Peaks - 100% Zero carrier (should never occur in practice) is set at 120 on scale

Figure 3-1. Video level measuring scales

a. These scales were designed to present a standard video level of 1 volt peak-to-peak. The scales are called Institute of Electrical and Electronics Engineers (IEEE) or Institute of Radio Engineers (IRE) scales. They are divided into 140 units which equal 1-volt peak-to-peak of composite video.

b. This 1-volt signal contains 0.714 volt video information (0 to 1000 units) and 0.286 volt sync (0 to -40 units).

3. The three scales in figure 3-1 illustrate the various points to be monitored in a system. Use operating scale No. 1 for points in the system where sync is not added. Operating Scale No. 2 is used in the system to measure composite signal (sync added). Operating Scale No. 3 is used at transmitter locations to relate IEEE units to depth of modulation.

Learning Event 2:
DESCRIBE THE USES OF A SIGNAL GENERATOR

1. A signal generator is a test device which generates an alternating voltage signal suitable for test purposes. It is, in effect, a small radio transmitter generating a signal of any desired frequency. The signal may be either modulated or unmodulated and is used for the following checks or tests:

a. Alignment of tuned circuits, sensitivity measurements, and approximate frequency measurements.

b. For frequency measurements, its use is limited because it is not a frequency meter and cannot be used as a frequency standard.

2. The signal generator is used primarily in the alignment of tuned circuits. A signal generator is classified according to its frequency and is one of two types: audio frequency or radio frequency.

a. Audio frequency generators produce signals with a frequency range from 20 Hz to 20kHz.

b. Radio-frequency generators produce signals covering a range of frequencies from 10 kHz to 10 GHz. Many radio-frequency generators have audio outputs separately available through front panel jacks. These outputs are normally 100 and 400 Hz.

3. When using the generator, the output test signal is coupled into the circuit being tested, and its progress through the equipment is traced by the use of high-impedance indicating devices such as vacuum-tube voltmeters or scopes. In many signal generators, calibrated networks of resistors, called attenuators, are provided. These are used to regulate the voltage of the output signal and also provide correct impedance values for matching the input impedance of the circuit under testing. Accurately calibrated attenuators are used, because the signal strength must be regulated to avoid overloading the circuit receiving the signal.

4. There are many types of signal generators. They may be classified roughly by frequency into audio signal generators, video signal generators, radio frequency generators, frequency-modulated RF generators, and special types which combine all of these frequency ranges.

5. Audio signal generators.

a. Audio signal generators produce stable audio-frequency signals used for testing audio equipment. Video signal generators produce signals which include the audio range and extend considerably further into the RF range. These generators are used in testing video amplifiers and other wideband circuits.

b. In both audio and video generators, the major components include a power supply, an oscillator, one or more amplifiers, and an output control. Voltage regulation circuits are necessary to ensure stability of the oscillator in the generators which derive power from 115-volt AC sources. In portable generators, battery power supplies are usually used, and these require no voltage regulation.

c. In the audio and video generators of the beat-frequency type, the output frequency is produced by mixing the signals of two radio frequency oscillators, one of which is fixed in frequency and the other variable. The difference in frequency of the two is equal to the desired audio or video frequency.

(1) Audio signal generators often include RC oscillators in which the audio frequency is directly produced. In these a resistance-capacitance circuit is the frequency-determining part of the oscillator. The frequency varies when either the resistance or the capacitance is changed in value.

(2) In commercial generators, however, the capacitance alone is often chosen as the variable element. The change in frequency which can be produced by this method is limited, and it is usually necessary to cover the entire range of the generator in steps. This is accomplished by providing several RC circuits, each corresponding to a portion of the entire range of frequency values. The circuits in the oscillator are switched one at a time to give the desired portion of the audio range.

d. The amplifier section of the block diagram (fig 3-2) usually consists of a voltage amplifier and one or two power amplifiers. These are coupled by means of RC networks, and the output of the final power amplifier is often coupled to the attenuator, or output control, by means of an output transformer.

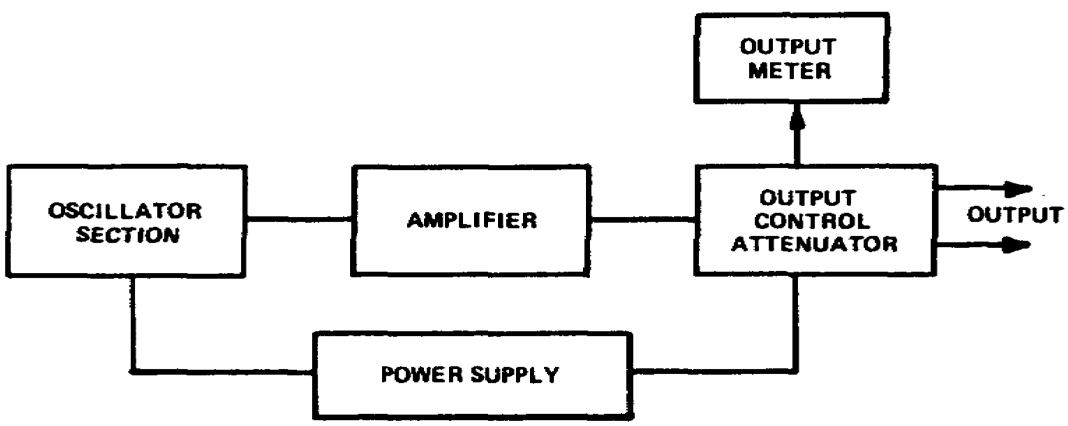


Figure 3-2. Block diagram of audio or video signal generator

e. The output control section provides a means of matching the output signal to the input of the equipment under test and regulating the amplitude of the signal.

6. Radio frequency (RF) signal generators.

a. A typical radio frequency signal generator contains, in addition to the necessary power supply, three main sections; an oscillator circuit, a modulator, and an output control circuit. The internal modulator modulates the radio frequency signal of the oscillator. In addition, most RF generators are provided with connections through which an external source of modulation of any desired waveform may be applied to the generated signal. Metal shielding surrounds the unit to prevent the entrance of signals from the oscillator into the circuit under test by means other than through the output circuit of the generator.

b. A block diagram of a representative RF signal generator is shown in Figure 3-3. The function of the oscillator stage is to produce a signal which can be accurately set in frequency at any point in the range of the generator. The type of oscillator circuit used depends on the range of the frequencies for which the generator is designed. In low frequency signal generators, the resonating circuit consists of a group of coils combined with a variable capacitor. One of the coils has a selector switch attached to the capacitor to provide an LC circuit that has the correct range of resonant frequencies.

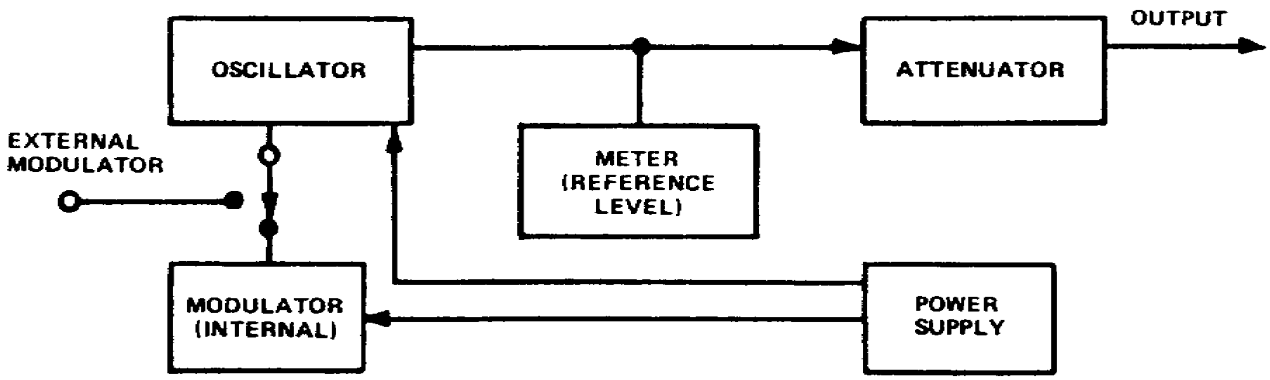


Figure 3-3. Block diagram of RF signal generator

c. The function of the modulating circuit is the production of audio (or video) voltage which can be superimposed on the RF signal produced by the oscillator. The modulating signal may be provided by an audio oscillator within the generator, or it may be derived from an external source. In some signal generators, either of these methods of modulation may be used. In addition, a means of disabling the modulator section is used whereby the pure unmodulated signal from the oscillator can be used when it is desired.

d. The type of modulation used depends on the application of the particular signal generator. The modulating voltage may be either a sine wave, a square wave, or pulse of varying duration. In some specialized generators, provision is made for pulse modulation in which the RF signal can be pulsed over a wide range of repetition rates and at various pulse widths.

e. Usually the output of the generator contains a calibrated attenuator and often an output level meter. The output level meter gives an indication of, and permits control of, the output voltage of the generator by indicating arbitrary values of output readings in tenths through the value of one. The attenuator selects the amount of this output. The attenuator, a group of resistors forming a voltage-dropping circuit, is controlled by a knob which is calibrated in microvolts. When the control element is adjusted so the output meter reads unity (1.0), the reading on the attenuator knob gives the exact value of the output in microvolts. If output voltage is desired at a lower value, the control is varied until the meter indicates some decimal value less than one, and this decimal is multiplied by the attenuator reading to give the output in microvolts.

7. Frequency-modulated RF signal generators. Frequency-modulated RF signal generators are widely used for testing frequency-modulated receivers and for visual alignment of AM receivers. A frequency-modulated signal is an alternating voltage in which the frequency varies above and below a given center frequency value. The overall frequency change is called the frequency swing.

Learning Event 3:
DETERMINE THE DIFFERENT MODES OF AN ELECTRONIC COUNTER

1. An electronic counter is used for the comparison of an unknown frequency or time interval with a known frequency or time interval. The counter's logic is designed to present this information in an easy-to-read numerical display. The accuracy of this measurement depends on the stability of the known frequency. This known frequency is obtained from the internal oscillator of the counter.

2. The logic control interconnects the proper circuit, selects the proper measurement units for display, and starts the measurement cycle.

a. An electronic counter can be operated in the totalizing mode with the main gate flip-flop controlled by the manual start-stop switch illustrated in Figure 3-4. With the switch at start, the decimal counter assemblies totalize the input pulses until the main gate is closed by changing the switch to stop. The display on the counter shows the pulses received during the interval between manual start and manual stop.

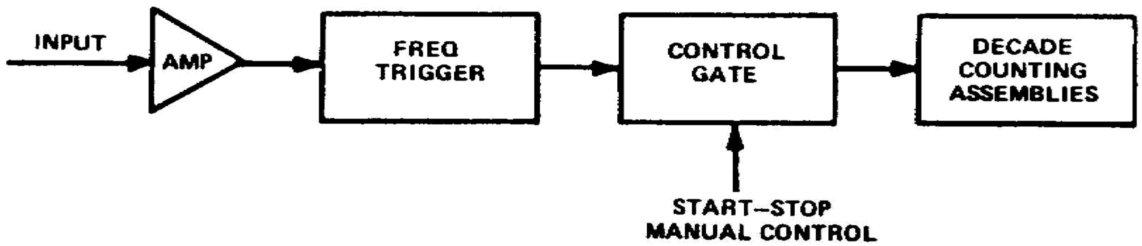


Figure 3-4. Electronic counter totalizing method, block diagram

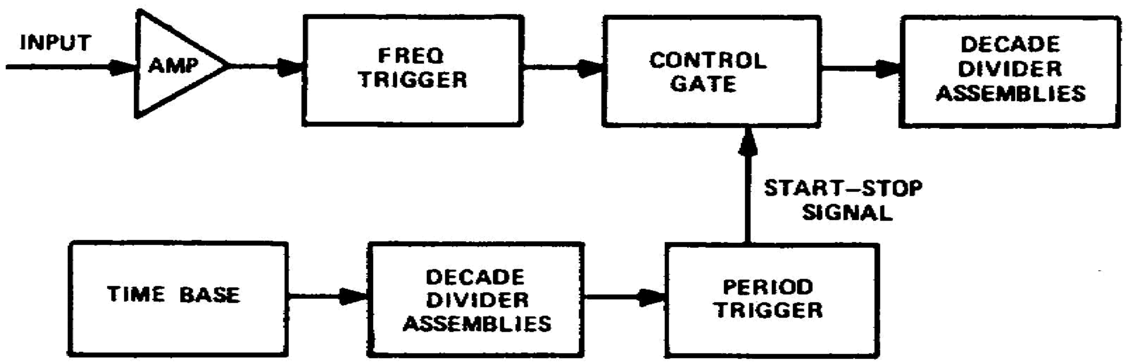


Figure 3-5. Electronic counter frequency measurement, block diagram

b. Frequency measurements. The input signal is first applied to a signal shaper that changes the input signal to uniform pulses. The output of the shaper is then applied to the decade counting assemblies, often passing through a gate which is controlled by the time base of the counter, as shown in Figure 3-5.

c. The number of pulses for the desired period of time, totalized in the decade-counting assemblies, represents the frequency of the input signal. The counted frequency is shown on a numerical readout with a positioned decimal point. This reading is held until a new sample is taken. The sample rate control decides the display time of the frequency measurement being performed. The sample rate control also starts counter reset and the next measurement cycle. The time base selector switch determines the gating interval, positions the decimal point, and selects the proper measurement units.

d. The electronic counter makes periodic measurements with its function arranged (fig 3-6). An unknown input signal controls the gate time. The time base frequency is counted in the decade-counting assemblies. The input shaping circuit uses the positive-going zero axis crossing of successive cycles as triggers for opening and closing the gate.

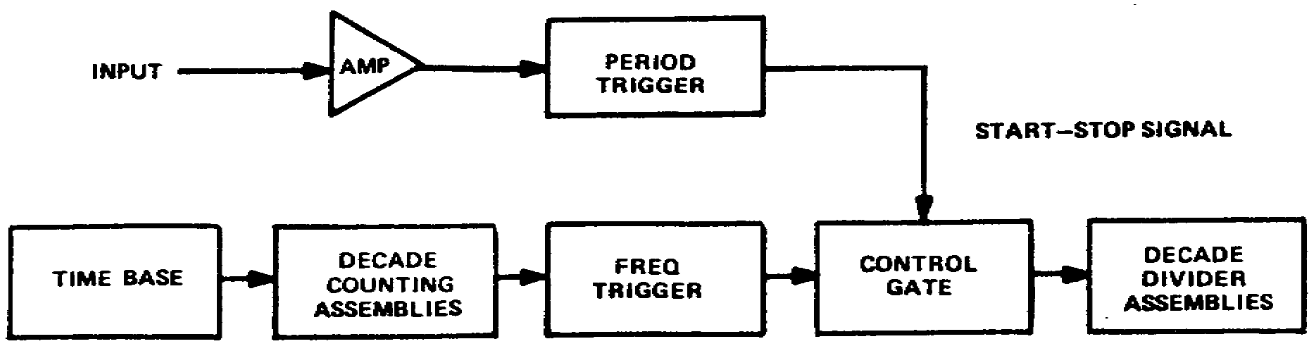


Figure 3-6. Electronic counter period measurement, block diagram

(1) A periodic measurement gives a more accurate measurement of an unknown low frequency signal because of increased resolution. A frequency measurement of 100 hertz on a counter with a 10-second gate time will be displayed as 0000.1000 kilohertz (kHz).

(2) When using the same counter, a single period measurement of 100 Hz with 10 megahertz (MHz) as the counter frequency would be displayed as 0010000.0 microseconds on the counter. The resolution is increased by a factor of 100.

e. The ratio of two frequencies is obtained by using the lower frequency signal for gate control and having the higher frequency signal counted (fig 3-7). If you use the proper transducers, ratio measurements may be applied to any phenomena, providing the phenomena can be represented by sine waves or pulses. Measurements that can be made with the ratio method are clutch slippage, gear ratios, and frequency divider operations.

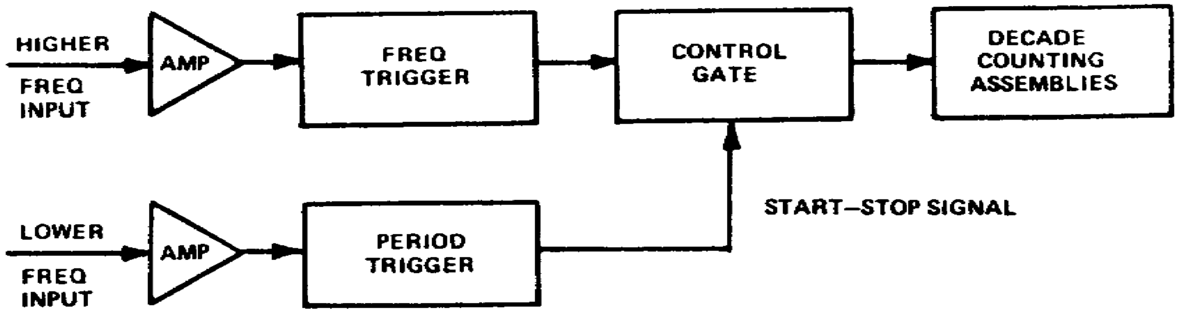


Figure 3-7. Electronic counter ratio measurement, block diagram

f. If you use a preset counter, or a counter with a preset plug-in unit, you may make frequency measurements by proper selections of the gate time. A plug-in unit may be set to a gate time of 600 milliseconds. This setting causes an input from a 100-pulse-per revolution tachometer to be displayed directly in revolutions per minute.

g. Time interval measurements are similar to period measurements. The only exception is that the trigger points on the single waveform or waveforms are adjustable, and when the com-sep switch is placed in COM position, measurements may be made from one point on a waveform to another point on the same waveform (fig 3-8). Triggering polarity, slope, and amplitude are selected for each channel separately. The time interval is displayed in microseconds, milliseconds, or seconds.

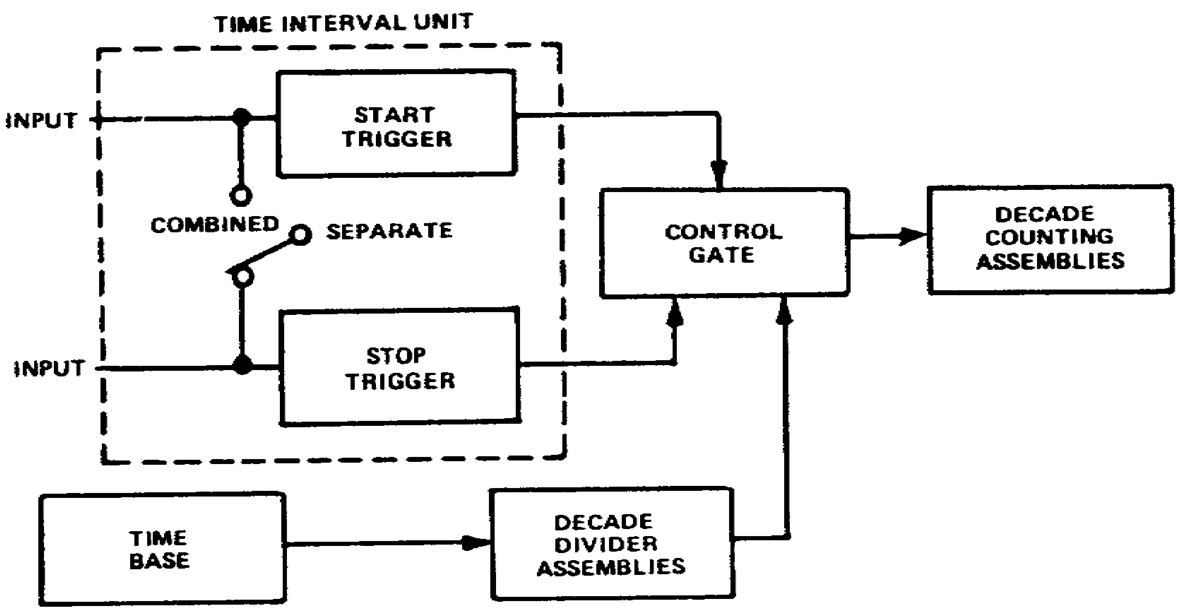


Figure 3-8. Electronic counter time interval measurement, block diagram

(1) A time interval counter that can measure extremely short time intervals is available.

(2) A 1-MHz external frequency standard is multiplied to 100 MHz in order to obtain 10-nanosecond time increments as the counted frequency, resulting in good resolution.

3. Precise high-frequency measurements are possible because of several innovations in quartz oscillator crystal design. These have resulted in superior electronic counter time bases. Ambient temperature affects the frequency by being outside ranges of -20 degrees to +50 degrees C. The accuracy of the counter is limited by the time base oscillator stability because this oscillator circuit furnishes the definitive time information for a measurement. The time base must be calibrated periodically, because the drift rate causes a cumulative deviation in frequency which can result in measurement error. The accuracy of precision quartz oscillators is usually expressed as long-term stability. Short-term stability refers to changes in average frequency over a time sufficiently short so that the change in frequency due to long-term effects is negligible.

4. There are four methods of extending the digital frequency measuring capability of electronic counters. These methods are the prescaling method, the heterodyne method, the harmonic generator, and the transfer oscillator method. Each of the four methods is explained, and the basic principles of operation are shown in block diagram.

a. In the prescaling method, (fig 3-9) the input signal is amplified and scaled by a decade in order to divide the input frequency by a factor of 10. The input to the counter from the prescaler is now within the direct measuring range of the counter. For example, if the prescaler is used in conjunction with a 10-MHz electronic counter, then the direct measuring range of the counter is extended to 100 MHz.

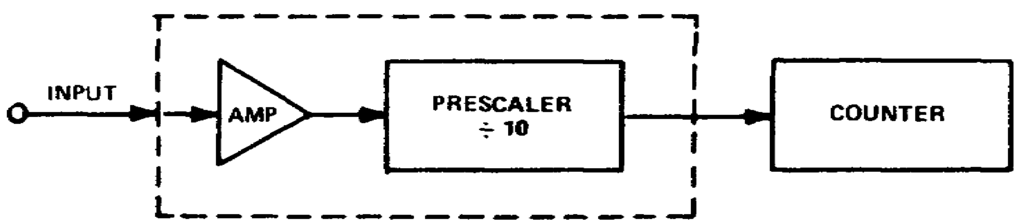


Figure 3-9. Electronic counter prescaling method, block diagram

b. The heterodyne method is a high frequency measuring method based on subtracting known reference frequencies until the different frequency is within the direct measuring range of the electronic counter.

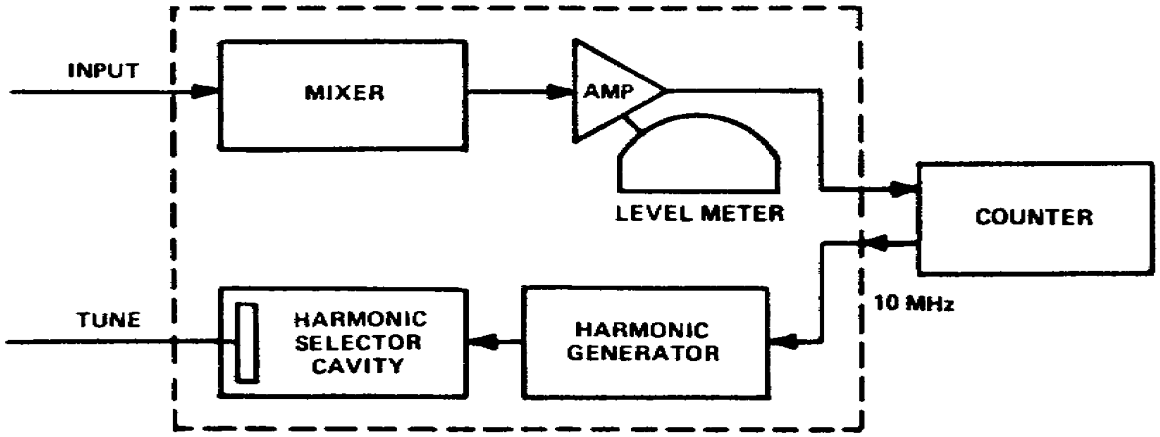


Figure 3-10. Electronic counter heterodyne method, block diagram

c. A harmonic generator produces all harmonics of 10 MHz. A harmonic selector cavity is manually tuned until the selected harmonic, mixed with the input, produces a different frequency that is fed through an amplifier to the counter. A level meter indicates when the harmonic selector reaches the proper reference frequency. To find the frequency being measured, add the reference frequencies to the electronic counter display. This addition usually involves nothing more than placing one or two digits before the counter reading.

d. The transfer oscillator method (fig 3-11) provides an extremely wide measuring range with counter accuracy. In this method, a transfer oscillator is used in conjunction with a 50-MHz electronic counter. The transfer oscillator method compares harmonics of a fundamental frequency with an unknown high frequency.

(1) When you are measuring, adjust the fundamental frequency to the point where one odd harmonics has the same frequency as the input signal. This is accomplished by beating harmonics against the input signal in a mixer and varying the fundamental frequency until the difference frequency is zero. The results are observed on a built-in scope.

(2) The counter can read out the unknown frequency which equals the fundamental frequency multiplied by the harmonic number. The proper harmonic number, selected by the front panel harmonic preset switches, automatically expands the counting period of the counter. This expansion results in a direct presentation of the input frequency in the readout of the counter.

(3) The transfer scope includes a phase lock that is designed to synchronize itself with the input signal. Changing the transfer oscillator frequency to maintain a precise 1-MHz beat frequency compensates for any frequency change in either the input signal or the transfer scope.

5. The automatic method (fig 3-12) makes it possible to obtain instantaneous direct readings of unknown microwave inputs.

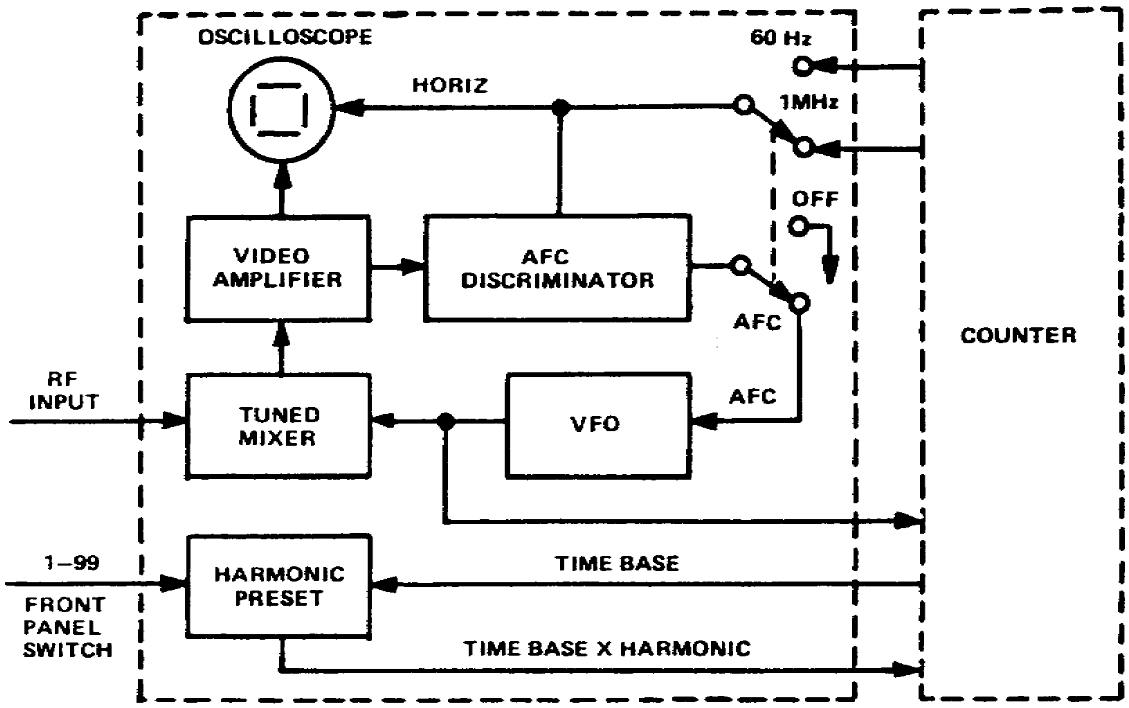


Figure 3-11. Electronic counter transfer oscillator method, block diagram

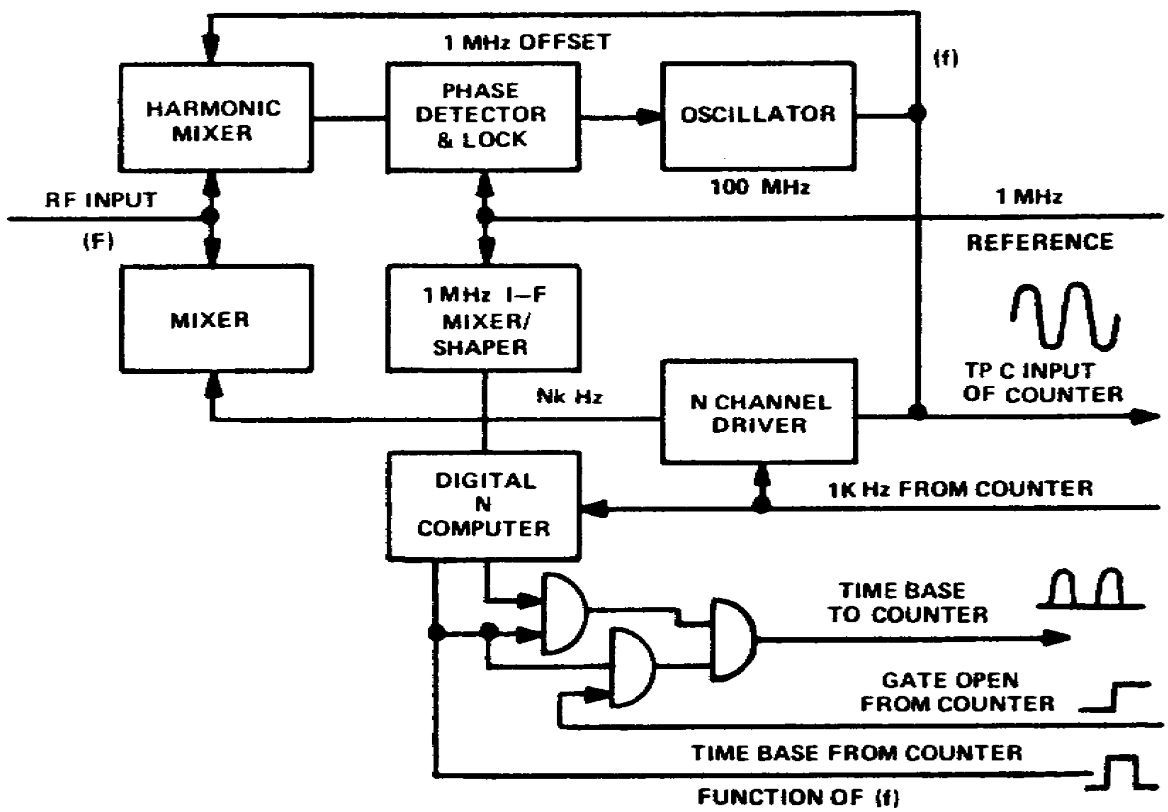


Figure 3-12. Electronic counter automatic method, block diagram

a. An unknown signal (F) is fed into a harmonic mixer. A swept oscillator frequency (f) is applied to a mixer, and harmonics are generated and mixed with the input signal. A 1-MHz signal from the counter time base is used as a phase detector and locking frequency for the output signal of the mixer. This circuit phase-locks the proper harmonic (N) of the swept oscillator signal (f) with the input signal (F) at a precise 1-MHz offset.

b. The input signal (F) is also applied to a second mixer which has the same swept oscillator signal (f) but with the addition of a 1-kHz signal from the counter. When the phase detector locks the swept oscillator, the signal in this second mixer will be N (f=1kHz) which is mixed with the input frequency (f).

c. When the offset is exactly 1 MHz, then F=fN +/-1 MHz. The output of the second mixer is 1 MHz plus N kHz. The 1-MHz signal from the counter is mixed with the output of the second mixer and the resultant signal is N kHz. The mixed signal (N kHz) is then applied to a digital N computer circuit along with the 1-kHz signal from the counter.

d. This circuit then divides the N kHz by 1 kHz and the result is N pulses. The N pulses are gated in conjunction with the counter time base signal. This extension multiplies fxN +/-1 MHz so the counter can read out the unknown input frequency directly with the 1-MHz offset.

Learning Event 4:
DESCRIBE THE USES OF A SOLID STATE DEVICE TESTER

1. There are several methods for testing solid state devices. In this section we will discuss the testing of diodes and transistors using a typical oscilloscope and locally manufactured diode and transistor testers. You must fully understand the operation of the scope. If you have any doubt about the operation of the scope, review the section on scopes.

2. Most diodes and transistors can be tested for shorts and opens with a multimeter, when no solid-state tester is available. The use of a multimeter is discouraged because the meter's internal power supply can cause damage to the component under testing or other components in the circuit under testing.

3. Using a diode tester and an oscilloscope, you can easily test and compare diodes. Diode testers are commercially available. In most cases your shop will not be authorized to have any type of diode tester. You can build your own which will be extremely accurate and efficient. Figure 3-13 shows the schematic diagram of a simple diode tester, and Figure 3-14 shows the pictorial diagram. A variable transformer provides the 0- to 110-volt input. For testing most diodes a 6-VAC input is sufficient, but you must exceed the breakdown voltage when testing a zener diode. With a variable 0- to 110-volt transformer, you can adjust the input to test most zener diodes. The 6.3-VAC center tap (C/T) input to this tester (fig 3-14) is for reference only. This input must be variable to exceed the breakdown voltage of a zener diode under test.

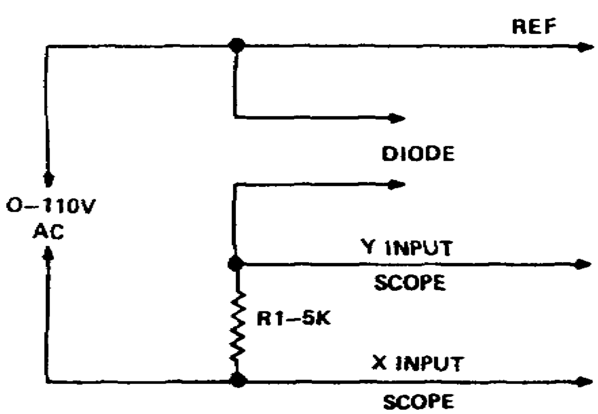


Figure 3-13. Diode tester schematic diagram

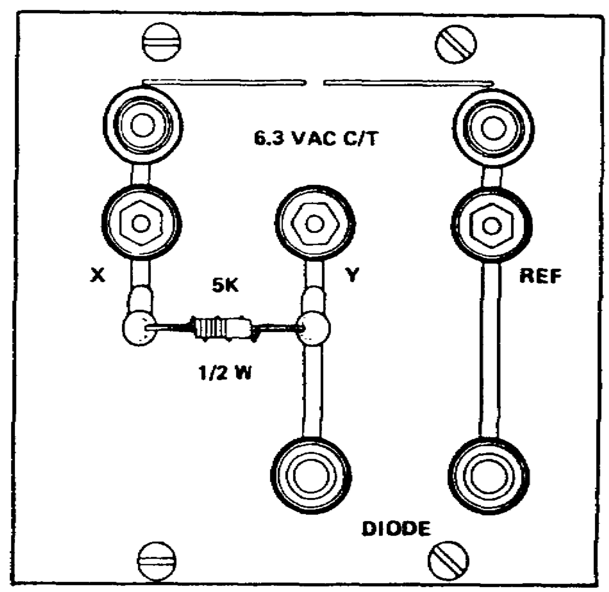


Figure 3-14. Locally manufactured diode tester

4. To test a diode, follow this procedure:

a. Connect the horizontal or sweep probe of the scope to the X terminal of the tester (fig 3-14) and adjust the display to a 2-centimeter horizontal line (common scope lead to reference).

b. Remove the X lead and connect the vertical probe of the scope to the Y terminal of the tester (fig 3-14) and adjust the vertical display on the scope to 4 centimeters by adjusting the variable AC input to the tester.

c. Reconnect the X lead as mentioned above. You should get a diagonal display on the scope as illustrated in Figure 3-15a.

d. Connect the diode between the diode terminals on the tester and compare the trace on the oscilloscope with those shown in Figure 3-15.

e. Determine the condition of the diode. By testing known good diodes you can make your own trace patterns for comparison with other diodes.

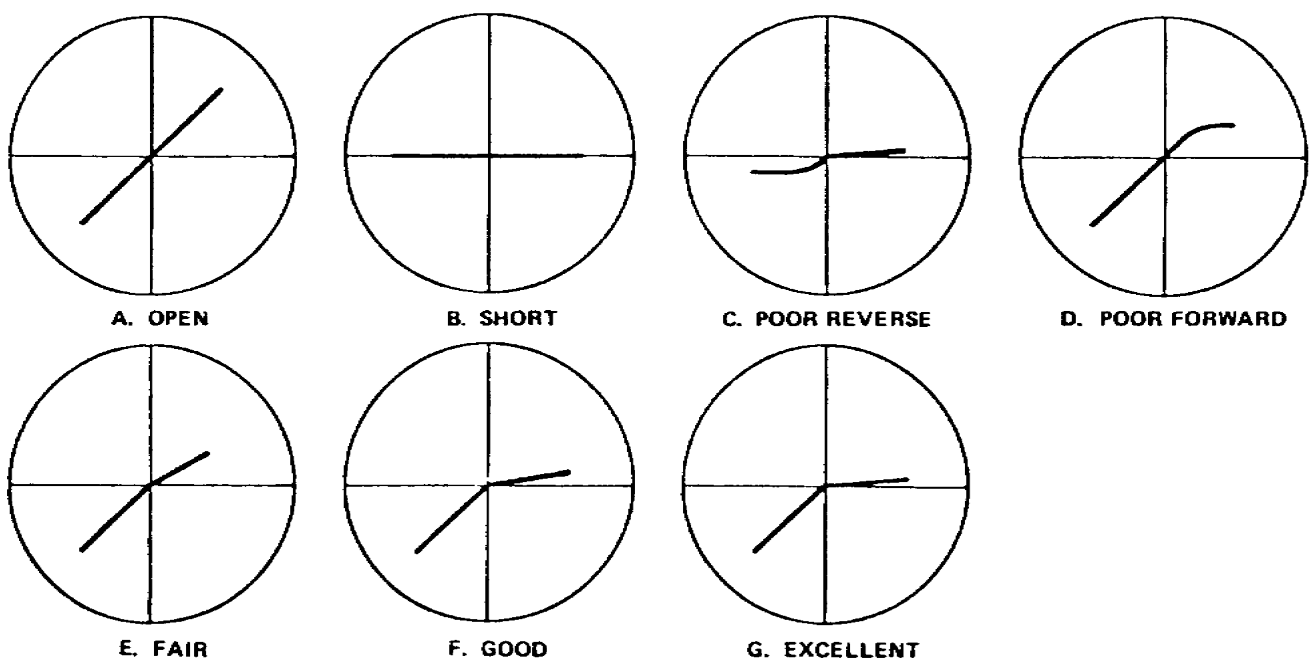


Figure 3-15. Oscilloscope traces of diodes

5. Transistors, unlike vacuum tubes, are very rugged because they can tolerate vibration and shock. Under normal operating conditions a transistor provides a long period of dependable operation. Transistors may fail when subjected to minor overloads. You can use various test methods to determine the condition of a transistor. In many cases you can substitute a transistor of known good quality for a questionable one. This method is highly accurate and sometimes expeditious. You should avoid indiscriminate substitution. When transistors are soldered into equipment, substitution is impractical because the transistor may be damaged during desoldering or soldering. In this case, it is generally desirable to test the transistor in the circuit if a tester with this capability is available.

6. Since certain fundamental characteristics are indicative of the condition of a transistor, test equipment is made to test these characteristics with the transistor either in or out of the circuit. Although triode testers are commercially available, as are diode testers, you may have to make your own. Figure 3-16 shows the schematic diagram of a typical transistor tester and Figure 3-17 shows a locally made transistor tester.

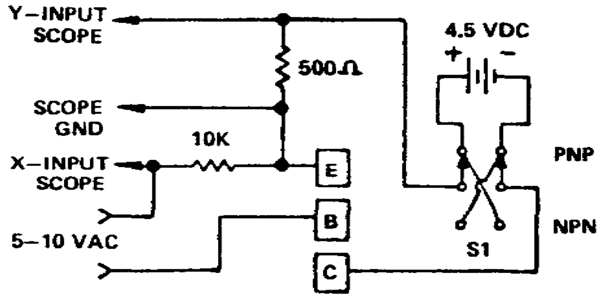


Figure 3-16. Transistor tester schematic

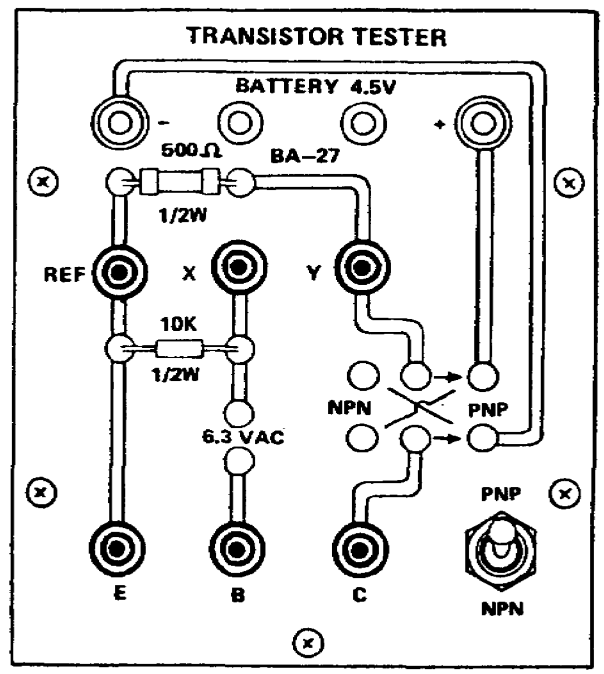


Figure 3-17. Locally manufactured transistor tester

7. By using a transistor tester and a scope you can test transistors in the same manner as you test diodes. To test a transistor connect the transistor tester to the scope, and adjust the scope as follows:

a. Connect the vertical input probe of the scope to the Y input terminal of the tester, the horizontal input probe of the scope to the X input terminal of the tester, and the common probe of the scope to the reference terminal on the tester.

b. Short E to B on the tester, and adjust the horizontal gain control on the scope until you get a 4-cm horizontal display on the scope.

c. Short E to C on the tester, and adjust the signal voltage until you get a 2-cm vertical display.

d. Connect a transistor to the tester (emitter to E, base to B, and collector to C).

8. Determine the condition of the transistor under testing by comparing your trace with the traces illustrated in Figures 3-18, 3-19, and 3-20. As in testing diodes, you can test known good transistors and make your own trace patterns to compare with other transistors.

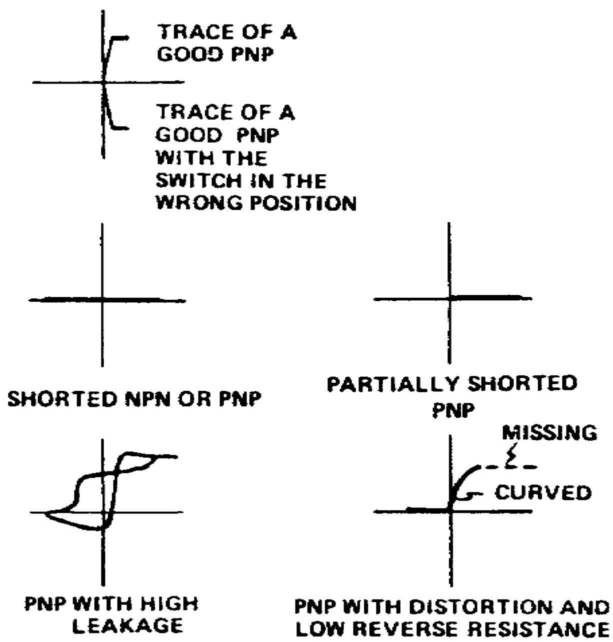


Figure 3-18. Oscilloscope traces of PNP transistors

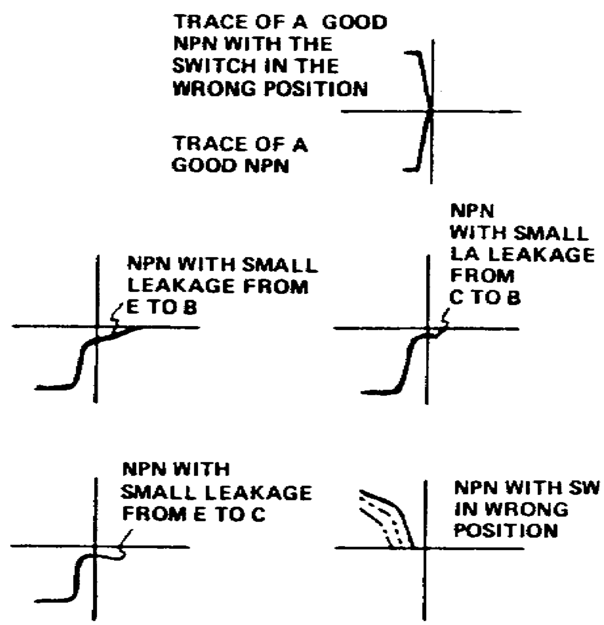


Figure 3-19. Oscilloscope traces of NPN transistors

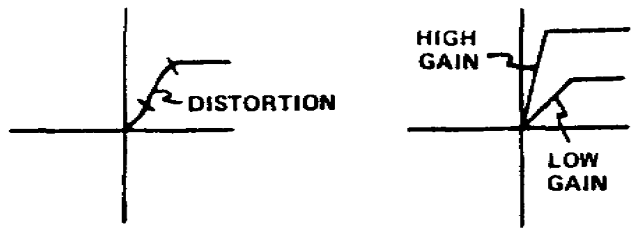


Figure 3-20. Oscilloscope traces of distortion and gain in transistors.

Learning Event 5:
IDENTIFY VIDEO TESTING EQUIPMENT AND ITS OPERATION

1. This section will discuss the grating generator, dot bar generator and video sweep marker generator. We will go through their purpose and operation, as well as interpret their output patterns.

2. The grating generator provides a convenient means of checking and adjusting the linearity of television deflection circuits. It generates a timing signal synchronized by standard synchronizing generator or the deflection circuits of the receiver under test, and injects this signal into the video circuit being tested. The pattern produced has the appearance of a grating as shown in Figure 3-21.

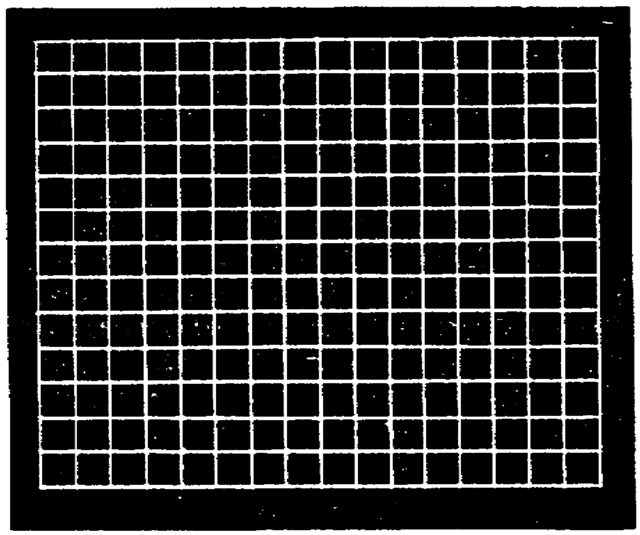


Figure 3-21. Grating test pattern

a. The block diagram, Figure 3-22, shows the typical grating generator circuitry necessary to produce a satisfactory grating pattern.

(1) The desired pattern is produced by inserting the horizontal and vertical pulses from either a standard television synchronizing generator or the deflection circuits of a television receiver, as previously stated.

(2) The vertical pulses are then multiplied 15 times, while the horizontal pulses are multiplied 20 times. They are vectorially added in the adder circuit and the output is applied to a clipper.

(3) The output pattern of the grating generator is determined by the bias point of the clipper circuit. When the bias is adjusted so that either the horizontal or vertical signal extends above the clipping level, the resulting output is a grating pattern.

(4) Moreover, the grating signal must be clipped at both ends of the amplitude range so that the lines will not appear blacker than black at their intersecting points.

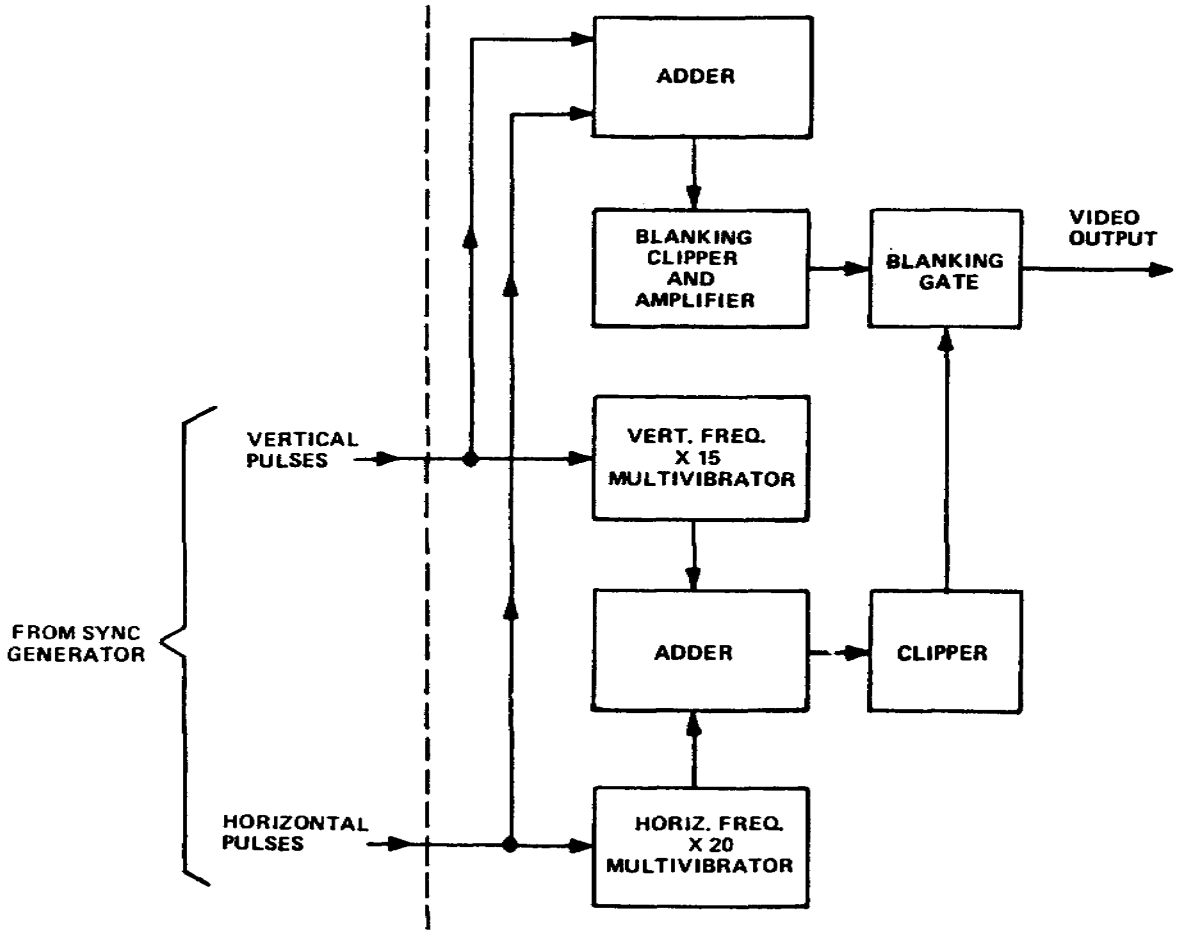


Figure 3-22. Grating generator, block diagram

b. To prevent lines from appearing during retrace, the horizontal and vertical retrace pulses are combined, as shown in Figure 3-22. When added, they form a blanking pulse, and this pulse is applied to the blanking gate circuit. An output signal is produced only when the incoming signal is strong enough to override the level of the blanking pulse.

c. The grating pattern is comprised of 14 horizontal bars and 17 vertical bars. The bars, being evenly spaced, conform with both the aspect ratio of the television system and linearity chart, discussed later on.

d. The grating generator also produces either horizontal or vertical bars separately. By selecting the output from either the times -15 or times -20 multivibrator and applying it to the signal clipper, the generator output results in horizontal or vertical bars only.

e. By injecting the grating pattern into a receiver or monitor and checking the display uniformity, you can determine discrepancies in the deflection circuit's linearity. The linearity is adjusted properly if the vertical and horizontal bars are both uniformly spaced over the entire viewing area. The grating pattern is also useful when you adjust the linearity of a camera chain.

f. Another valuable feature of the grating pattern is apparent when you adjust the convergence of a color receiver or monitor.

3. The same generator is often used to generate the dot pattern or the grating pattern. Only the clipper bias point will determine which output is produced. If the signal clipper bias is so adjusted for an output only when horizontal and vertical pulses are added, a dot pattern results (fig 3-23). The other circuits in the dot bar generator and their operation are identical to those in the grating generator.

4. The video sweep marker generator is a convenient device for checking the frequency response of a given amplifier.

a. In a typical generator, the output of a fixed RF oscillator, operating at approximately 70 MHz, is heterodyned against a sweep frequency oscillator. The sweep oscillator is being swept at a 60-Hz rate. The 0- to 10-MHz beat frequency is then applied to the circuit or unit being tested, and the resulting output, after detection, is observed on a scope.

b. Marker notches are inserted at 1-MHZ intervals for frequency calibration of the beat frequency; this is accomplished by an additional oscillator stage in the sweep generator.

c. A more accurate means of calibrating can be obtained with a sweep generator unit that uses a calibrated CW oscillator as a marker source. This type of marker source provides either variable or fixed markers over a marker source range of 100 kHz or 10 MHz.

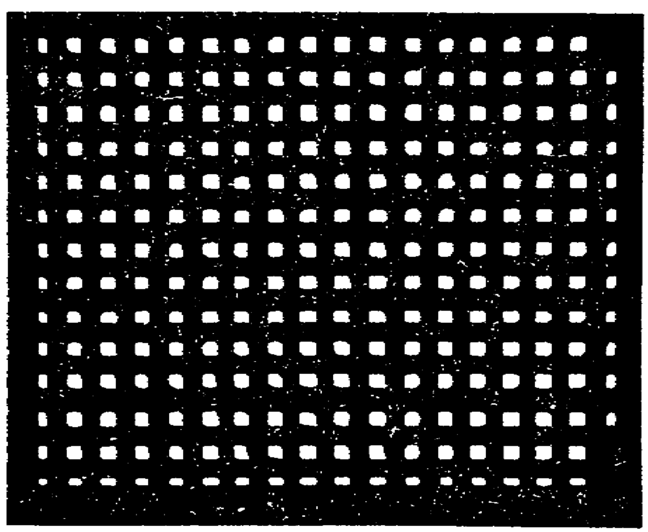


Figure 3-23. Dot test pattern

d. The most useful function of the sweep marker generator is to test and adjust the bandpass of camera preamplifiers. The equipment layout used to check a camera preamplifier with a sweep marker generator is shown in Figure 3-24. Figure 3-25 shows the output pattern of a properly tuned camera preamplifier as seen on the scope. Notice the notches inserted in the output. These markers help you observe the range of frequency response of the output pattern from the camera preamplifier. These marks are important because the frequency response curve must be flat to 8 MHz for adequate bandpass of the television video information.

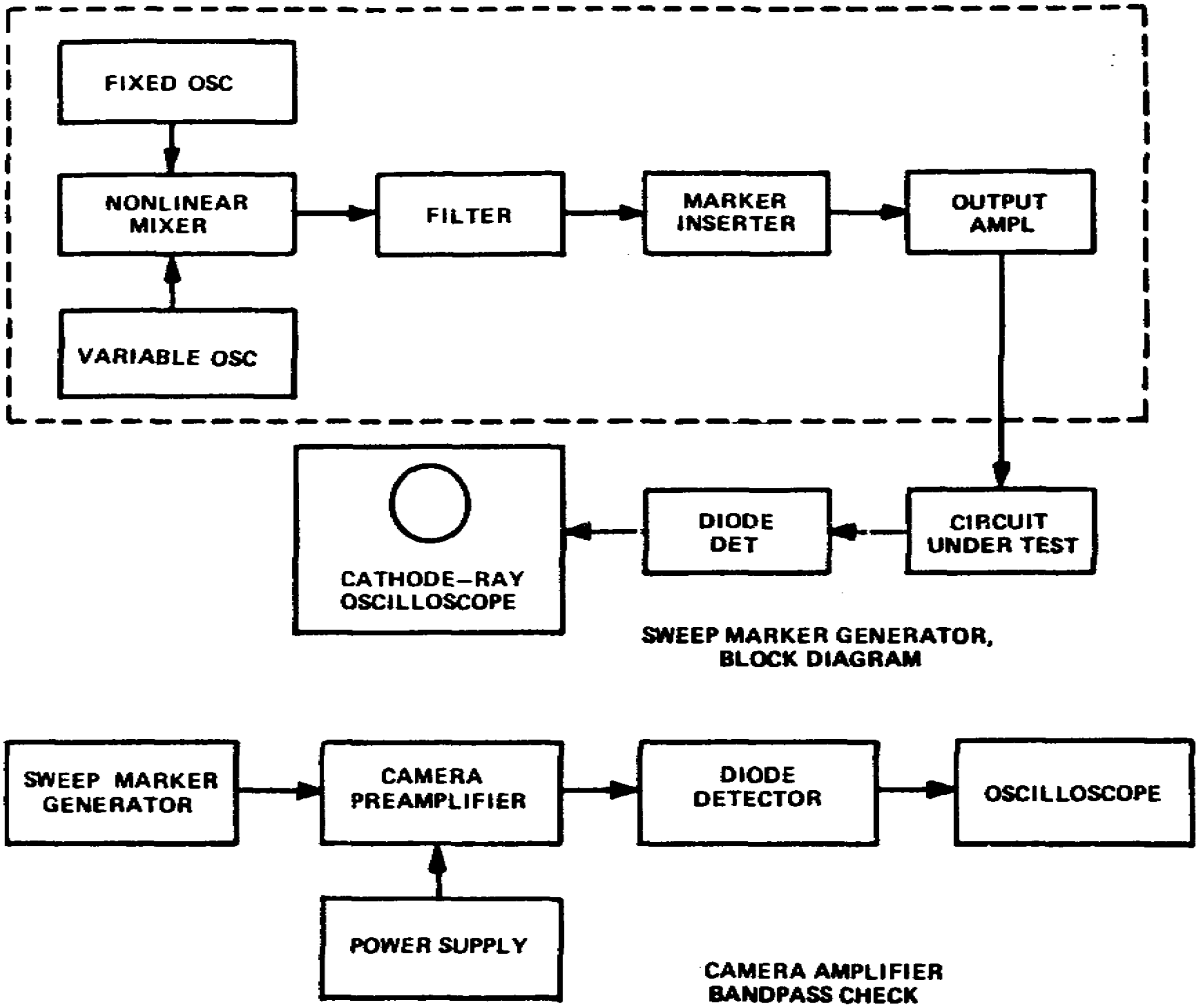


Figure 3-24. Camera amplifier bandpass check

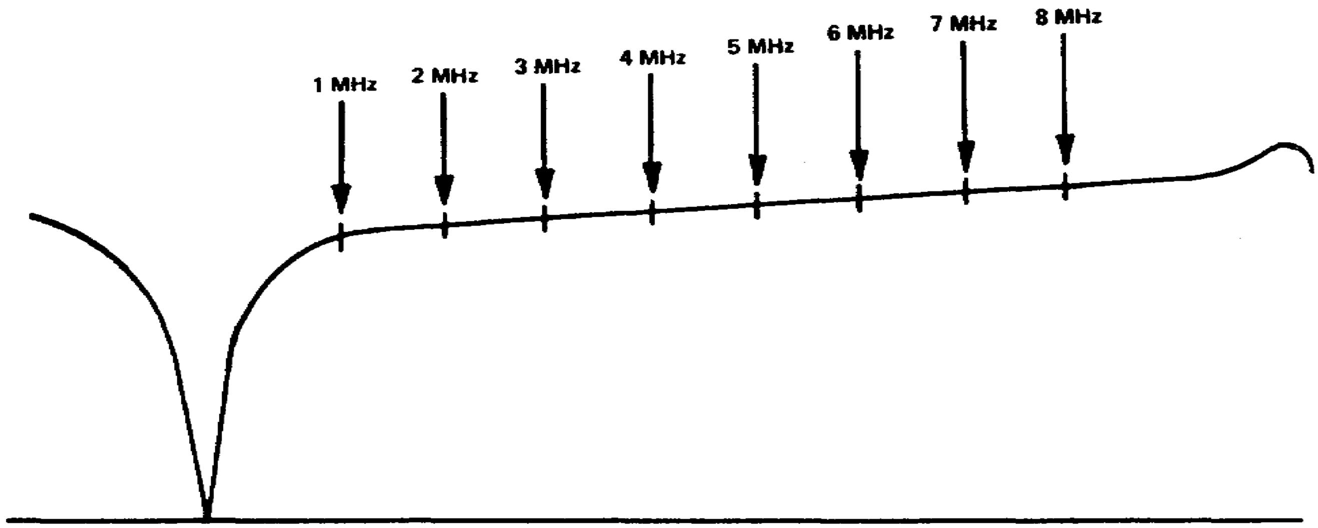


Figure 3-25. Oscilloscope presentation of camera bandpass

5. The pulse cross display is one of the most important measurements in television and it is used to determine whether the synchronizing generator is producing the proper pulse sequence, width, and amplitude.

a. The pulse cross display, along with its correct interpretation, is a convenient means of conducting operational measurements of the output pulse produced in the synchronizing generator. The pulse cross display is practical for routine operational measurements because this test requires only the use of modified video monitor. This monitor is usually available in any television station.

b. Other types of more detailed pulse analysis and adjustments may be necessary at periodic intervals. These functions require the use of specialized test equipment.

c. In normal video transmission, the horizontal and vertical synchronizing pulses occur at the end of each scanning line and each field respectively. The front porch of the horizontal synchronizing pulse occurs at the right edge of the picture, and the back porch occurs at the left edge. The vertical blanking interval occurs during vertical retrace. This information contained in the vertical blanking pulse occurs at the top and bottom of the viewing screen. Since all of the synchronizing and blanking information occurs at the edges of the picture area, its information is hidden by the picture tube mask.

d. Though detailed information may be difficult to distinguish, the general shape of the vertical blanking interval can be observed on most standard receivers and monitors by rotating the vertical-hold control until the vertical blanking bar is located in the viewing area. The horizontal synchronizing and blanking pulses at the end of each scan line are much more difficult to observe. With the modifications normally provided, the standard television monitor eliminates any definition, vertical displacement, or horizontal displacement problems. The pulse cross display can be observed instantly or monitored continually for extended periods of time.

e. The individual lines can be seen more readily if the horizontal and vertical scanning process is expanded. As a result, the pulse cross display information is seen in more detail. Expansion of the picture tube sweep circuits permits the horizontal and vertical synchronizing and blanking information to be placed in the viewing area of the picture tube.

f. Interpretation of the pulse cross display is relatively easy when you understand that the individual pulse amplitudes are indicated by light intensity. In the pulse cross display shown in Figure 3-26 the horizontal dimensions of the light intensities are relative measures of time or pulse widths. Use Figure 3-26 to identify the following pulse group patterns:

(1) The horizontal synchronizing pulse duration (0.075H-0.98H).

(2) The horizontal blanking pulse duration (0.165H-0.18H).

(3) The vertical synchronizing pulse interval (0.42H-0.44H).

(4) The vertical blanking interval (13.1H-21.0H).

(5) E and F- the equalizing pulse intervals.

(6) G- the six dark lines which show vertical synchronizing pulse duration.

(7) I- the equalizing pulse duration (0.5 horiz sync width).

(8) H- the horizontal blanking and synchronizing pulses that continue to occur at the end of each horizontal video scan line until the beginning of the next vertical blanking interval.

(9) K- the front porch of the horizontal blanking pulse (0.02H).

(10) L- the back porch of the horizontal blanking pulse (0.05H).

(11) M- the pulses which occur during the remaining vertical blanking time.

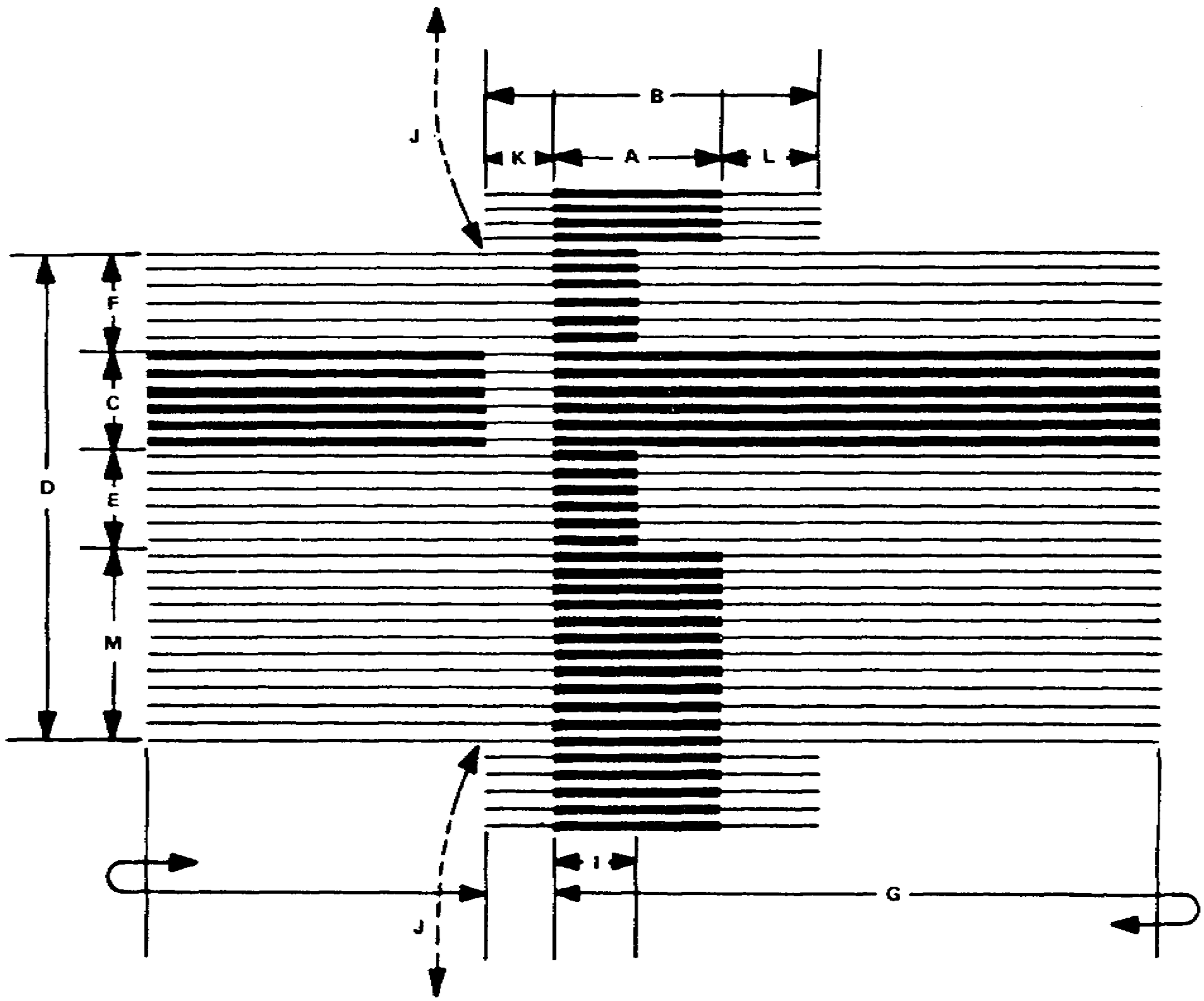


Figure 3-26. Pulse cross display

g. Each pulse width may be compared to its normal duration. After you have had some experience in using the cross display, you may devise a ruler calibrated in normal pulse widths to check the pulse cross display. Of course this ruler would apply only to a particular monitor. You can also use the pulse cross display to check the number of lines in the equalizing and vertical pulses.

6. Good resolution of a picture is indicated by sharply defined objects and no blurring or running together of closely spaced lines or points. Horizontal detail and vertical detail must be considered separately in a television picture. The maximum vertical resolution is determined by the number of active scanning lines. The horizontal resolution is determined by the maximum number of changes in voltage that can occur in each line that is scanned.

7. Standard test charts have been developed to permit more comprehensive testing of system performance.

a. The resolution chart (fig 3-27) can be used for making system quality tests for geometric distortion (linearity), aspect ratio, resolution, shading uniformity, frequency response, streaking, interlace, gray scale reproduction (contrast), brightness, and RF or other high frequency interference.

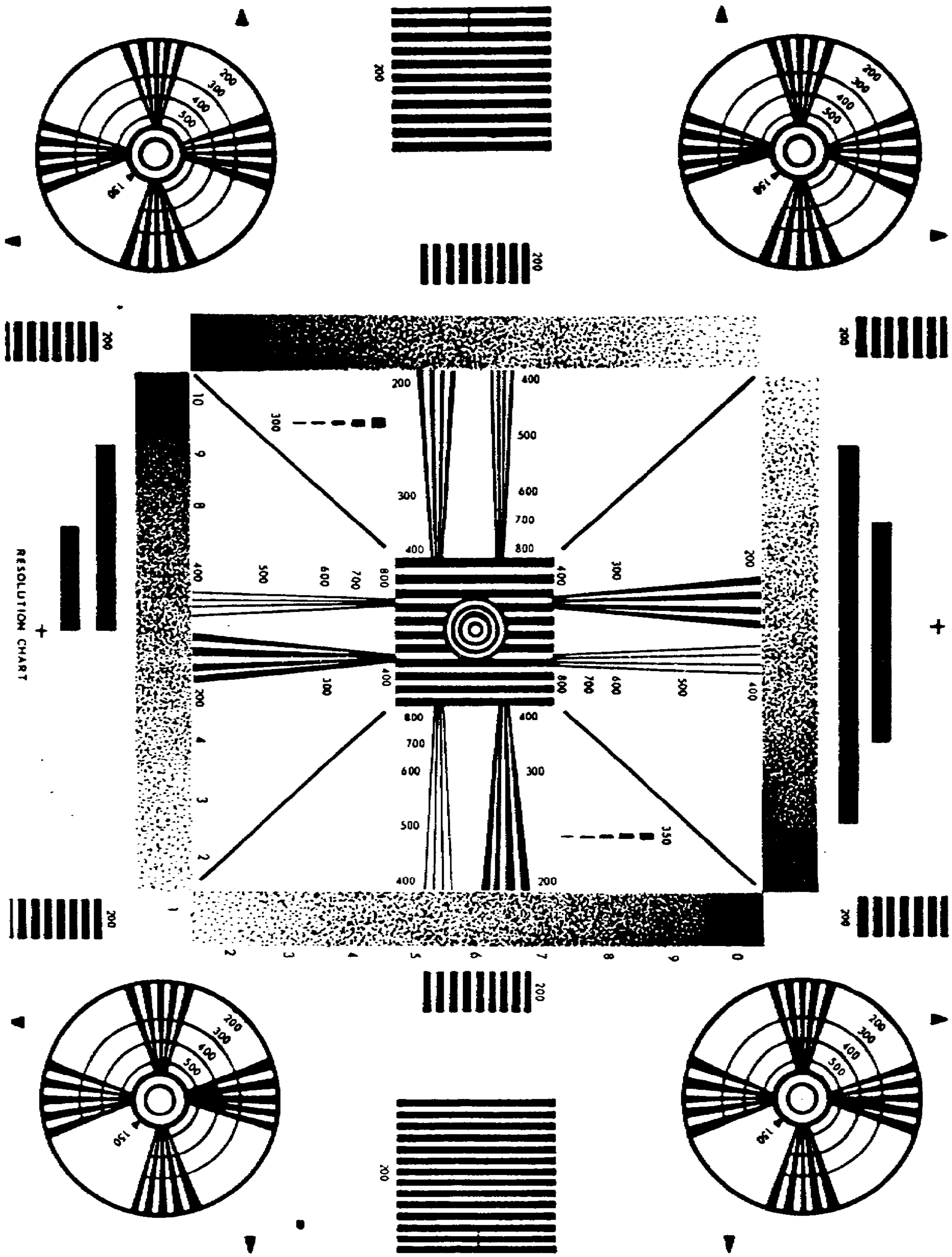


Figure 3-27. Resolution chart

b. When making a geometric distortion check, position your camera, and focus on the test chart. A picture free from distortion has linear scanning and correct aspect ratio. Check your linearity by comparing the spacing between the short horizontal bars at the top, bottom, and center of the picture.

(1) If the spacing is equal in each set of horizontal bars, vertical linearity is satisfactory. The circles located in each corner and at the center of the chart are a further check for geometric distortion.

(2) Circles that are nonlinear or distorted in shape indicate incorrect adjustment of the vertical, the horizontal, or both horizontal and vertical sweep linearity.

(3) You can check the aspect ratio by measuring the large portion of the picture formed by the four grayscale bars. If the pattern is square and the scanning is linear your aspect ratio is correct.

c. To check interlace, you observe the diagonal lines in the center square of the picture. Interlace is correct if the lines appear similar to those in Figure 3-27. Jagged diagonal lines indicate partial pairing of the lines. The diagonal lines do not appear jagged if complete line pairing occurs. Under this condition, total line pairing can be determined by the resolution wedges, since vertical resolution cannot exceed 250 lines.

d. Radio frequency or other high frequency interference is sometimes introduced into the video amplifier scanning circuits. Radio frequency interference in the horizontal sweep circuits from the power supply is indicated when the vertical lines in the test pattern become modulated and take on a ripple appearance. Radio frequency or other high frequency interference in the video amplifier is indicated by a moire pattern over the whole picture.

e. The standard linearity chart (fig 3-28) is used when camera linearity adjustments are to be made. This chart has an aspect ratio equal to that of the grating pattern. The circles occur at the same positions in the linearity chart that the lines intersect in the grating pattern. The two test patterns are superimposed on a monitor screen when you focus the video camera on the linearity chart and simultaneously transmit it and the pattern from a grating generator. A camera with linear scanning produces a picture uniformly distributed on the screen. You can adjust the linearity of the camera by adjusting the camera linearity controls so that the circles of the linearity chart coincide with the intersections on the grating pattern within an acceptable percent of tolerance.

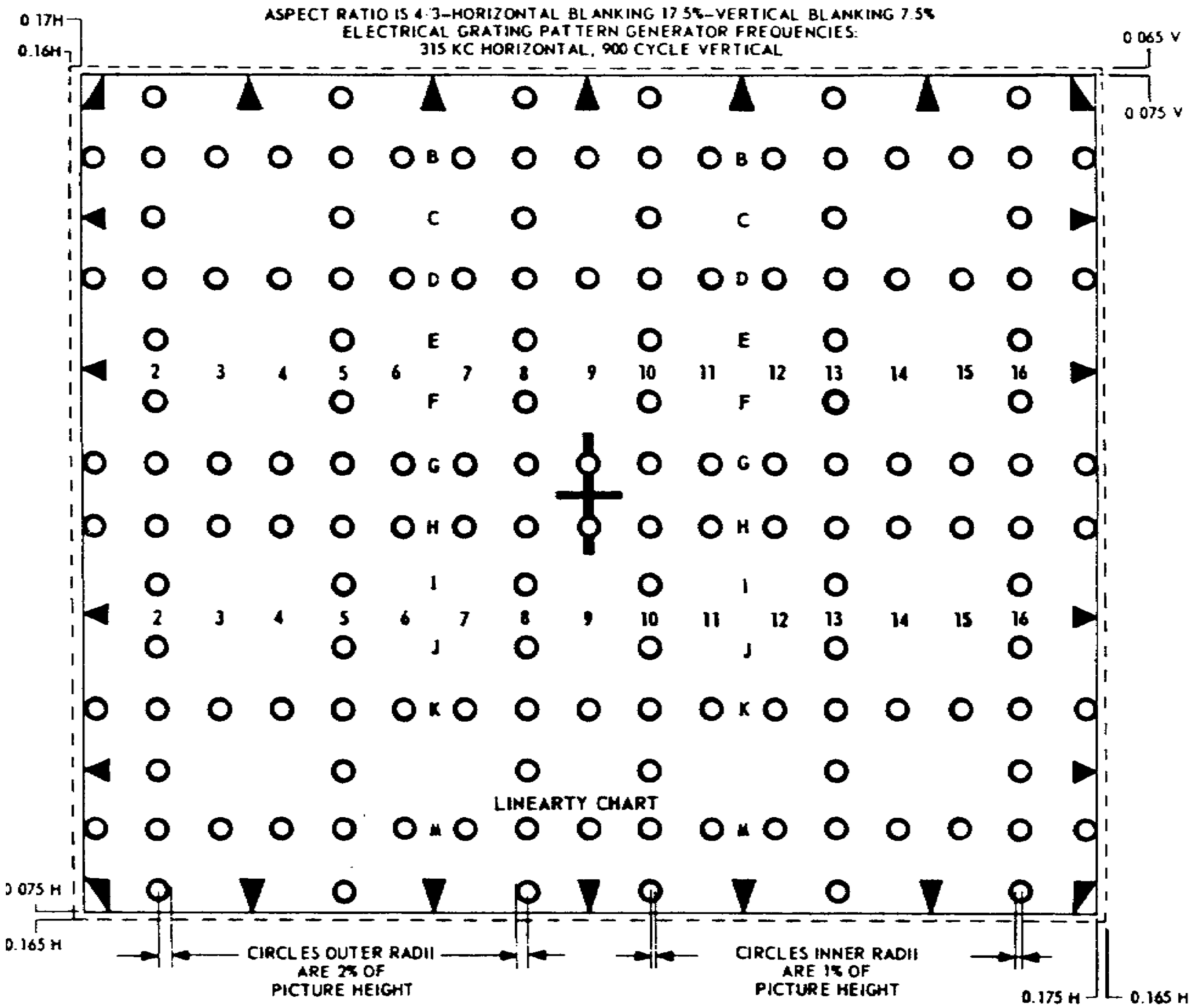


Figure 3-28. Linearity chart

Learning Event 6:
DESCRIBE THE PURPOSE AND TYPES OF COLOR TEST EQUIPMENT

1. Since color television requires more critical standards of operation, several types of test equipment are necessary to maintain these standards. In this section, we shall discuss the purpose and usefulness of some of the test equipment used to maintain these critical standards and the function of such equipment as the linearity checker, color-bar generator, vectorscope, and grating generator. We will also interpret the output patterns produced by this equipment.

2. The gain and phase in a color video signal must be maintained at an established level. A composite color signal consists of a luminance component on which is imposed the 3.58-MHz color subcarrier. The subcarrier is modulated so that the amplitude determines the degree of saturation of the reproduced colors, and phase relationships produce hue.

3. The typical linearity checker provides a means for measuring differential gain and phase, dynamic gain, luminance signal linearity, and luminance distortion caused by chrominance signal nonlinearity in systems under test. The linearity test signals are useful for measuring nonlinear distortions such as differential gain, differential phase, and line-time nonlinearity (fig 3-28).

a. Differential gain is, basically, the change in the chrominance signal amplitude as the amplitude of the luminance signal changes between black and white.

b. Differential phase is the change in phase of the chrominance signal amplitude changes between black and white.

c. Differential phase and gain measurements can be made using a vectorscope.

d. Line-time nonlinearity signal is the difference in gain from the black level to the white level of a video signal. Monochrome signals and the luminance portion of color signals are affected by this distortion.

e. The 5-step linearity signal is commonly used to measure the amount of line-time nonlinearity. The output of the circuit being measured is differentiated and fed to a scope or waveform monitor. An external differentiating network may be used.

f. During the active portion of each field the flat field signal has a luminance level which is variable from 0 to 100 IRE units in 10 IRE increments. It is used to test clamper amplifiers and systems in general for APL (average picture level) dependent distortions.

4. There are two basic models of the color bar generator. The first is a compact, lightweight generator instrument used primarily where portability is desired. The second mounts in a standard 19-inch rack, and is used primarily in the television broadcast system. In both units the operation is about the same, and the desired outputs serve the same basic purpose.

a. With its variety of test signals, the color bar generator is an excellent tool for use in analyzing television system defects or anomalies. The following paragraphs list the color bar generator test signals and their general applications.

(1) The standard full field color bar signal consists of eight equal intervals arranged in descending order of luminance as follows: gray, yellow, cyan, green, magenta, red, blue, and black (fig 3-29). This signal is used for checking luminance, hue, and saturation parameters of the television system.

(2) Split field Y reference signal provides standard color bars in the first part of the test pattern display and luminance-only shades of gray to black in the second part (fig 3-30). The split field Y reference signal is especially useful for checking color balance and tracking of color picture monitors.

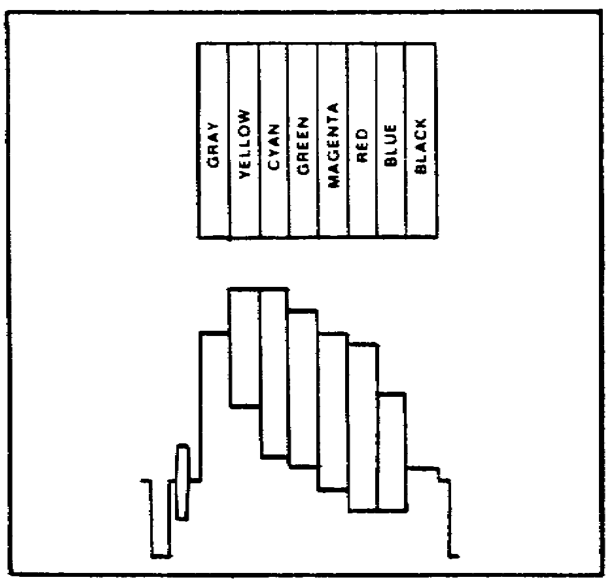


Figure 3-29. Full field color bars

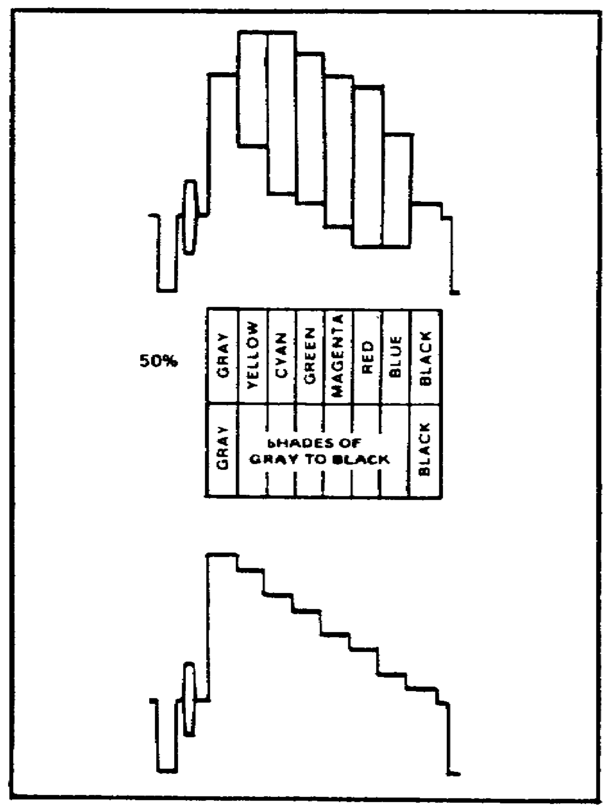


Figure 3-30. Split field Y Reference

(3) Split field red signal includes the standard color bars in the first part, while the second part contains the red color-bar signal only (fig 3-31). Video system noise, VTR head banding, and red phase are readily seen by using the solid red split field signal. Split field reverse signal provides standard color bars in the first part and color bars in the reverse order during the second part (fig 3-32). Dynamic range and color tracking of video monitors can be checked with this test signal pattern.

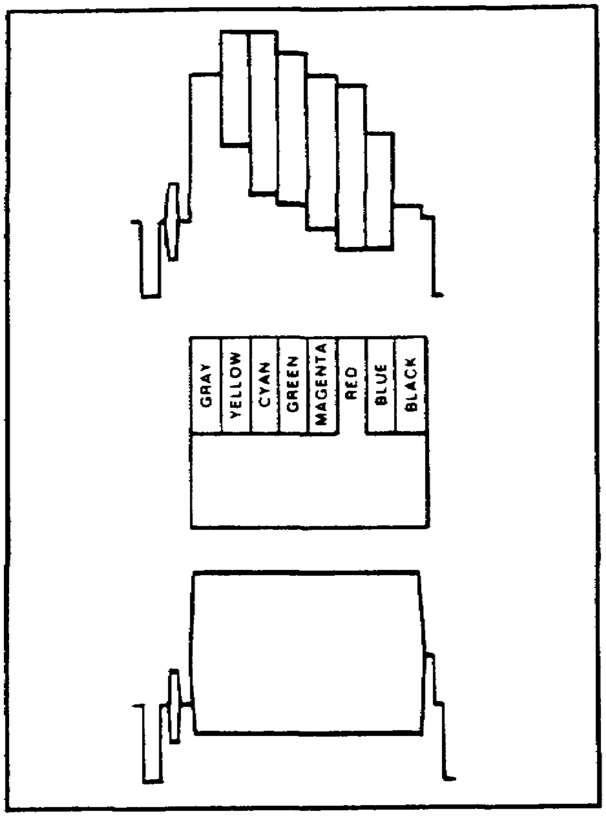


Figure 3-31. Split field red

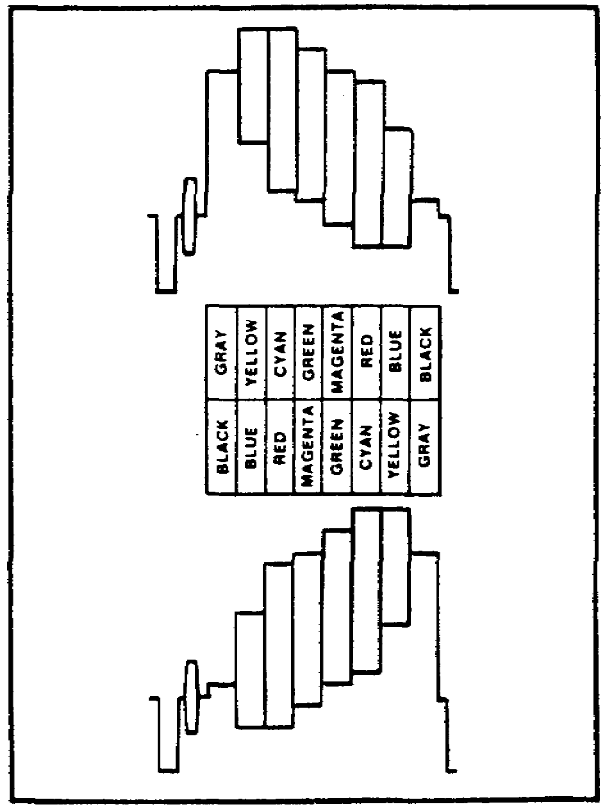


Figure 3-32. Split field reverse

(4) EIA standard color bar signals comply with RETMA ENGINEERING COMMITTEE TR-4 on television transmitters, "EIA Standard for Encoded Color Bar Signals." It is used for adjustment of color monitors and encoders and for making rapid checks of color television transmission systems.

(5) The standard EIA signal consists of two major parts. Three-fourths of the active scanning lines in each field are divided into seven equal intervals arranged in descending order of luminance as follows: gray, yellow, cyan, green, magenta, red, and blue (fig 3-33a). The remaining one-fourth of active scanning lines in each field is used for the transmission of special test information consisting of a subcarrier signal envelope with a phase corresponding to a reference white pulse, a subcarrier signal envelope with a phase corresponding to -1, and a reference black interval (fig 3-33b).

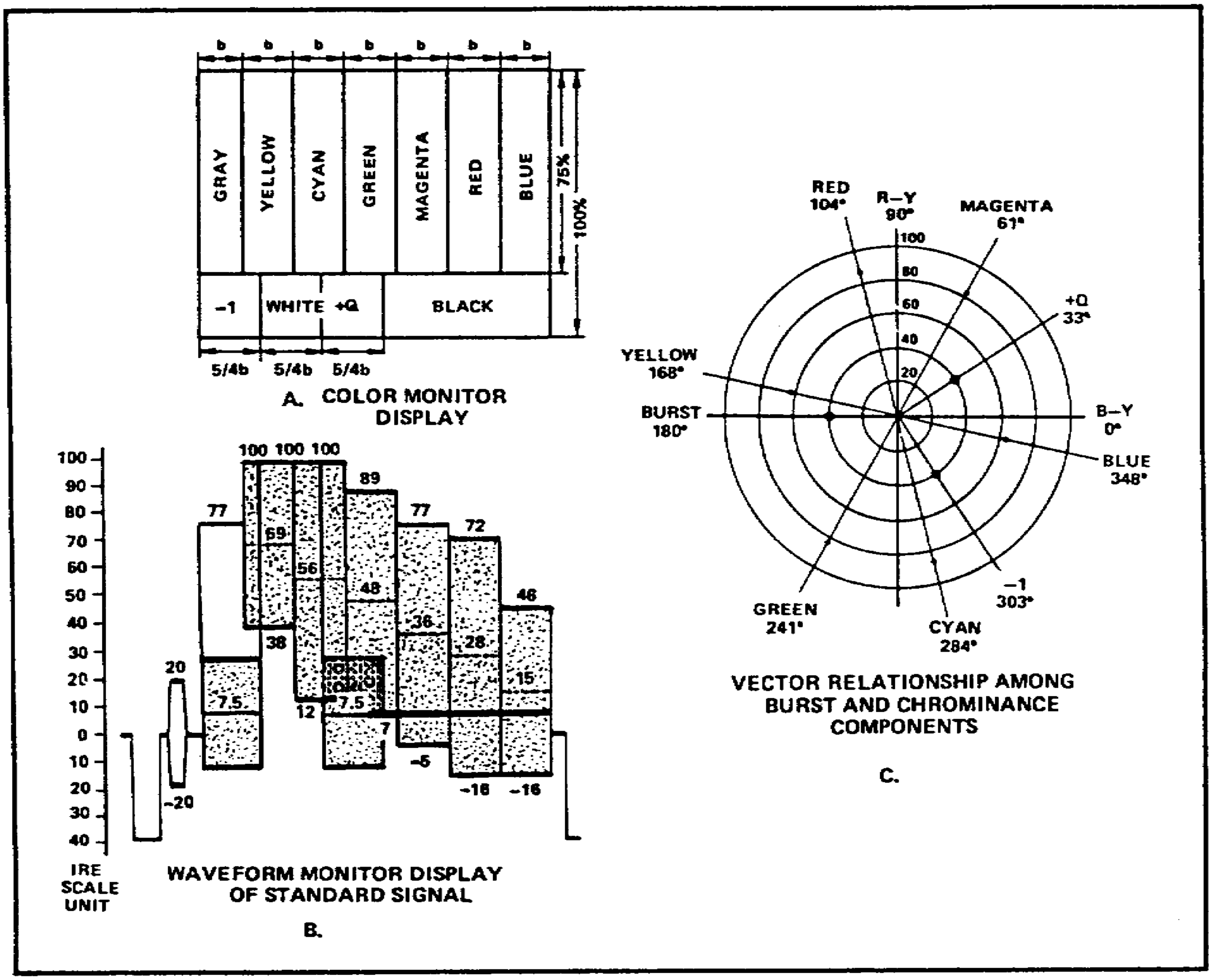


Figure 3-33a, b, and c. Picture monitor, waveform monitor, and vectorscope displays of the standard EIA test pattern signal

(6) Figure 3-33b shows the color bar signal as seen on a waveform monitor triggered at horizontal rate. Vector relationships of the various burst and chrominance components are shown in Figure 3-33a.

(7) The standard color bar signal may be used for making phase and gain adjustments in color monitors, or for verifying overall accuracy of the decoding function. An experienced operator can learn to judge the accuracy of monitor adjustments by direct observation of color bar pattern on the display device. For more objective measurements, the waveforms resulting from the decoding of the standard color bar signal can be used.

(8) The accuracy of matrix and phase adjustments in encoders may be readily checked by comparison of the standard color bar signal with the output of such a device, when the standard signal is applied to the encoder inputs. The signal embodies several convenient references and relationships that facilitate its use. The relative amplitudes of all signal components can be checked by direct observation of the complete waveform on a television waveform monitor. A waveform monitor display should exhibit the following relationships (fig 3-33b).

(a) The positive peak levels of yellow and cyan bars are nominally equal to reference white level.

(b) The negative peak level of the green bar is nominally equal to reference black level.

(c) The negative peak levels of the red and blue bars are nominally equal.

(9) The relative phase and amplitudes of the chrominance portion of the signal are generally checked by observation on a vectorscope (fig 3-33c). The quadrature phase relationship between the I and Q components of the encoder signal can be conveniently checked by observation of the -I and Q signal axis.

(10) When making rapid checks of color television transmission systems, observation of the standard color bar signal waveform at the output of a transmission system can yield a number of clues with respect to the quality of the transmission system. The color bar signal is useful for checking transmission level, relative frequency response, and the presence of differential gain and phase.

5. One of the newer test equipment items developed for close inspection of amplitudes and phase of subcarrier signals is the vector display scope, commonly called the vectorscope. A block diagram of a typical vectorscope is shown in Figure 3-34. Generally this equipment uses a pair of quadrature demodulators. The demodulator outputs are applied to the X and Y plates of a DC scope. Most designs incorporate a burst-control oscillator to generate a reference subcarrier from the synchronizing burst of the signal under test.

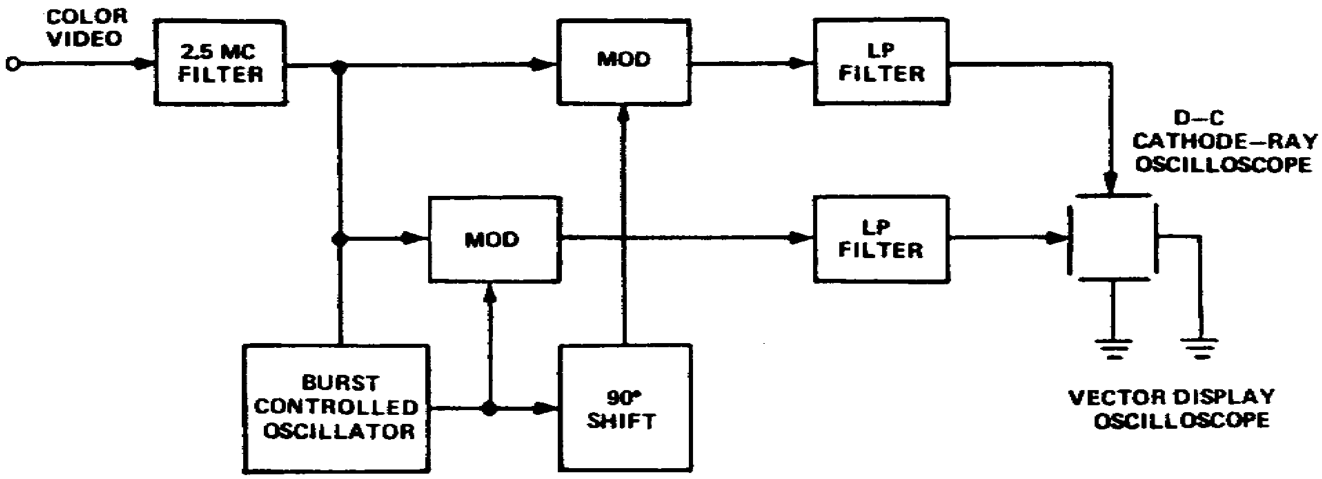


Figure 3-34. Block diagram of a typical vector display oscilloscope

a. When used with color bar signals, the vectorscope produces a pattern of lines and dots which indicate the vectors corresponding to the various colors. The pattern appears as bright dots linked by relatively faint lines. As illustrated in Figure 3-35, boxes may be drawn on the oscilloscope face to indicate phase and amplitude tolerances.

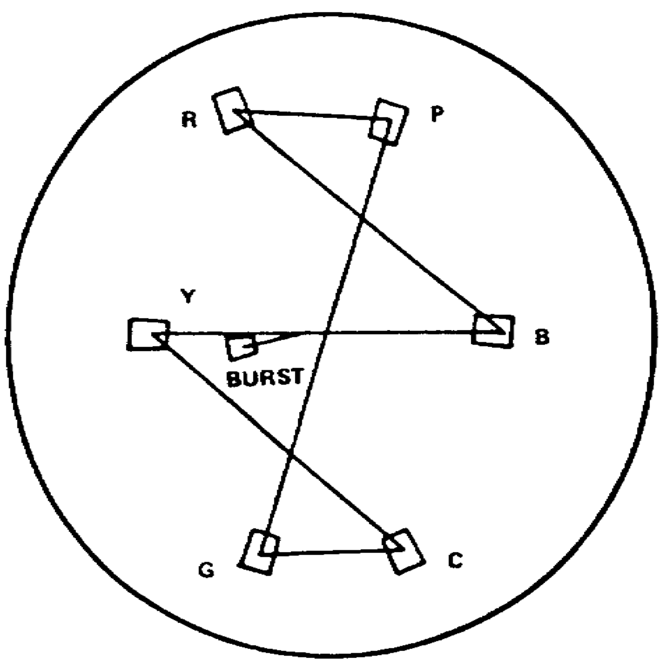


Figure 3-35. Typical vector display oscilloscope pattern

b. The vectorscope must be used for making certain measurements on a color television system, particularly differential phase measurements. It is also an excellent tool for evaluating both luminance and chrominance channels of most video equipment.

6. The purpose and outstanding feature of the grating generator as applied to black and white television were discussed earlier in this lesson. Now we will examine its operation and functions as they pertain to color operation.

a. The cross-hatch pattern generated by the grating generator is extremely useful when making adjustments in the convergence of a color picture tube.

b. When viewing the picture area of the receiver, with the grating pattern applied, look for proper alignment of the vertical and horizontal bars. The convergence is properly adjusted if the bars are placed over one another and no color fringing is apparent.

Lesson 3

PRACTICE EXERCISE

1. What are the two voltage values of a video signal applied to a waveform monitor?

   a. 0.7 volts and 0.3 volts
   b. 0.714 volts and 0.286 volts
   c. 0.8 volts and 0.2 volts
   d. 0.814 volts and 0.186 volts

2. What is the output range of a radio frequency generator?

   a. 10 MHz to 10 GHz
   b. 20 KHz to 10 MHz
   c. 10 KHz to 10 GHz
   d. 20 KHz to 20 GHZ

3. What is the overall frequency change called?

   a. Frequency - modulation
   b. Frequency swing
   c. Attenuator
   d. Waveform

4. What must happen to the input signal before you can make a frequency measurement reading?

   a. Applied to the signal shaper
   b. Sent to horizontal deflection
   c. Sent to the vertical deflection
   d. Sent to the time base

5. Why is it discouraged to use a multimeter to test transistors or diodes?

   a. Accuracy not close enough
   b. Frequency too low
   c. Frequency too high
   d. Meter can damage components

6. For what purpose is the video sweep marker generator used?

   a. Frequency response of a given amplifier
   b. Best picture
   c. To set picture registration
   d. Set gray scale reproduction

7. What test signal on the color bar generator is best to use, when checking color balance and tracking of color picture monitor?

    a. Standard full field color bars
    b. Split field red signal
    c. Split field Y reference signal
    d. Grating generator

8. What test instrument is used to make differential phase measurements of a color TV system?

    a. Oscilloscope
    b. Color bar generator
    c. Video sweep marker generator
    d. Vector scope

ANSWERS TO PRACTICE EXERCISES

Lesson 1

1. B
2. B
3. D
4. B
5. D
6. B
7. A
8. C
9. C
10. D

Lesson 2

1. A
2. B
3. C
4. B
5. D

Lesson 3

1. B
2. C
3. B
4. A
5. D
6. A
7. C
8. D