CHAPTER 13
METERS

When working with electromechnical devices, it is imperative that the technician be able to gauge certain aspects of the electrical power and the signals being utilized by the equipment. This gauging may be as simple as connecting a light bulb to verify power or it may require a highly sensitive vacuum tube voltmeter to monitor extremely low voltages. Similarly, a signal may be verified with a simple loudspeaker or it may require the sophisticated display of an oscilloscope. In any case, a preliminary understanding of meters and their uses is extremely valuable information to have under your belt.

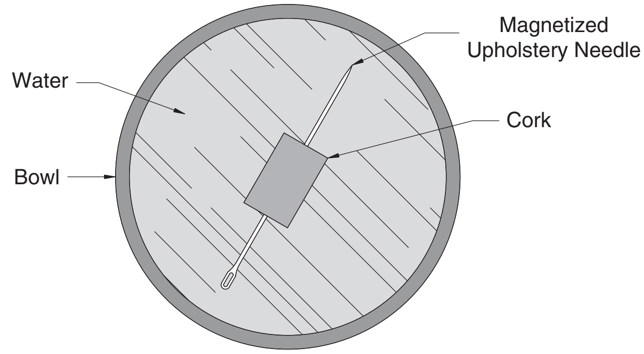

Figure 13-2 Bench Built Compass

Compass

Let's start by examining one of the most basic electromagnetic instruments, the compass. Figure 13-1 shows a typical commercial compass such as may be found in any sports and outdoor store. This instrument is made by mounting a magnetized needle onto a precision pivot. The pivot allows the needle to freely align with the magnetic field of the earth. In doing so, the North Pole of the needle will always point toward the magnetic North Pole of the earth. The pivot is mounted in the center of a graduated face, which, in turn, is placed in the bottom a nonferrous case. The case is typically sealed with a glass window that prevents the needle from coming off the pivot when the instrument is transported in a pack or pocket.

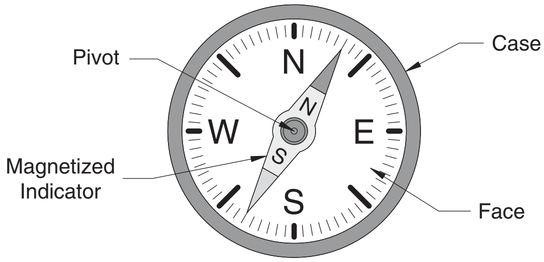

Figure 13-1 Magnetic Compass

Building a compass couldn't be easier. An upholstery needle is magnetized by stroking it with a permanent magnet. Once the needle is magnetized, it is forced through the center of a cork. The cork and needle assembly is then floated in a bowl of water. The needle will rotate until its North Pole is pointing towards the magnetic North Pole of the earth. Figure 13-2 shows a simple bench built compass.

Galvanometers

The earliest type of electrical meter was the fixed coil galvanometer. These instruments used a simple compass and a coil of wire to detect and measure electrical signals. Early fixed coil galvanometers consisted of a compass mounted on a pedestal or support post and then surrounded with a large coil of wire. The instrument was set up so that the needle pointed north and the coil position was adjusted to be parallel

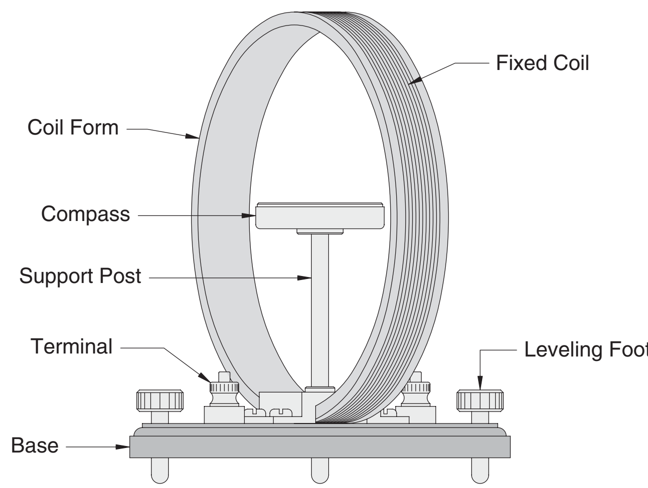

Figure 13-3 Fixed Coil Galvanometer

to the needle. When an electrical signal was applied to the coil, the compass needle deflected. These instruments could be made to detect extremely low signal levels. Figure 13-3 shows an early laboratory galvanometer.

Building a fixed coil galvanometer can be accomplished by winding a coil around a piece of 6-inch polyvinyl chloride (PVC) pipe, as shown in Figure 13-4. The coil is mounted to

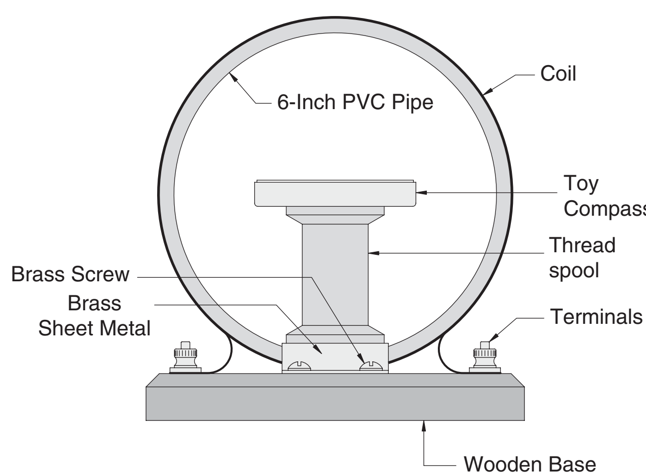

Figure 13-4 Bench Built Fixed Coil Galvanometer

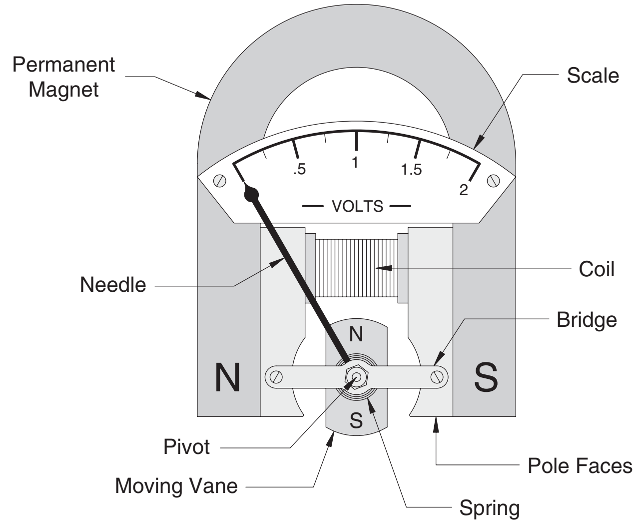

Figure 13-5 Permanent Magnet Galvanometer

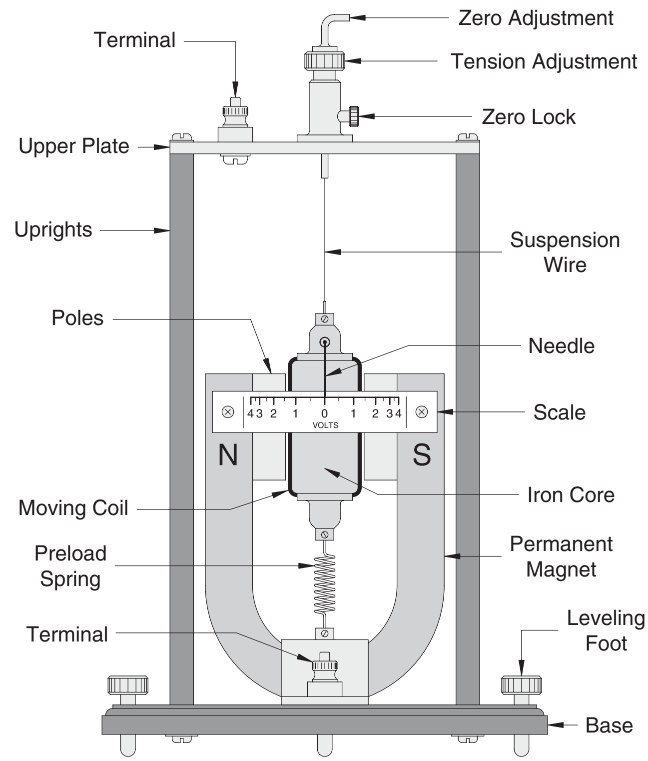

Figure 13-7 Moving Coil Galvanometer

a baseboard and a toy compass is placed on top of a thread spool in the middle of the coil.

The permanent magnet galvanometer is designed to operate independent of the earth's magnetic field. A magnet is added to counter the effects of stray magnetic fields, as shown in Figure 13-5. When the coil is energized, the instrument's field is altered and the needle deflects in direct proportion to the signal.

Figure 13-6 shows how to build a permanent magnet galvanometer. A toy compass is glued to the base of a plastic box. A curved, magnetized strip is placed around the magnet, as shown. The coil is then wrapped around the box, compass, and poles of the magnet. When a signal is applied to the terminals, the compass needle will deflect.

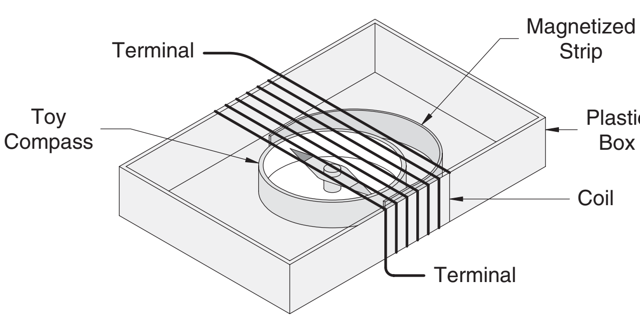

Figure 13-6 Bench Built Permanent Magnet Galvanometer

Moving coil galvanometers are the most common configuration for this class of instruments. Figure 13-7 shows an early moving coil galvanometer. A coil, with an iron core, is suspended from a fine wire so that it is located between the poles of a horseshoe magnet. Tension is maintained with a preload spring at the bottom of the coil. A needle, which points to a volts scale, is mounted to the top of the coil assembly. When a signal is applied, the coil deflects and the needle indicates the applied voltage. To improve the sensitivity and resolution of these instruments, the needle is often replaced with a mirror. A focused light source is reflected off the mirror and onto a scale located at a distance from the instrument. The distance of the scale from the mirror amplifies any movement of the coil.

Moving Coil Voltmeters

The most common type of voltmeter is the moving coil design. This type of meter operates in the same fashion as a moving coil galvanometer. The principal difference between the two instruments is that the voltmeters are generally less sensitive and considerably more rugged. Their lower sensitivity is generally due to the higher resistance of the coil. These instruments are also more compact than a galvanometer because they are usually mounted into a panel or stand-alone equipment.

Figure 13-8 shows a stylized view of a typical moving coil voltmeter. A coil and an iron core are positioned between the poles of a permanent magnet. The coil/core assembly is allowed to rotate on two pivot points. A needle, or pointer, is affixed to the core and a small clock spring is used to return the mechanism back to a zero reading. The needle points to a scale mounted onto the magnet. When a signal is applied to the terminals, the coil generates a magnetic field and the coil/core assembly rotates to align with the field of the permanent magnet. The stronger the signal, the more the coil/core assembly rotates, which, in turn, generates a higher reading.

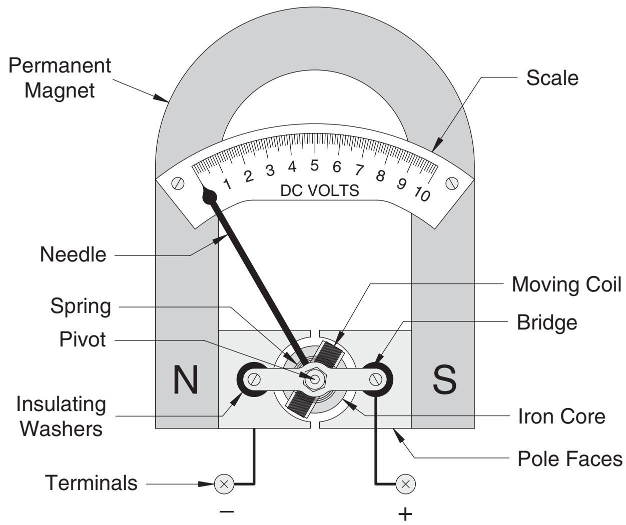

Figure 13-8 Moving Coil Voltmeter

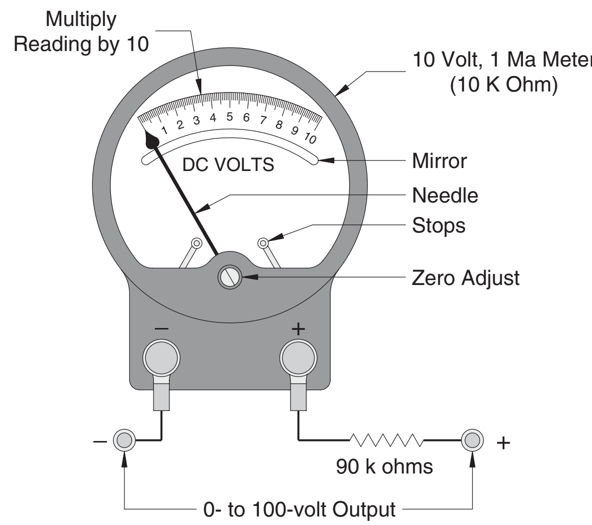

Figure 13-10 Voltmeter with Single Voltage Compensation resistor

By adjusting the position of the coil/core assembly and needle, as shown in Figure 13-9, it is possible to set up a voltmeter to indicate the polarity of the incoming signal. If the signal matches the polarity of the meter then the needle will deflect to the right. If the signal has a reverse polarity, then the needle will deflect to the left.

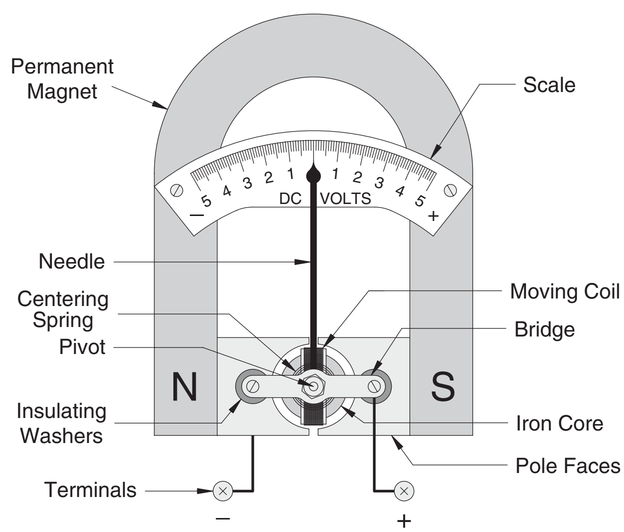

Figure 13-9 +/– Indicating Moving Coil Voltmeter

The range of any voltmeter can be adjusted to read higher voltages by adding a compensation resistor, as shown in Figure 13-10. In this example, the internal resistance of a 0 to 10 volt meter is 10,000 ohm. By adding a 900,000-ohm resistor, the effective resistance of the instrument is 10 times higher and, therefore, will read one-tenth of the input signal. To get a full reading at 10 volts, the input signal must be 100 volts. By simply adding the resistor, the 10-volt meter has been converted to a 100-volt meter. In this way, virtually any voltage can be measured on a relatively low voltmeter.

Multirange voltmeters can be configured by setting up an array of resistors, as shown in Figure 13-11. In this case there is a common terminal and four voltage terminals. Each terminal is arranged with a resistor in series with the meter. The "Times 0" terminal doesn't require a resistor. The voltage reading is based on the multiplier associated with each terminal. As an example, if an 8-volt reading is shown while a voltage is connected across the "Times 100" terminal and the common, then the actual indication would be multiplied by 100. ($8 \times 100 = 800$ volts)

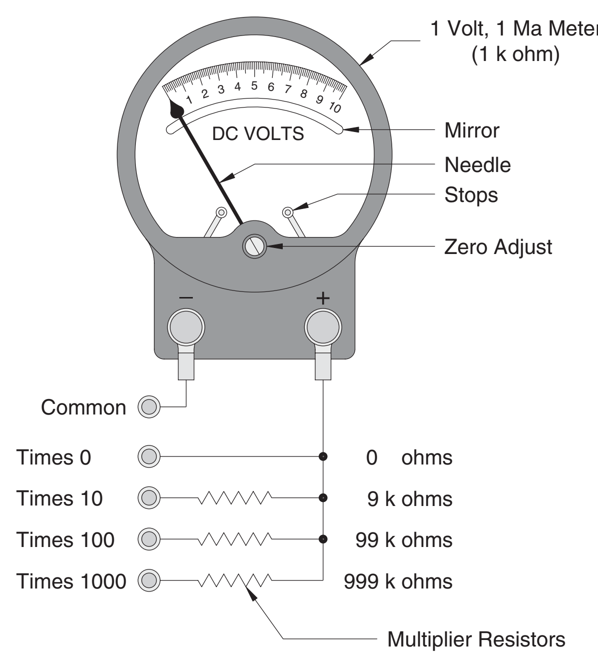

Figure 13-11 Voltmeter with Multi Range Multiplying Resistors

Another method to read higher voltages with a low voltmeter is to incorporate a voltage divider, as discussed in Chapter 4. Figure 13-12 shows a 10-volt meter configured to accept a 0- to 100-volt input signal. This method is normally not used on analog meters because the current loss over the circuit can be fairly high. This, in turn, affects the sensitivity of the meter. As an example, the circuit shown would require a 10-mA drive current to read full scale.

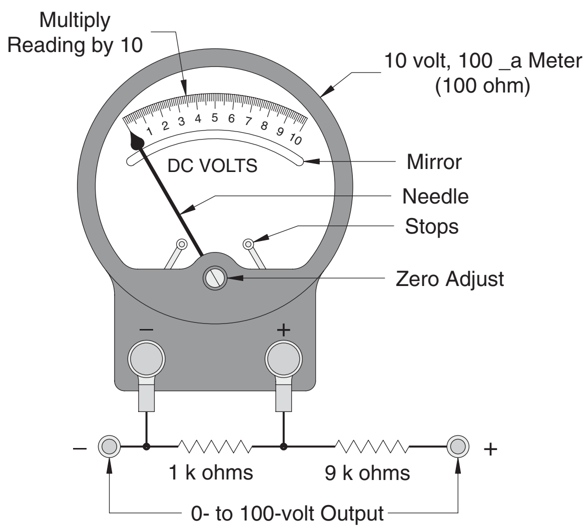

Figure 13-12 Voltmeter with Voltage Divider Compensation Resistors

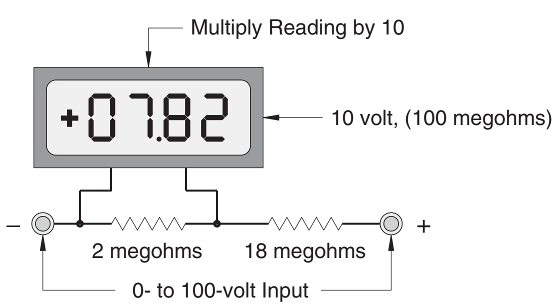

Figure 13-13 Digital Voltmeter with Voltage Divider Resistors

Voltage dividers are more commonly used on digital meters, as shown in Figure 13-13. Because a digital meter has an extremely high input impedance, the resistors that are used for the voltage divider can be in the megohm range and, therefore, require very low driving currents. As an example, the circuit shown would only require a 0.5-μA drive current to read full scale.

A multirange digital voltmeter can be set up using a voltage divider network coupled with a selector switch, as shown in Figure 13-14. In this case the input impedance is 100 megohms, which translates to an extremely low drive current.

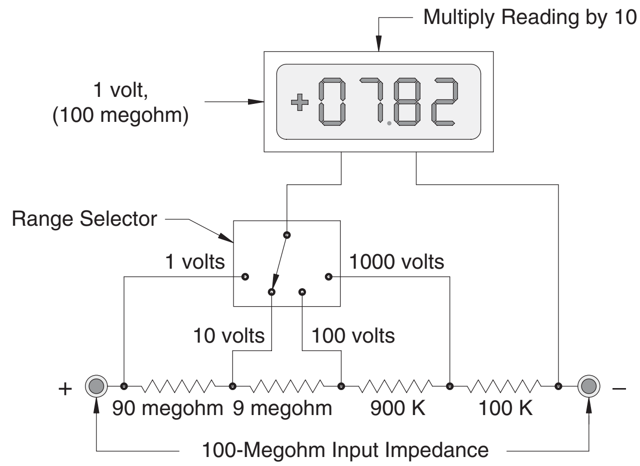

Figure 13-14 Digital Voltmeter with Four Range Voltage Divider

If an extremely high input impedance is required while using a moving coil voltmeter, then an amplifier must be incorporated, as shown in Figure 13-15. The voltage divider network is the same as with a digital voltmeter. The output of the selector switch is fed through a calibration potentiometer and then into an amplifier, which, in turn, drives the meter. The calibration adjustment is intended to tune the input signal to the amplifier so that the meter can be referenced against a standard voltage.

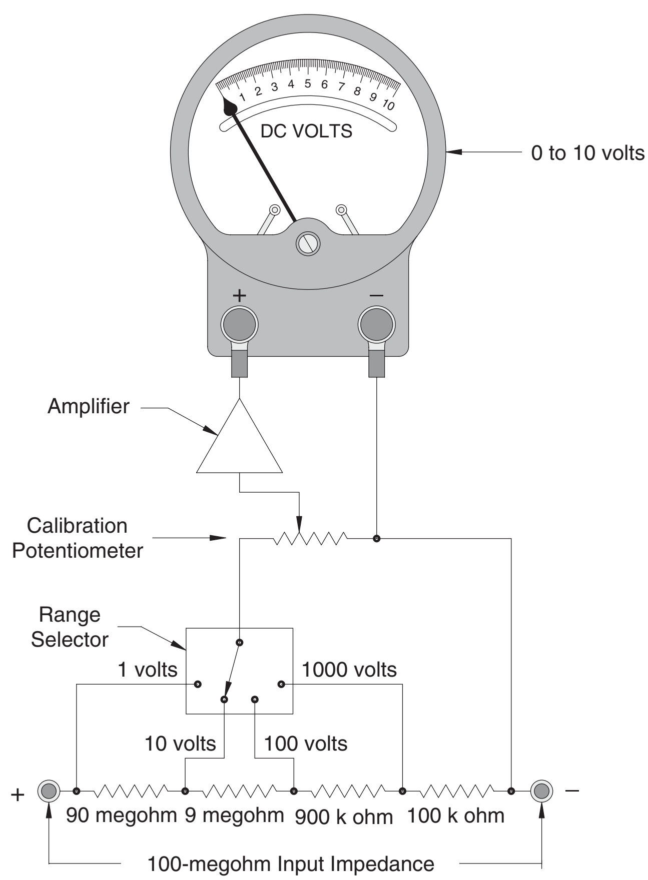

Figure 13-15 Amplified Analog Voltmeter with Four Range Voltage Divider

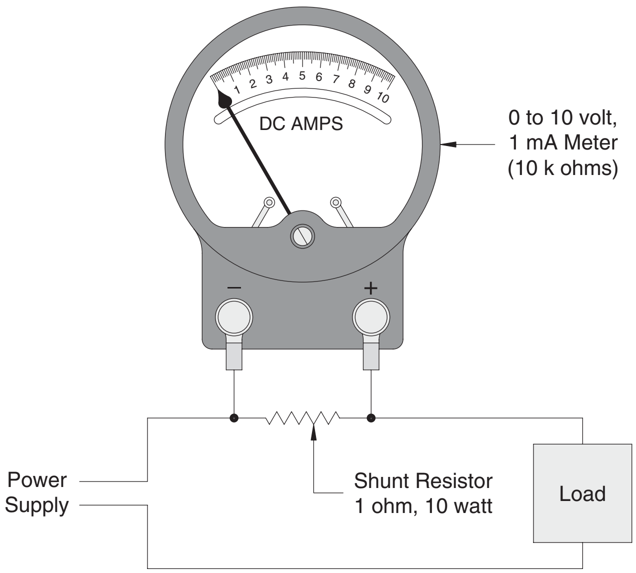

Figure 13-16 Voltmeter Configured to Indicate Amperes

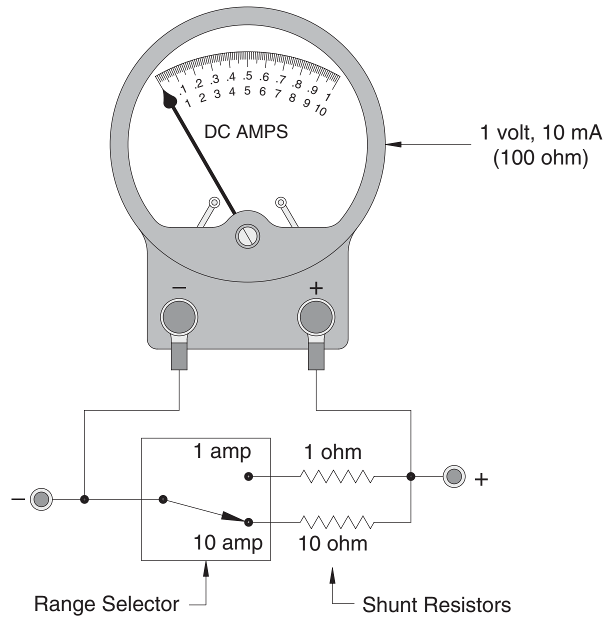

Figure 13-17 Voltmeter Configured to Indicate Three Current Ranges

Measuring current with a standard voltmeter is a simple proposition. A shunt resistor is added across the terminals of the meter, as shown in Figure 13-16. The resistance is matched to the meter so that 1 volt is equal to 1 amp. In this case a 1-ohm resistor is placed in parallel with the meter to act as a shunt. If the load pulls 8 amps, then the voltage drop across the resistor will be 8 volts and the meter will read 8 amps. It should also be noted that the resistor selected for this application must be able to carry a significant percentage of the current that is being tested. In this case, if the circuit requires 800 watts under normal operation and 1000 watts at peak meter deflection, then the shunt the resistor selected should have a minimum power rating of 10 watts.

To calculate the valve of a shunt resistor, use the following formula:

$$R_s = R_m \div [(D_s \div O_s) - 1]$$

where: R_s is the resistance of the shunt
R_m is the internal resistance of the meter
D_s is the desired current scale in amps
O_s is the original or meter current scale in amps

As an example, our circuit is calculated as follows:

$$[10\ (D_s) \div 0.001\ (O_s) - 1] \div 10{,}000\ (R_m) = 1\ (R_s)$$

Figure 13-17 shows a one voltmeter set up to indicate two different current ranges. The 1-amp range uses a 1-ohm shunt and the 10 range uses a 10-ohm shunt. The two different ranges are selected with a simple toggle switch.

A voltmeter can also be set up to measure resistance. A battery is placed in series with the resistance to be determined, and by knowing the voltage of the battery and the internal resistance of the meter; the unknown resistance can be determined. Figure 13-18 shows a schematic of a voltmeter set up for multirange resistance readings. The 0 ohms adjust is used to calibrate the meter before use. The range that is being used is connected directly to the common terminal. The meter will deflect to zero, but may not be exactly on zero. The zero adjust can then be used to tune the needle precisely to zero, calibrating the meter. The X100 range is actually the direct reading range. The X10 and X1 ranges are achieved by switching a shunt resistor across the meter terminals and

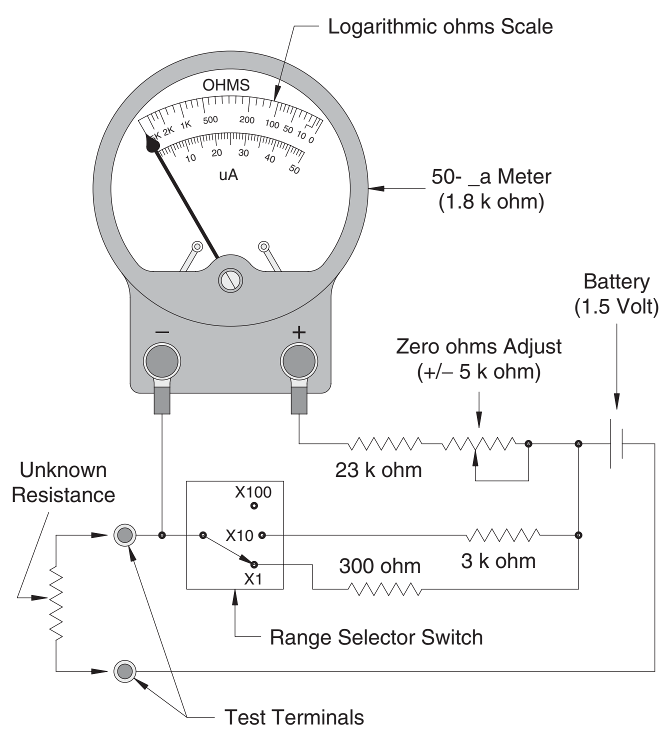

Figure 13-18 Microammeter Configured to Measure Ohms

scaling the current reading. When measuring ohms in this fashion the ohms scale is logarithmic so a conversion from the current reading can be calculated with Ohm's law. Use the following formula to convert the current reading of this circuit to ohms:

[1.5 (battery volts) ÷ (indicated current)] ÷ range = ohms

Doing the math every time you measure a resistor is a little inconvenient, so a special meter face can be printed and glued over the existing face. The special face should have both current and Ohms scales as shown in the illustration. This will make the meter movement direct reading in the X1 range. The ohms indication is simply multiplied by the range for higher resistance values.

Plunger Type Voltmeters

Figure 13-19 shows a plunger type voltmeter mechanism. The movement is a needle that is affixed to an iron core piece. The bottom of the core carries an axle, which is mounted into a pivot set. A clock spring is utilized to return the movement back to zero. The iron core piece has a circular vane protruding from the right side. Just below the far end of the vane, a solenoid coil is positioned so that its magnetic field will act on the iron vane. When a signal is applied to the coil, the plunger is pulled into the coil in direct proportion to the strength of the magnetic field produced.

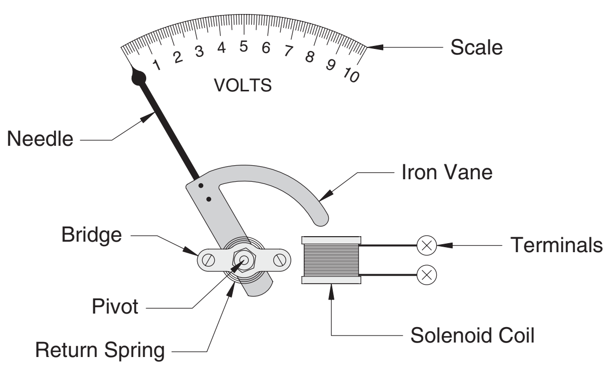

Figure 13-19 Plunger Type Voltmeter

Repulsion Vane Voltmeters

The repulsion vane mechanism consists of a coil of wire with two iron cores. One core is in a fixed position while the other is allowed to rotate about the axis of the coil. When a signal is applied to the coil, a magnetic field is generated causing the moving core to attempt to adopt a position in the field that will bring about a balance. The moving core rotates against the clock spring with the needle reading in direct proportion to the input signal. Figure 13-20 shows a repulsion vane voltmeter mechanism.

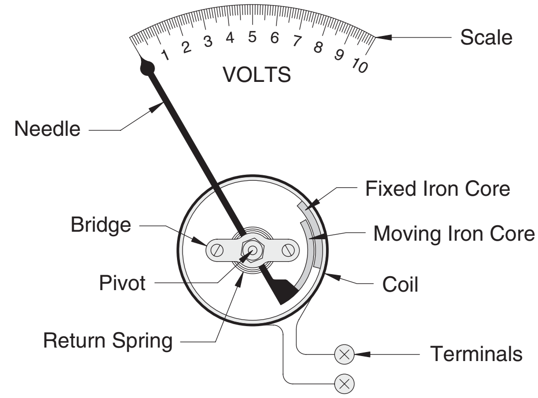

Figure 13-20 Repulsion Vane Voltmeter

Dynamometer Voltmeters

This type of voltmeter does not rely on permanent magnets or iron cores. In this arrangement, the signal itself generates the opposing magnetic fields to provide the requisite deflection. Three coils are used in the design, two are fixed and the third is a moving coil mounted in a pivot set with a clock spring. The two fixed coils are aligned so as to provide a uniform magnetic field. The moving coil is placed off-axis and in opposition to the fixed coils. When a signal is applied to the coils, the moving coil deflects in direct proportion to strength of the applied voltage. Figure 13-21 shows a dynamometer voltmeter arrangement.

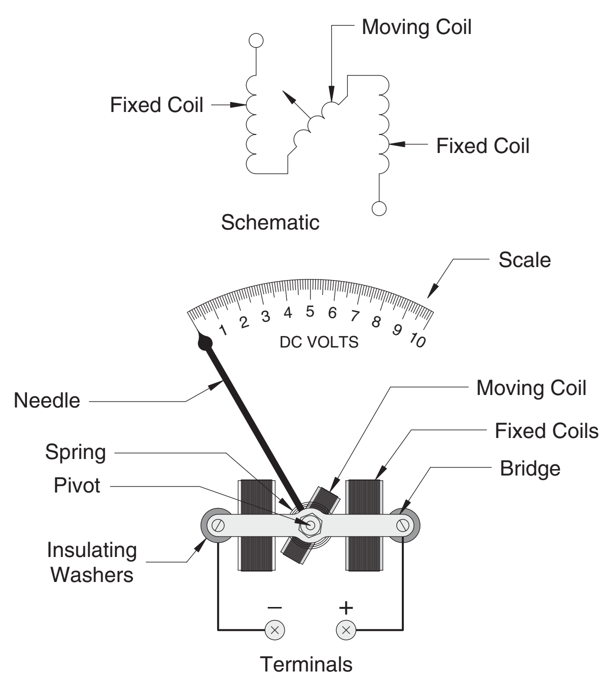

Figure 13-21 Dynamometer Voltmeter

Watt Meters

A watt meter is a dynamometer with the center coil driven independently from the two fixed coils, as shown in Figure 13-22. The moving coil is connected to the power feed, while the fixed coils are connected in series with the power source and the load. In this manner, the moving coil's deflection is based on the amount of current that the load uses while the fixed coils are based on the line voltage. Therefore, the meter indicates wattage.

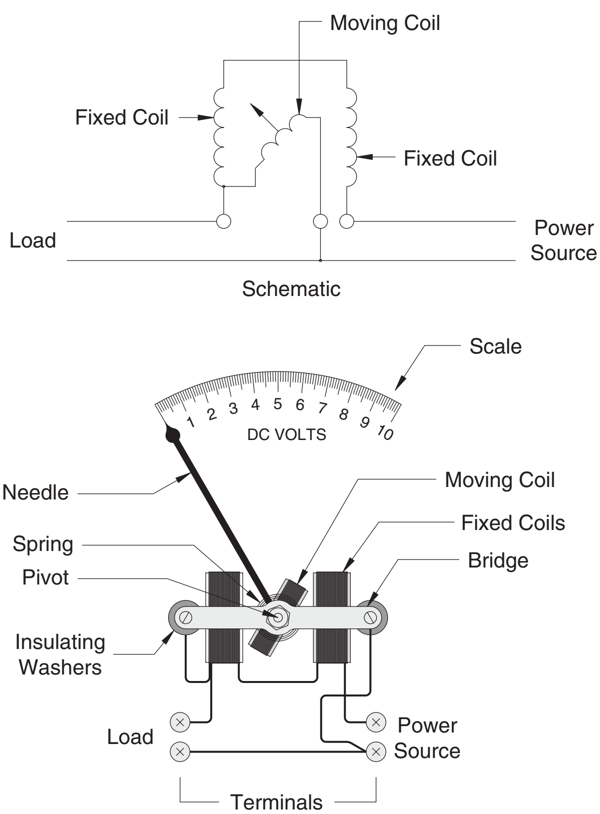

Figure 13-22 Watt Meter

Watt-Hour Meters

A watt-hour meter is effectively a watt meter with the moving coil replaced with a motor armature. The higher the load placed on the motor, the higher the speed at which the motor turns. The motor drives a totalizer mechanism that records the total wattage used during any given period. To prevent inaccurate transients, most watt-hour meters use an eddy current damper in the form of an aluminum disk with two permanent magnets. Figure 13-23 shows a stylized view of a watt-hour mechanism.

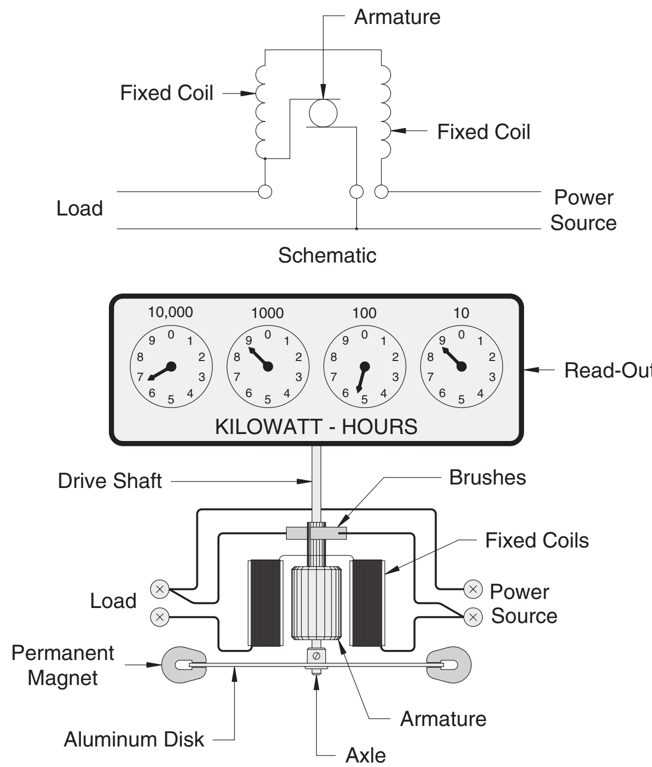

Figure 13-23 Watt-Hour Meter

Hot Wire Meters

These meters rely on the expansion and contraction of a wire element in reference to its temperature. As a current is applied to the hot wire element, as shown in Figure 13-24, it expands. The traction wire pulls the hot wire down via the preload spring and the needle deflects in reference to the expansion of the hot wire. A hot wire meter is an excellent choice for applications where a slow or averaging response to signal changes is desired.

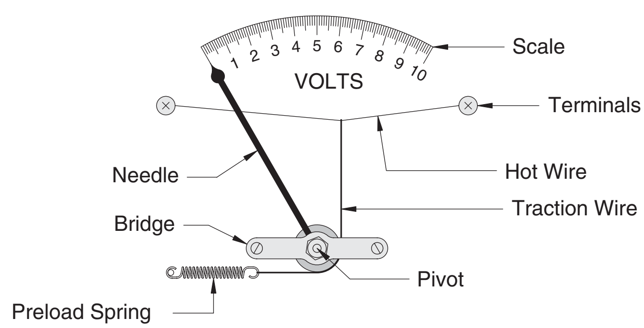

Figure 13-24 Hot Wire Meter

Multimeters

The single most important piece of electrical and electronic test equipment is the multimeter. These meters are designed to test for a broad range of voltages and values. Figure 13-25 shows a typical analog multimeter. These units have an analog meter movement, a network of matching resistors, and a selector switch housed in a compact, high-impact plastic

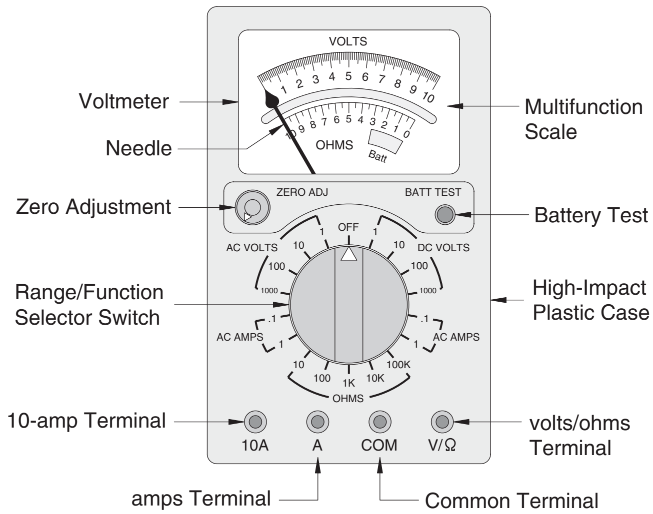

Figure 13-25 Portable Analog Multimeter

housing. They are easily placed in a toolbox or the technician's pocket.

Most multimeters will read AC volts, DC volts, AC amps, DC amps, and ohms. Many units also provide a beeper for continuity testing and a battery check function. As previously discussed, analog units will have a fairly low impedance, so sensitivity to very low voltages will be poor.

Vacuum Tube Voltmeters

Vacuum tube voltmeters, or VTVM's as they are sometimes referred to, are a type of multimeter that is designed to provide high sensitivity. Figure 13-26 shows the front panel of a

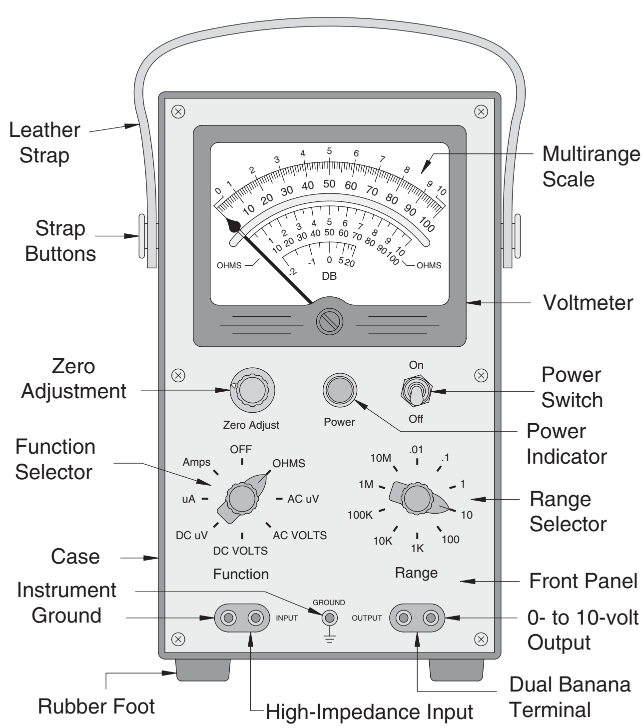

Figure 13-26 Vacuum Tube Voltmeter

typical VTVM. These meters generally have the same functions as a typical multimeter, but with boarder ranges. They also have a high input impedance and are accurate over a broad frequency range. To accomplish the broader parameters, the high input impedance and broad frequency range, these meters are equipped with an internal amplifier similar to the circuit shown in Figure 13-15. Another feature that is common to VTVM's is a 0- to 10-volt output. Regardless of the input range selected, the output mirrors a 0- to 10-volt signal. This allows easy interfacing to other instruments.

Digital Multimeters

Most modern multimeters are equipped with a digital readout, as shown in Figure 13-27. A digital multimeter combines the compactness of an analog unit with the sensitivity of a VTVM. These instruments have become very affordable and are an excellent addition to any toolbox or workbench.

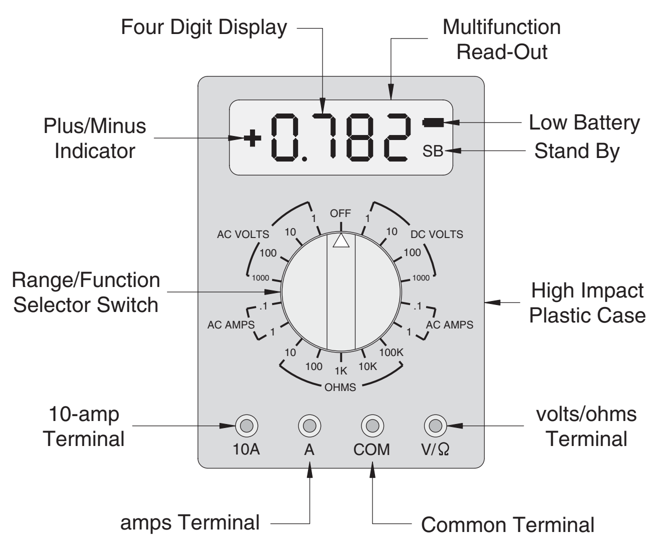

Figure 13-27 Portable Digital Multimeter

Bench Built Multimeter

Building a simple multimeter is an excellent way to gain some experience with electromechnical devices. This is a very inexpensive project that can be built in just a few evenings. In addition, when you are finished you will have a useful instrument that will provide support for future efforts.

Figure 13-28 shows a schematic and list of components for a basic analog multimeter. The meter is a 50 μA, panel mount movement with an internal resistance of 1800 ohms. The selector switch is simply a banana jumper set. The volt and ohm resistors are common 2% carbon units. The current resistors are high wattage 5% units. The battery is an ordinary 1.5-volt AA cell.

Item	Description
B1	1.5-volt Dry Cell Battery
D1	1500 PIV Diode
J1	Banana Jumper
M1	50- _a, 1.8-k ohm, Meter
P1	10-k ohm Potentiometer
R1	23 k ohm
R2	300 ohm
R3	3 k ohm
R4	20 k ohm
R5	200 k ohm
R6	2 megohm
R7	20 megohm
R8	9 ohm
R9	0.09 ohm
R10	0.009 ohm
R11	– ohm
S1	SPDT Toggle Switch

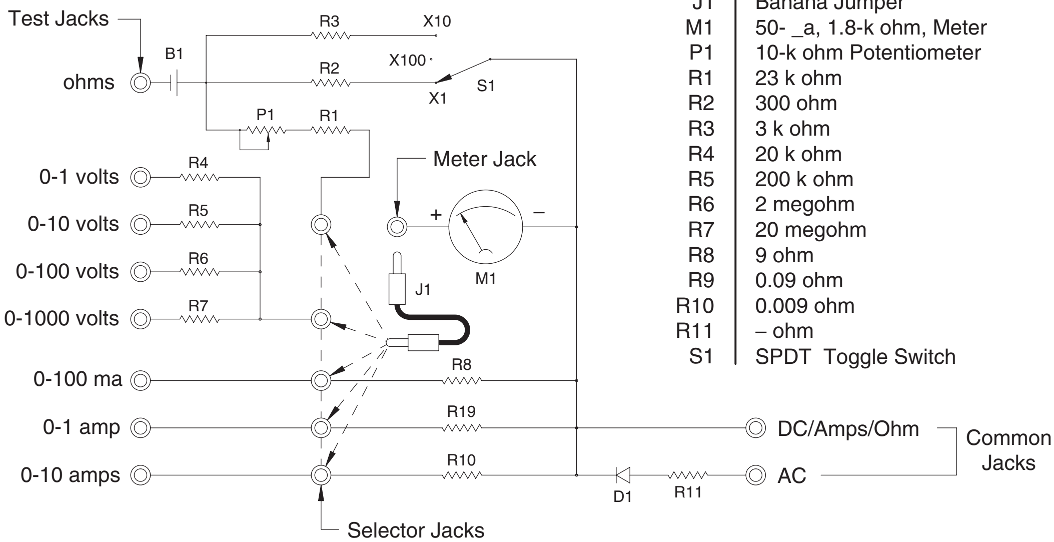

Figure 13-28 Bench Built Multimeter Schematic

Figure 13-29 shows a suggested layout for the front panel. If compactness is not a concern, then increase the size to accommodate your personal desires. The banana selector is made by mounting six panel jacks, as shown. The distance from the center jack to each outer jack should be $^3/_4$ of an inch. This spacing will allow you to use a dual banana plug as your jumper and prevent misconnection.

Figure 13-30 shows the back side of the finished panel. All of the connections are soldered except for the meter. R_{13} and R_{14} should be mounted so that there is ample clearance around them, as they may get hot during normal operation. Be certain to select a sturdy battery holder so that the cell is not knocked out when the finished meter is moved.

Figure 13-31 shows the case assembly. The top and bottom panels can be plastic or laminated Masonite. The box itself is a simple frame made from 1 inch × 2 inch #1 pine boards, held together with drywall screws.

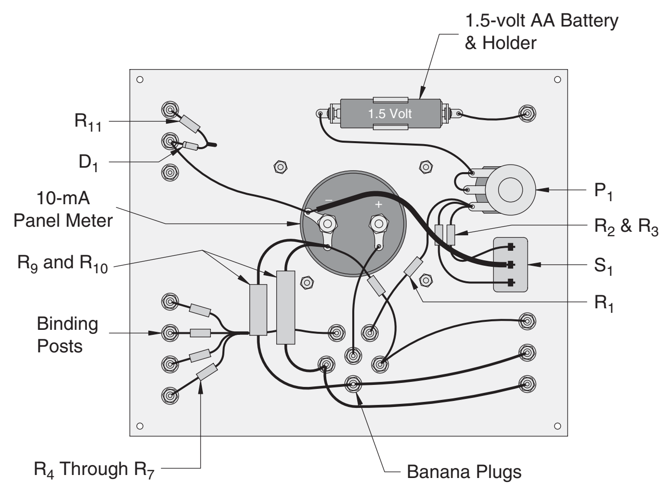

Figure 13-30 Bench Built Multimeter Panel Wiring

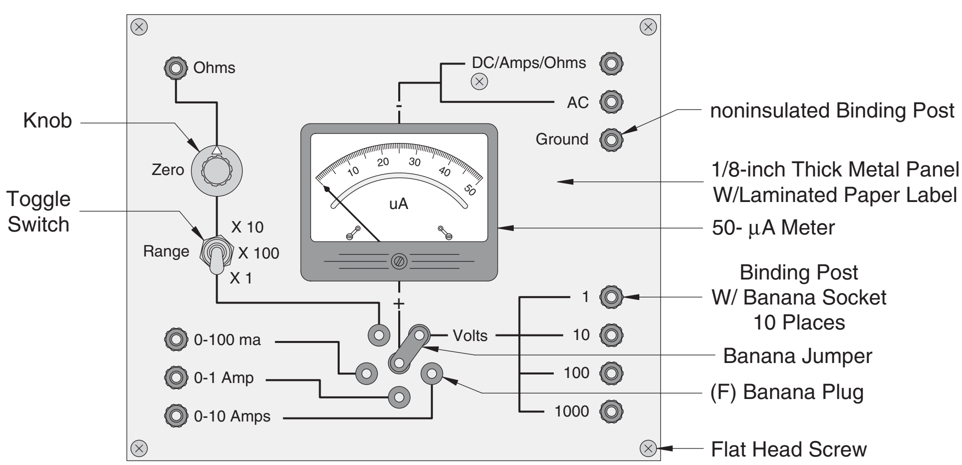

Figure 13-29 Bench Built Multimeter Panel

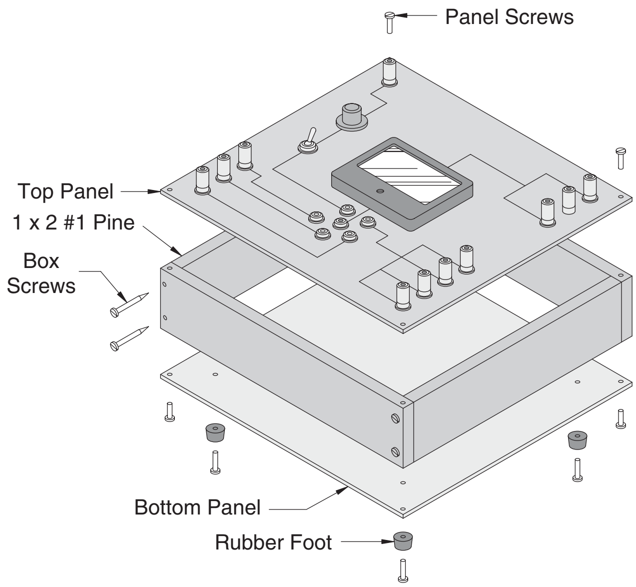

Figure 13-31 Bench Built Multimeter Cabinet Assembly

The probe set shown in Figure 13-32 is made by pressing a brass rod, with a wire soldered to one end, into a heavy-wall plastic tube. After the rod is in place use a file to sharpen the ends. The opposite ends of the leads are equipped with standard banana plugs.

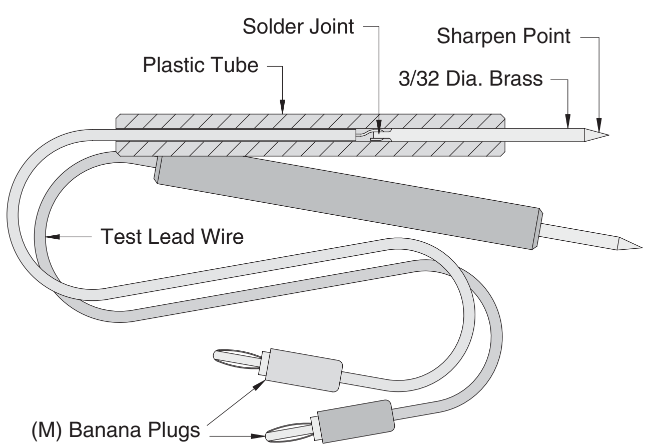

Figure 13-32 Bench Built Multimeter Test Probes

Strip Chart Recorders

For applications that require monitoring, a strip chart recorder is often used. These instruments are simply a voltmeter with an ink pen replacing the needle. A roll of paper is continuously moved under the pen and a continuous record is maintained. Strip chart recorders are generally multirange voltmeters with a speed range selector to control the paper feed. Figure 13-33 shows a typical strip chart recorder.

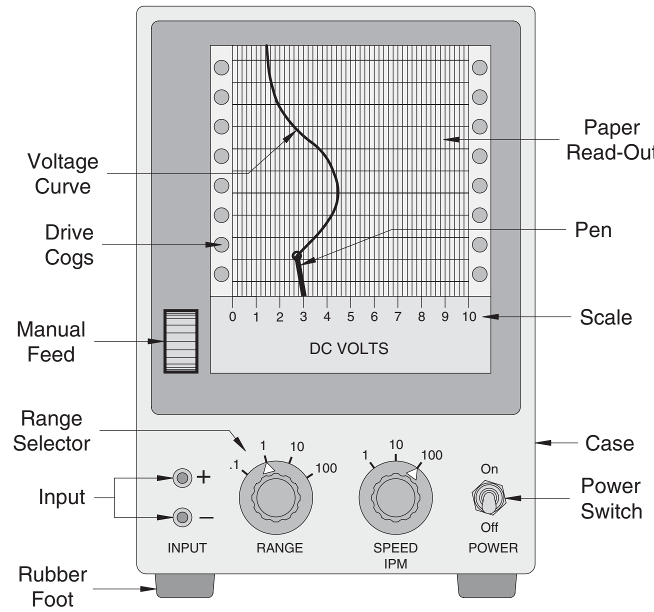

Figure 13-33 Strip Chart Recorder

Circular Chart Recorders

Another type of recording instrument is the circular chart recorder. These recorders provide the same function as a strip chart unit, except that they are generally used for long-term monitoring. Speeds on the units are usually in hours, days, and/or weeks. Figure 13-34 shows a typical circular chart recorder.

Because of the internal mechanism, chart recorders are not particularly sensitive. To monitor lower level signals some sort of amplifier is required. Figure 13-35 shows a strip chart recorder being driven from the 0-to 10-volt output of an ordinary VTVM.

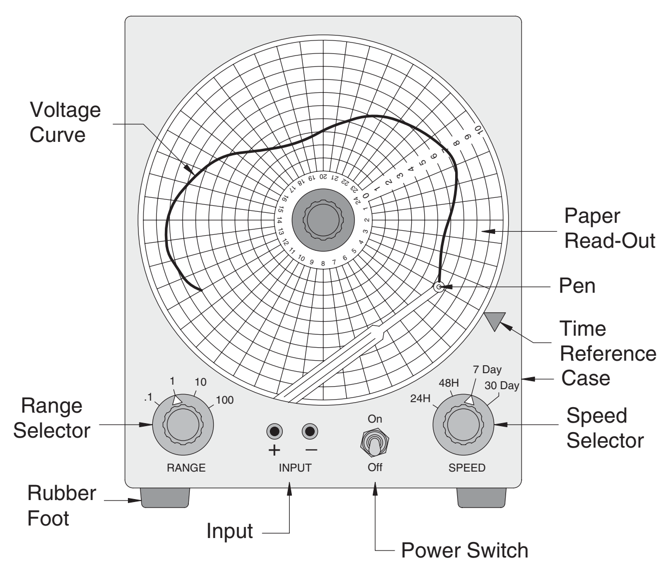

Figure 13-34 Circular Chart Recorder

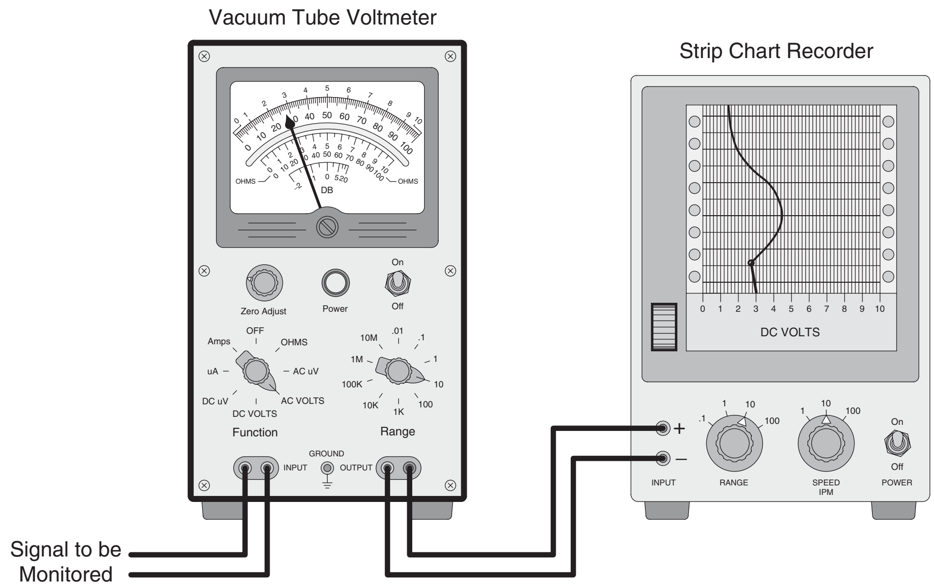

Figure 13-35 Using a Strip Chart Recorder with a Vacuum Tube Voltmeter

Meter Accessories

A basic probe set is by far the most important accessory that any meter can have. An ordinary probe set, as shown in Figure 13-32, can be built or purchased and will provide suitable performance for most situations. A better choice is a commercial set with interchangeable tips, as shown in Figure 13-36. The variety of tips provides better access to intricate circuits and hands-off use.

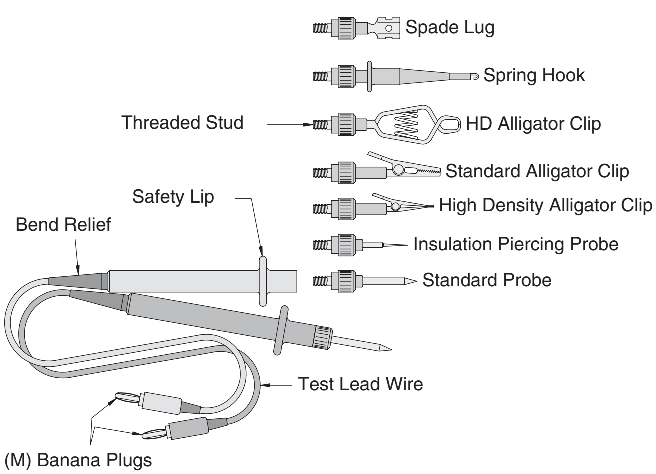

Figure 13-36 Multi Purpose Test Probe Set

The high-voltage probe shown in Figure 13-37 is used to gauge voltages in excess of the meter's range. These probes use a dropping resistor in the head of the body that generally drops the output voltage to 1 volt per 1000. That is to say that if the probe is connected to an 8000-volt source the meter will

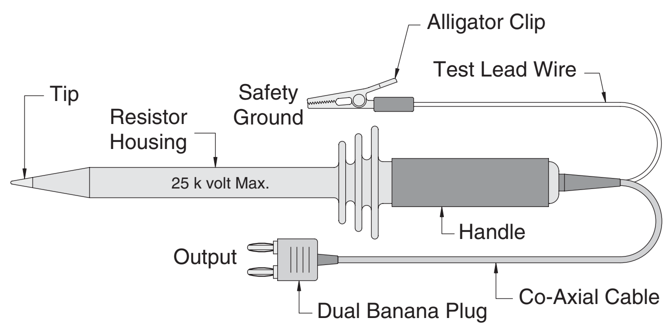

Figure 13-37 High-Voltage Probe

read 8 volts. Before using a high-voltage probe, it should be carefully inspected for any damage and should be clean. If the probe is damaged in any way, it should be immediately discarded. A high-voltage probe with even a small crack in the housing can be lethal. Always follow the manufacturer's recommendations when using high-voltage probes.

A clamp-on AC current probe, as shown in Figure 13-38, is an excellent accessory for any multimeter. These units make reading current very easy. Simply clamp the jaws around the wire to be surveyed and read the voltage on the meter. Generally, these units output 1 volt per amp. It should be noted that at maximum current, the voltage at the banana plugs can be dangerously high and great care should be taken not to disconnect the probe from the meter while the head is clamped onto a cable.

Figure 13-39 shows a schematic representation of a current probe. The jaw set is actually the core of a transformer. The primary is the cable being measured and the secondary provides the output signal. It should be noted that if the cable is looped twice around the core, the output voltage will double.

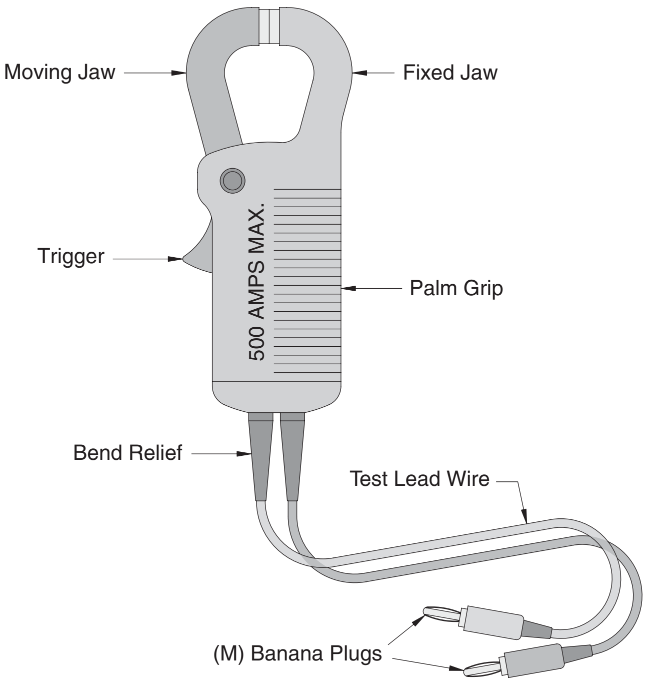

Figure 13-38 Inductive Pickup

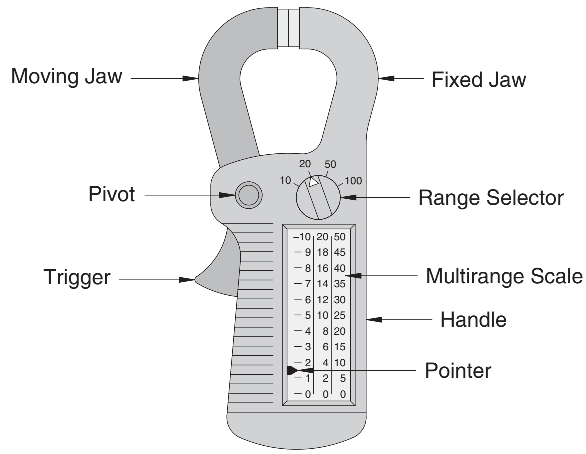

Figure 13-40 Hand Held Inductive Current Meter

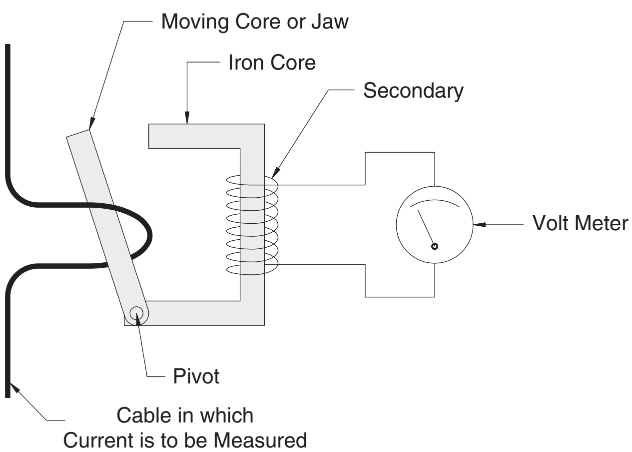

Figure 13-39 Inductive Pickup Schematic

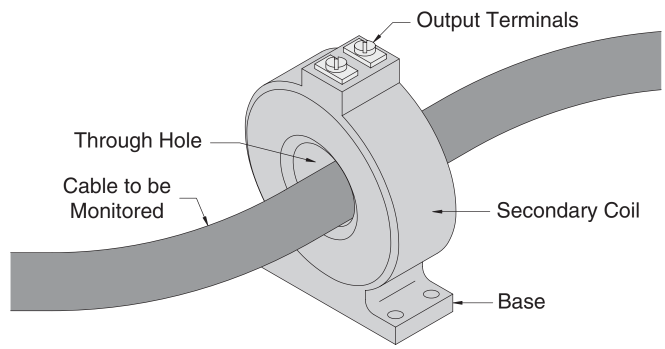

Figure 13-41 Commercial Current Transformer

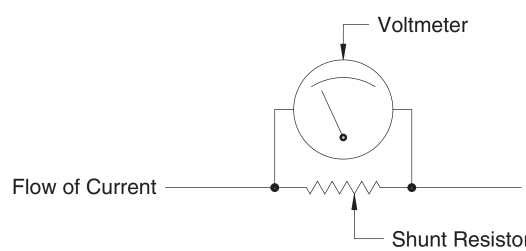

Figure 13-42 Current Shunt Schematic

Current probes that are complete, self-contained instruments are available, as shown in Figure 13-40. These instruments are very popular with technicians in most industries and are used to gauge the performance of all types of equipment.

For fixed applications, component current transformers are available, as shown in Figure 13-41. In this case, the current transformer is mounted in a location appropriate to conveniently route the high-current cable in the through hole. The output of the transformer is wired to a remote voltmeter. Using these devices throughout a plant, and routing their outputs to a central location, allows one technician to monitor a rather substantial facility.

Using a voltmeter to read amps is as simple as adding a shunt resistor, as shown in Figure 13-42. Oftentimes the real problem is finding a resistor with a low enough resistance and a high enough current capacity to do the job.

Figure 13-43 shows a typical commercial current shunt. These shunts are delivered with meter terminals that are properly spaced on the resistor. The shunt should also specify the volts per amp it is designed to output. For high current shunts this is usually 0.1 volts per amp. Therefore, a 600-amp shunt would output 0 to 60 volts.

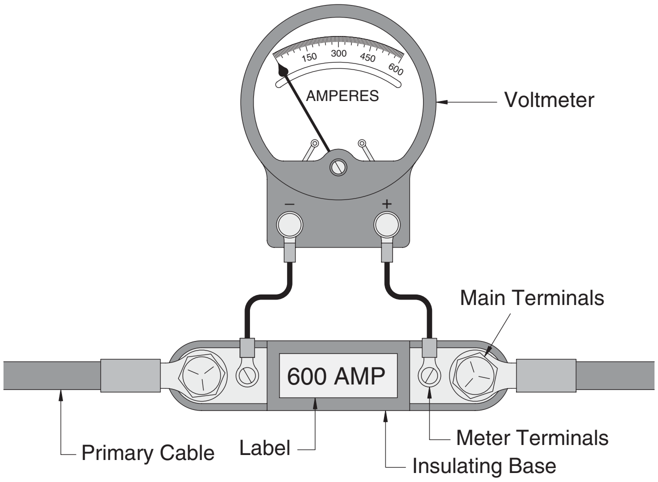

Figure 13-43 Commercial Current Shunt

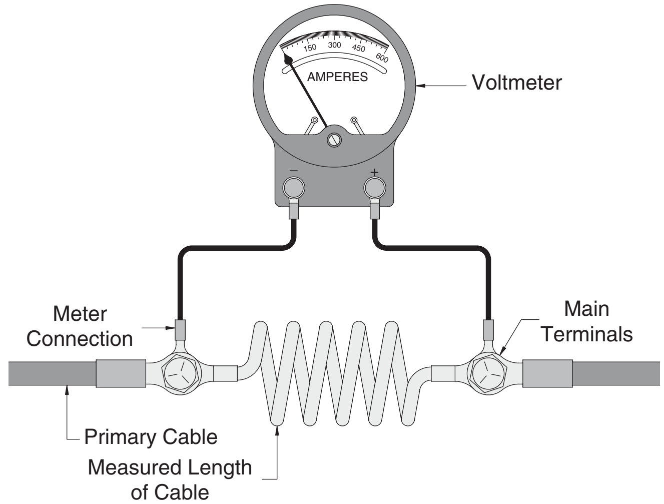

Figure 13-45 Cable Shunt

A shunt may be constructed using a copper buss bar, as shown in Figure 13-44. A voltage drop over the spacing of the meter terminals is calculated in reference to the resistance of the copper buss bar and an appropriate meter is selected. This type of shunt is often used for extremely high-current applications.

A measured length of cable can also act as a current shunt. Figure 13-45 shows a piece of coiled cable acting as a shunt. Like the buss bar shunt, this arrangement is generally reserved for extremely high-current applications.

Continuity Testers

Continuity testing is probably the most common test conducted on electrical and electronic equipment. It is an indispensable technique, which verifies the electrical soundness of a conductor. Continuity testing is also used extensively to trace and diagnose circuits.

Figure 13-46 shows two common commercial continuity testers. The combination flashlight and continuity tester is a popular tool among industrial service technicians. The basic tester is a very handy device when working in cramped environments. In both of these units, a battery is connected to a light bulb and a pair of test leads. When the test leads are touched together, the lamp turns on.

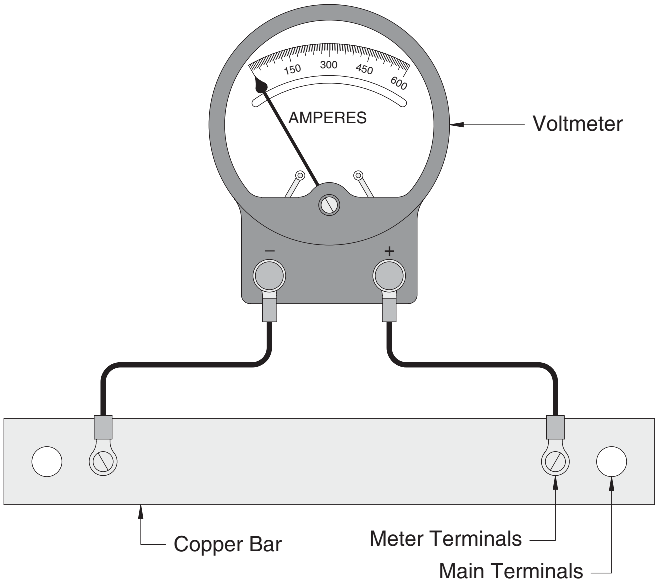

Figure 13-44 Buss Bar Shunt

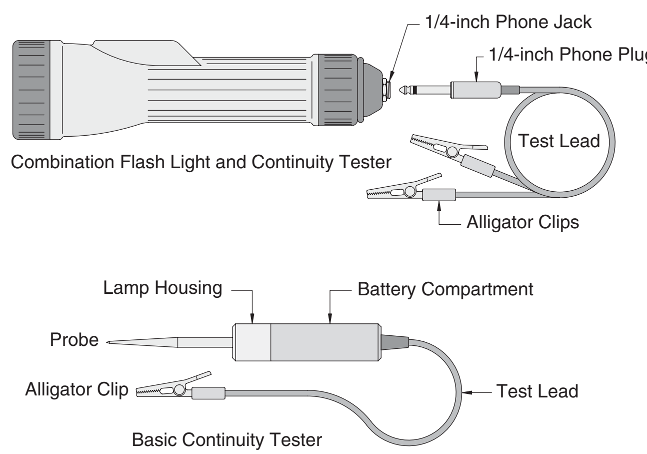

Figure 13-46 Continuity Testers

A basic continuity tester can be easily built by mounting a lamp base and battery holder onto a baseboard, as shown in Figure 13-47. The test leads are connected with banana plugs and combination binding posts. This provides for the use of the finished instrument in semipermanent applications on the bench.

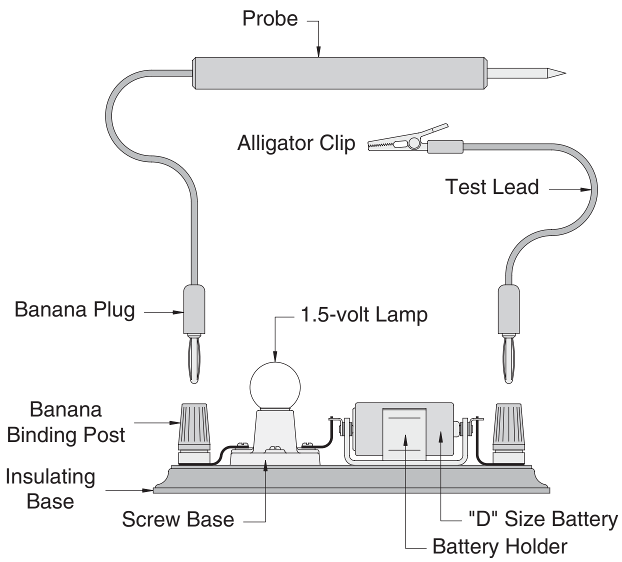

Figure 13-47 Bench Built Continuity Tester

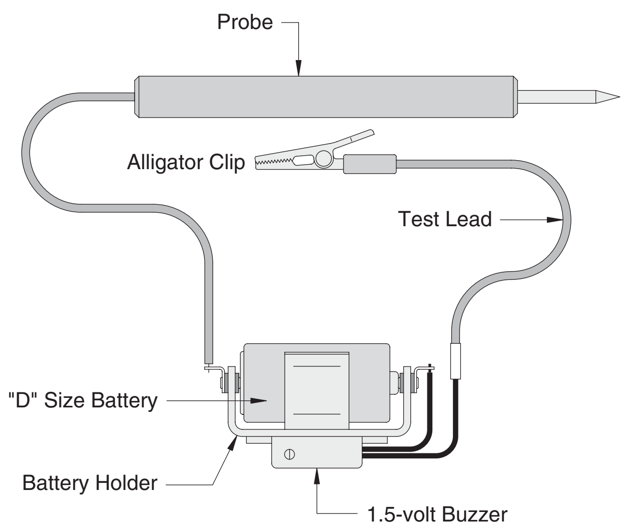

Figure 13-48 Bench Built Continuity Tester with Buzzer

Figure 13-48 shows a continuity tester made from a battery holder and audible buzzer. Instead of relying on a visual indicator, the buzzer alerts the technician of continuity.

Power Indicators

Power indicators are very inexpensive and quite handy to have in your pocket or toolbox. These devices allow a technician to quickly determine whether or not a circuit has power. Figure 13-49 shows three common commercial power indicators, a single voltage unit, a dual voltage unit, and dual voltage unit with a ground fault indicator.

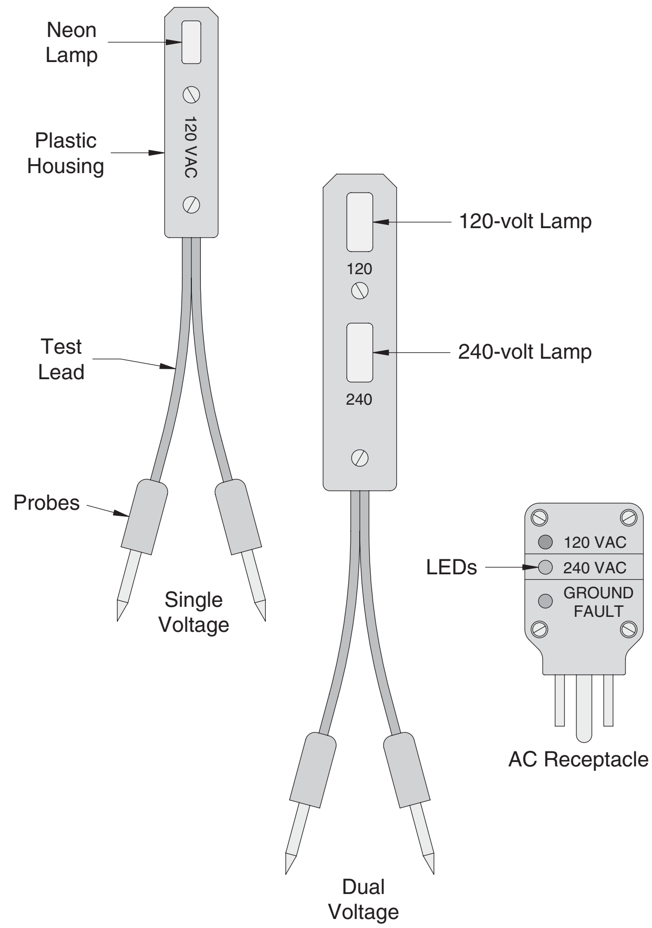

Figure 13-49 Power Indicators

In days gone by, technicians often used what they referred to as a service light. This device is simple a rubberized screw base with a 40-watt incandescent light bulb. The socket is equipped with a cage to protect the bulb and the base is wired to two probes. Figure 13-50 shows a typical, bench built, service light.

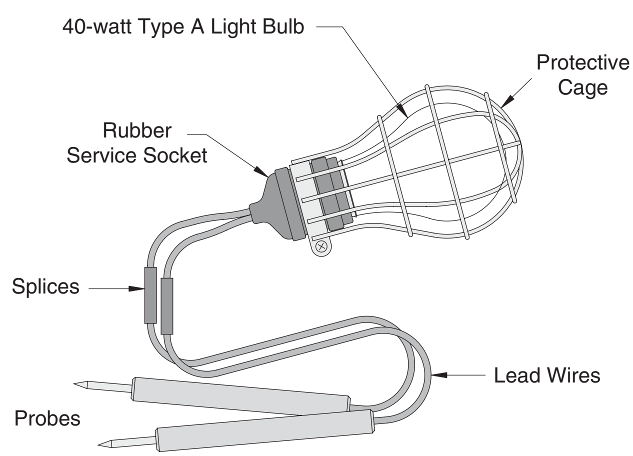

Figure 13-50 Bench Built Power Indicator or Service Light

Capacitor Function Test

An analog multimeter can be used to perform a basic test on a capacitor, as shown in Figure 13-51. The meter is set to ohms and one probe is clipped to one lead on the capacitor to be tested. When the other probe is touched to the opposite lead, the needle on the meter will jump up and then settle back down towards zero. This indicates that the internal resistance of the capacitor is initially nearly zero and, as it charges, the resistance climbs to a higher value. This is only a relative test and is not suitable for determining the actual value of the capacitor.

Measuring Resistance

Using a multimeter to measure resistance is a simple matter. Figure 13-52 shows a basic resistance test. The meter is set to an appropriate Ohms scale and the probes are connected to the leads of the resistor. The resistance reads out in ohms on the meter.

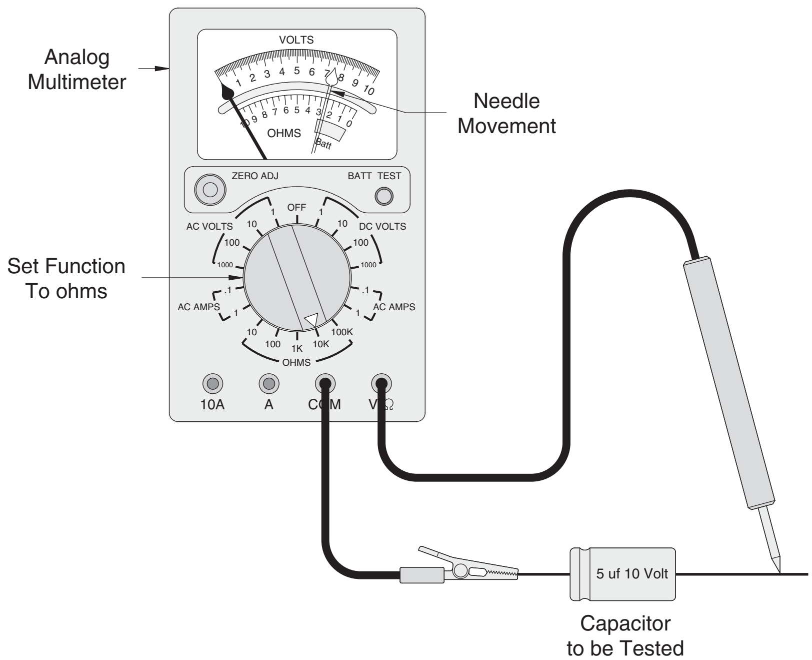

Figure 13-51 Basic Capacitor Function Test

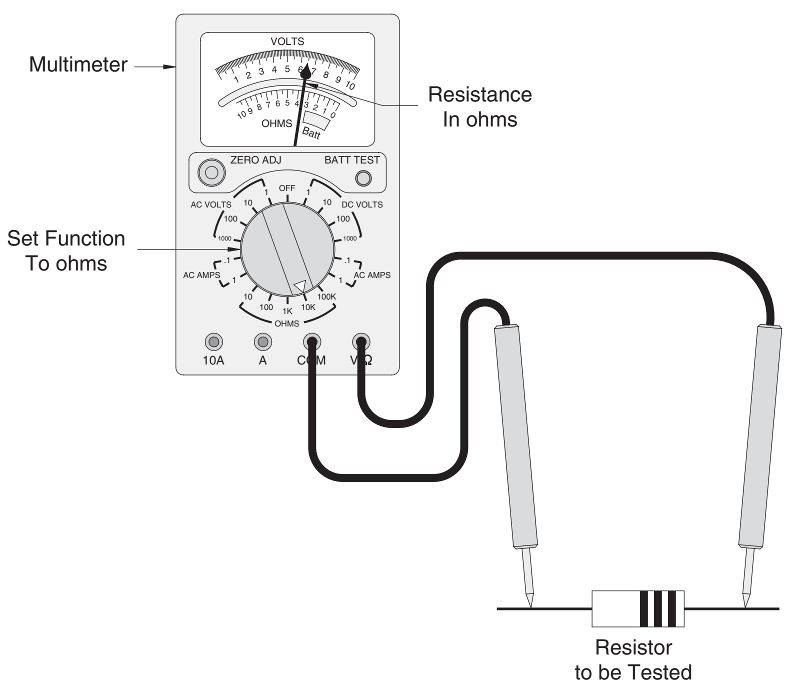

Figure 13-52 Measuring a Resistor

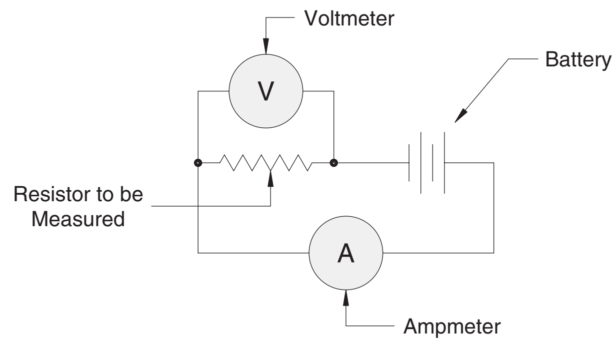

Figure 13-53 Measuring Resistance with an Amp and Voltmeter

Another method to measure resistance is by measuring the current and voltage drop across a resistor and calculating the resistance using Ohm's law, as outlined in Chapter 1. Figure 13-53 shows a schematic for a current/voltage resistance measurement.

The Wheatstone Bridge

For more accurate resistance measurements, a Wheatstone bridge can be utilized, as shown in the schematic of Figure 13-54. The Wheatstone bridge is comprised of four resistors arranged in a closed pattern. Two of the resistors are of known value, one resistor is variable, and the fourth resistor is the device to be tested. A voltmeter is set up to bridge the junction between the known resistors and the junction between the variable and unknown resistors. When a voltage is applied across the junction between the known and variable resistors, and between the known and unknown resistors, current flows through the bridge. The voltmeter will deflect in direct proportion to the imbalance in resistance between the known resistors and the variable/unknown resistors. By adjusting the resistance of the variable resistor until the voltmeter reads zero, it can be matched to the unknown resistor. The resistance reading of the variable unit is then equal to the resistance of the unknown unit.

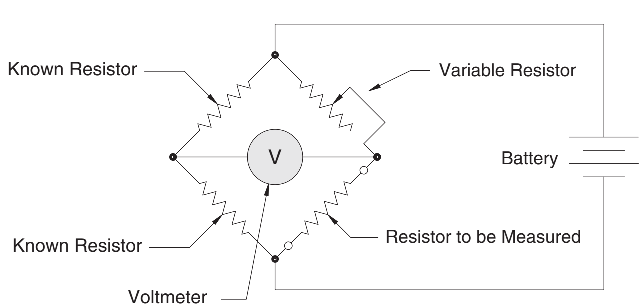

Figure 13-54 Measuring Resistance with a Wheatstone Bridge

Normally a decade resistance box, as discussed in Chapter 4, is set up as one of the known resistors. In this manner, the range of the bridge can easily be adjusted. The variable resistor is generally a calibrated test unit. Using a digital multimeter and progressively selecting lower voltage ranges can make an extremely accurate measurement.

The SlideWire Bridge

A slide wire bridge is a high accuracy version of the Wheatstone bridge. Figure 13-55 shows a schematic representation of a slide wire bridge. Like the Wheatstone bridge, the known resistor is usually a decade resistance box. The unknown resistor is placed opposite the known resistor. The upper known and variable resistors are replaced with a slide wire. A slide wire usually consists of a 36-inch length of resistance wire, a sliding contact, and a scale. The resistance of the slide wire, and thus the balance of the bridge, is adjusted by moving the contact along the scale. This arrangement provides an extremely accurate method for measuring resistance.

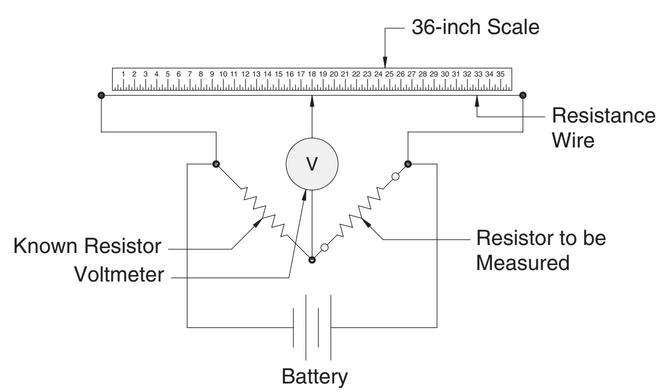

Figure 13-55 Measuring Resistance with a Slide-Wire Bridge

Other Useful Test Equipment

Although most electromechnical equipment can be gauged with a continuity tester, power indicator, or multimeter, there are times that more sophisticated test equipment must be utilized. The following briefly reviews some of the more common instruments and how they may be applied.

Circuit Tracers

Circuit tracers are instruments that are used to follow and map a signal through a live circuit. The most fundamental circuit tracer is a set of headphones that is equipped with a capacitor, as shown in Figure 13-56. The alligator clip is connected to the common and the lead from the capacitor is used to probe

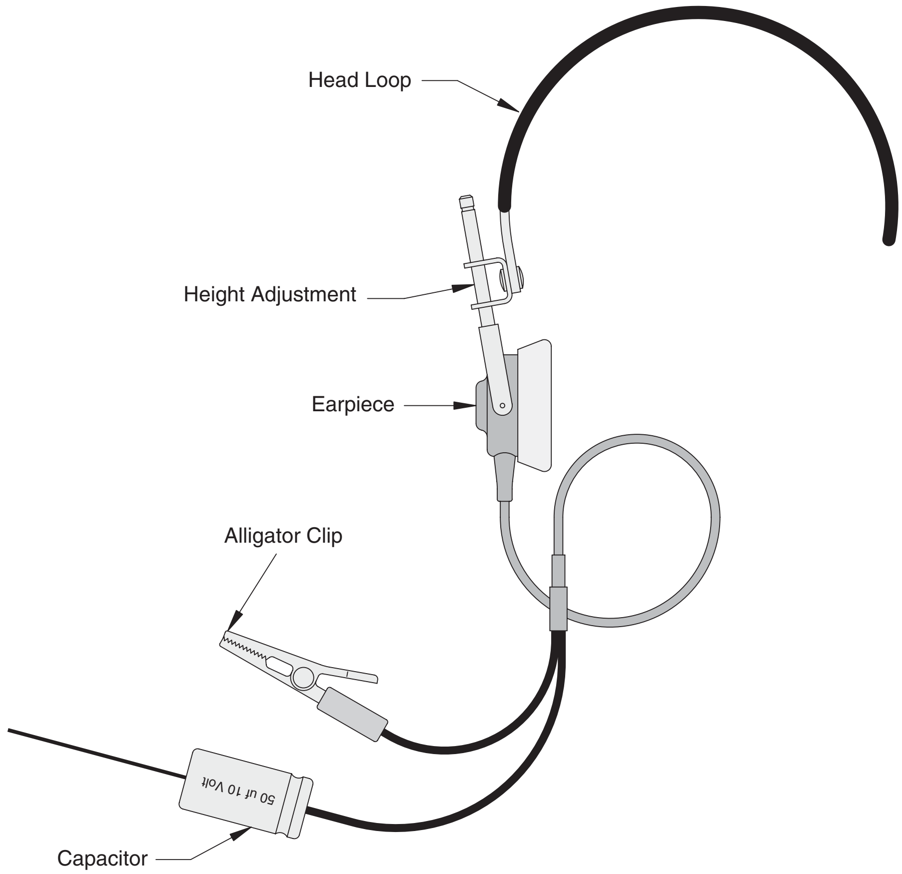

Figure 13-56 Head Set Circuit Tracer

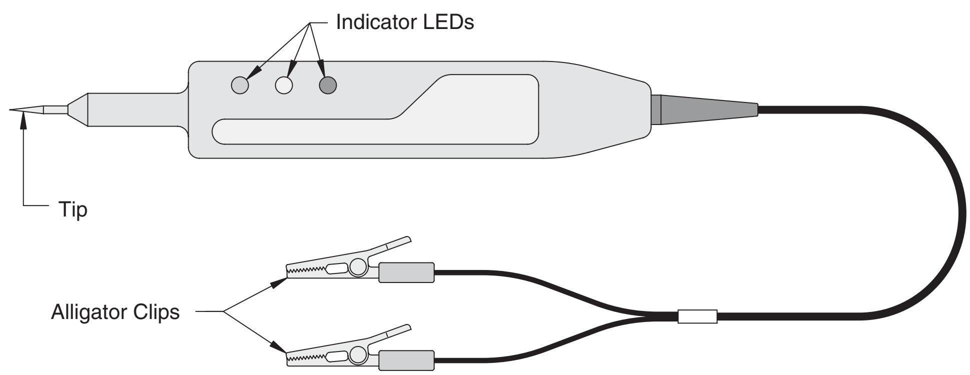

Figure 13-57 Logic Probe

the circuit. The capacitor's function is to protect the headphones from being damaged by high-powered signals.

Logic Probes

Logic probes are circuit tracers that are specifically designed to operate with digital circuitry. Figure 13-57 shows a typical logic probe.

Oscilloscopes

An oscilloscope is literally a television that allows the technician to view the particulars of an electrical signal. These instruments are invaluable tools in the electronics industry, allowing detailed analysis of complex signal and waveforms. Figure 13-58 shows a typical commercial oscilloscope.

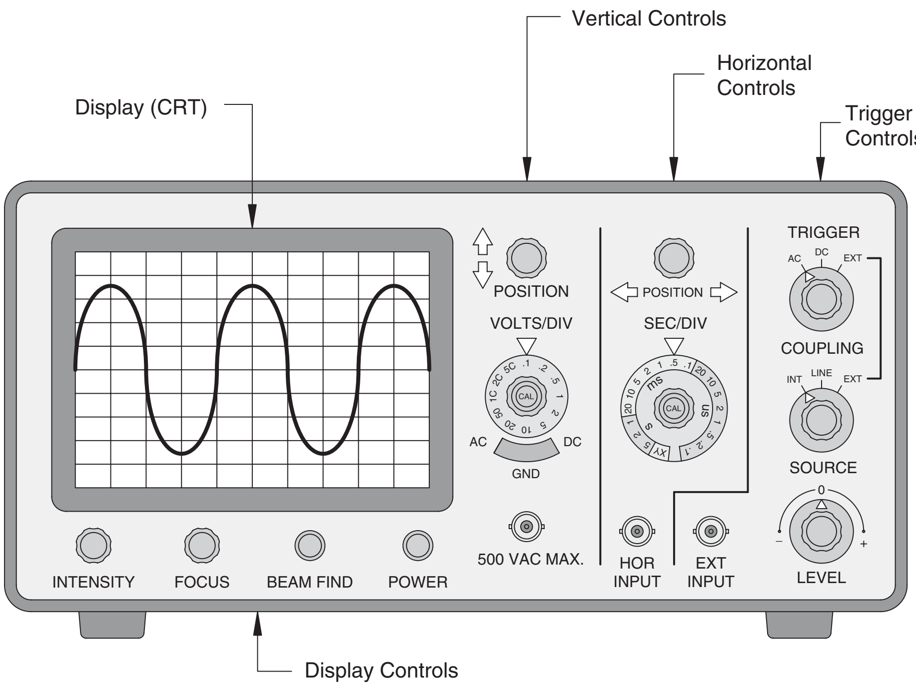

Figure 13-58 Oscilloscope

Sine Wave Generators

These instruments are used to generate a standard sine wave at any frequency that the technician may desire. The sine wave is the base waveform for power generation, audio equipment, and motor controllers. Figure 13-59 shows a typical bench type sine wave generator

Function Generators

The function generator takes the sine wave generator a step further. These instruments will produce several waveforms and any frequency that the technician may desire. Standard waveforms that a typical function generator will produce are sine, triangle, sawtooth, and square. Figure 13-60 shows a typical commercial function generator.

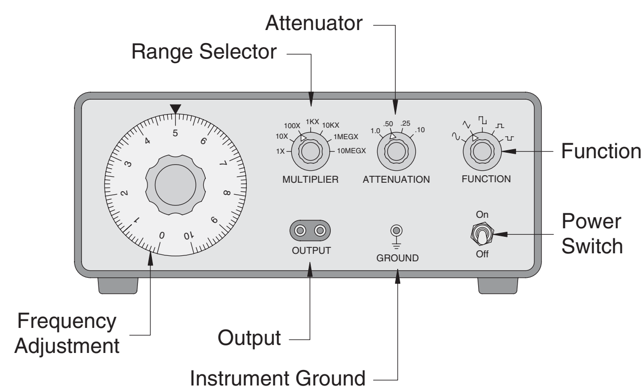

Figure 13-60 Function Generator

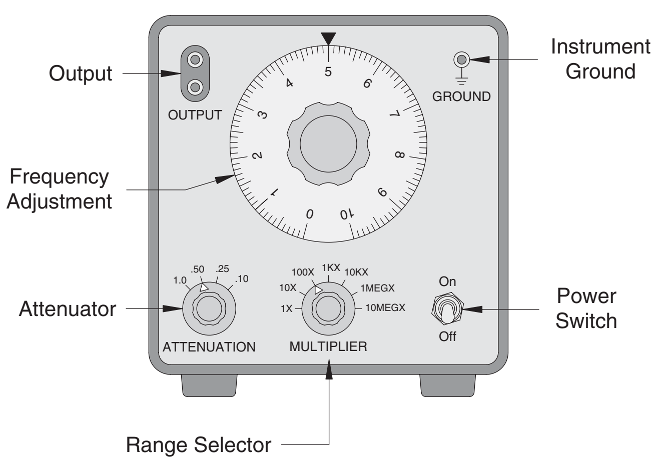

Figure 13-59 Sine Wave Generator

Frequency Counters

In some applications, principally radio frequency (RF) and digital, it is necessary to determine the frequency at which a circuit is operating. In these cases a frequency counter, as shown in Figure 13-61, is used. These instruments generally have an LED (light emitting diode) display that provides a direct frequency reading.

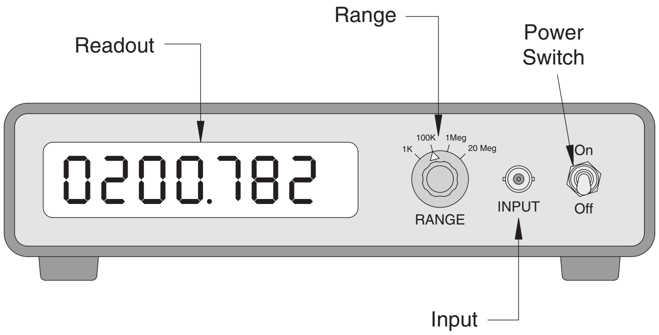

Figure 13-61 Frequency Counter

Insulation Testers (Meggers)

Insulation testers, or meggers as they are sometimes referred to, are used to test and verify the effectiveness of electrical insulation and isolation. These units have a high-voltage generator and a meter that displays the leakage of the voltage across the insulation being tested. The leakage can be directly converted into ohms and the gauge will normally read in megohms. Figure 13-62 shows a typical insulation tester. It should be noted that while crank sets are quite common; these instruments are also available with battery powered high-voltage supplies.

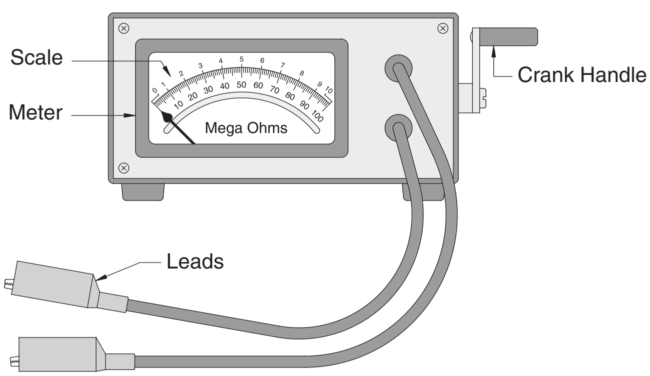

Figure 13-62 Insulation Tester (Megger)

Sound Level Meters

Various industrial, public address, theater, and home audio applications can benefit from the ability to gauge the output level of sound producing equipment. To accomplish this, a sound level meter, as shown in Figure 13-63, is commonly used. These instruments consist of a microphone, amplifier, and readout packaged in a single unit. The readout is in decibels (dB). Most sound level meters are also equipped with a fast/slow response switch and A and B weighting selector. The range is selected until the needle is as near to zero as possible. The value off zero is either added or subtracted from the selected range value to provide the sound level.

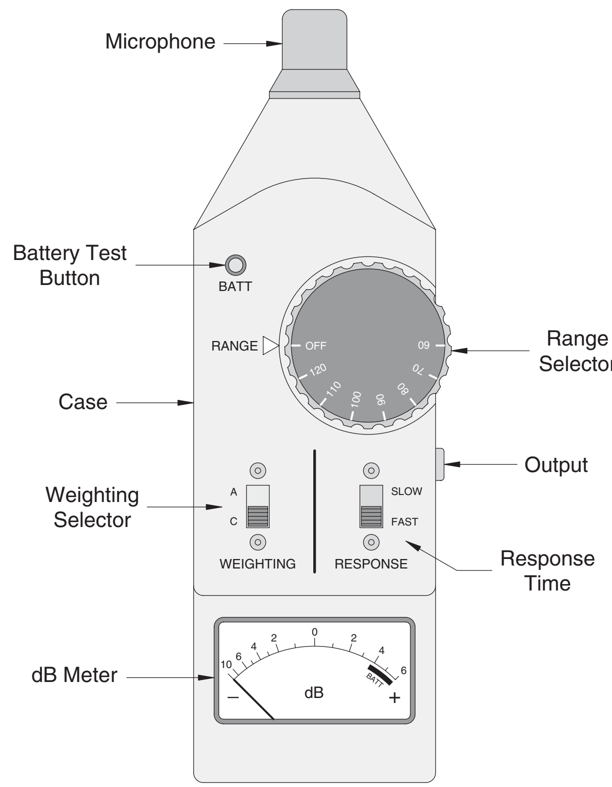

Figure 13-63 Sound Level Meter