Electrical Tech Note — 214

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MEASURING VOLTAGE, RESISTANCE AND CURRENT

A digital multimeter is the most common tool for measuring voltage and resistance. The typical multimeter can make both ac and dc measurements. It can usually measure voltage, resistance, and low levels of electrical current. For practical applications in the field a clamp-on ammeter is generally used to measure ac current. Proper use of these meters to measure voltage, resistance, and current is discussed using common digital meters. Most brands of digital meters work in a similar manner.

Making a Voltage Measurement: To make an ac voltage measurement, turn the selector dial on the meter to the position with a sine wave above the V as shown in Figure 214.1. The letters VAC will appear in the upper right hand corner of the multimeter indicator screen. Direct current circuit voltage measurements are made with the selector switch pointing to the position with a straight line above the V. Make sure all voltage measurements are within the withstand rating of the meter. Digital voltmeters are usually auto-ranging. This means the meter has several internal ranges available, and the meter will automatically select the lowest range possible to make the measurement. Selecting the lowest possible range will insure the greatest accuracy of measurement.

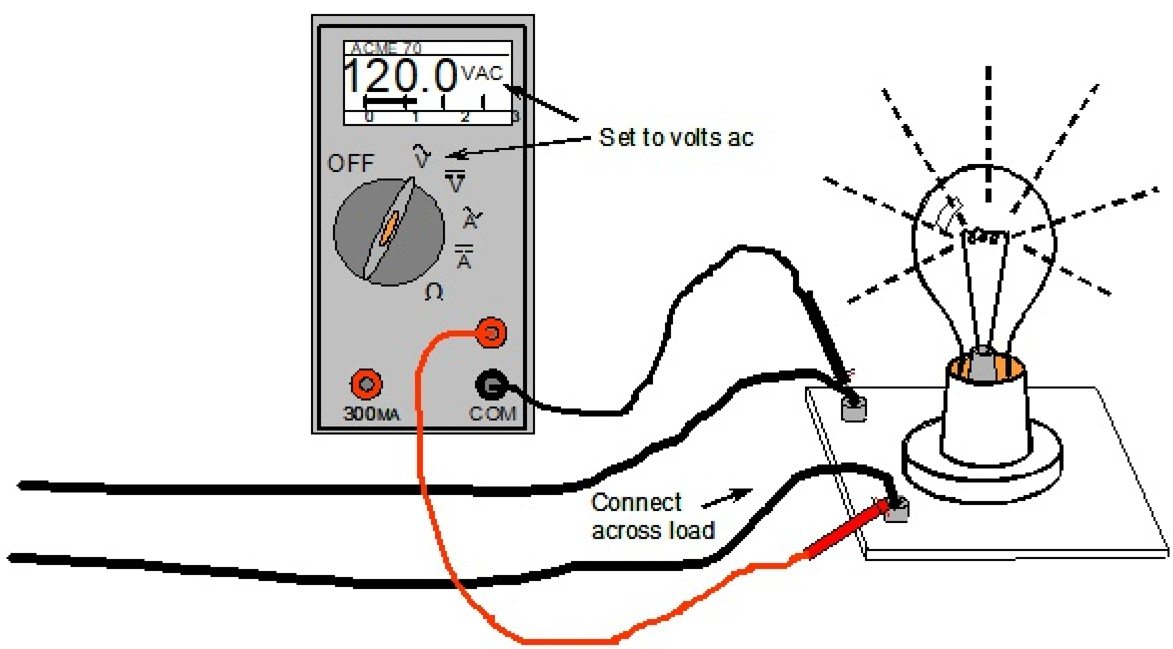

Figure 214.1 Voltage of a lamp or other electrical equipment is measured by touching both wires with the probes of the voltmeter.

A voltmeter has a high internal resistance and can be connected directly across a circuit as long as the circuit voltage does not exceed the withstand rating of the meter. Measure voltage by touching one circuit terminal with one meter probe and the other circuit terminal with the other meter probe. When taking ac voltage readings, it does not matter which probe touches which terminal. (For dc voltage, the red is positive and the black is negative) Figure 214.1 shows the proper way to measure voltage across a light bulb in a circuit.

When making a voltage measurement an analog scale will appear along the bottom of the readout screen. This analog scale will indicate how high the voltage reading is on the particular range being used by the meter. If the reading is near the top of the range, the analog bar will extend all the way to the right of the readout screen. When the analog bar is less than 20% from the bottom of the scale (left hand side), the reading will be less accurate. The digital voltmeter readout screen is shown in Figure 214.2. The digital value on the voltmeter screen is the root mean square (rms) value of the voltage sine wave. Many digital voltmeters set to the ac voltage scale assume the voltage is a sine wave. If the voltage input to the meter is distorted and not a sine wave the reading on the screen is probably not accurate. When measuring voltage of a typical ac circuit, generally the wave distortion is minimal and the error in the reading is small. A voltmeter marked "true rms" will give an accurate reading of rms voltage even when the voltage wave is not a true sine wave.

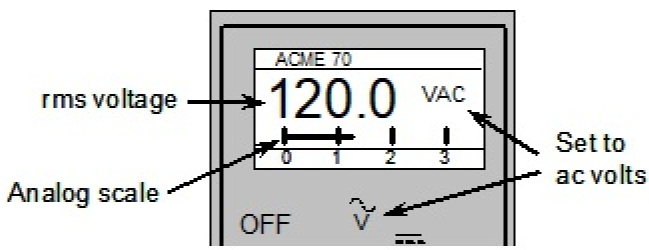

Figure 214.2. The digital readout is the rms value of the ac voltage wave and the analog scale at the bottom of the screen indicates how much of the particular voltage range is being used for the value being measured.

Making a Resistance Measurement: The multimeter can be used to make a resistance measurement, but there is a caution. Disconnect power to the circuit. Connect the circuit or component in the circuit to the ohmmeter. The meter has a battery that will pass current through the circuit or component. Set the meter selector to the resistance position which may say Ohms or it may give the symbol for resistance Ω. A resistance measurement is illustrated in Figure 214.3. The symbol M on the readout screen means millions of ohms. The symbol k on the readout screen means thousands of ohms. When finished making a resistance measurement, turn the meter off to save the battery.

The resistance of an electrical component is highly dependant upon the temperature. A resistance measurement made at room temperature may not be an accurate determination of the resistance of a circuit in operation. An example is an incandescent lamp. When measured at room temperature the resistance of the lamp will be much less than when the lamp is operating and the filament is hot. The resistance of the lamp cannot be measured directly when the circuit is energized, so the resistance must be determined by another method. For an incandescent lamp the current through the lamp and the voltage across the lamp can be measured. Then Ohm's law can be used to calculate the resistance of the lamp when it is operating. A similar technique can be used to determine the impedance of an inductive load such as a motor, but the method is more difficult.

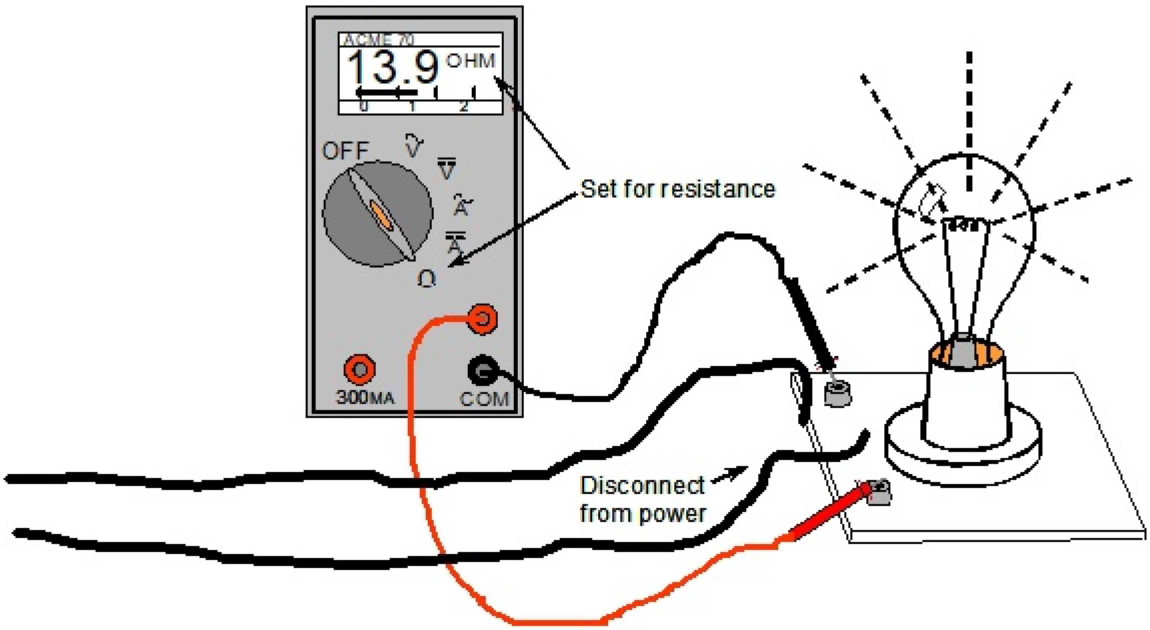

Figure 214.3. Disconnect power from the circuit and connect the component for which resistance is desired to the meter.

How to Use a Clamp-on Ammeter: Electrical current flowing in a wire produces a magnetic field to build up around the wire. With alternating current this magnetic field is in constant motion which means it can be detected by a coil placed around the wire The more current that flows in the wire, the stronger the magnetic field. A device called a clamp-on ammeter can be used to measure the current flowing in a wire by clamping the jaws around one of the circuit wires. The clamp-on ammeter measures the current by measuring the strength of the magnetic field around the wire. A typical clamp-on ammeter is shown in Figure 214.4. Digital clamp-on ammeters are usually auto-ranging. They start with the highest range and work down to the lowest range sufficient to measure the current flow. This process takes several seconds. Sometimes it will be necessary to set the ammeter to the correct range in advance. There is a range button on the meter for this purpose.

Electronic equipment tends to cause a distortion of the sine wave current in an ac circuit. It is not uncommon for the current flow to be of some form other than a sine wave. When the current is not a sine wave, the ammeter must be of the “true rms” type in order to obtain an accurate measurement of current. See Tech Note 231 for more about sine wave distortion.

Digital ammeters frequently have an analog scale at the bottom of the readout screen. This scale is particularly useful in determining how high the current reading is on the particular range being used for the measurement. Any time the current is less than 20% of the range being used, the reading is likely to be inaccurate. Most clamp-on ammeters are inaccurate when measuring a small fraction of an ampere. There are clamp-on ammeters that will accurately measure current flow even to a fraction of a milliampere (less than 1 mA). When making current measurements expected to be less than 0.1 ampere, make sure the ammeter is suited for such measurements.

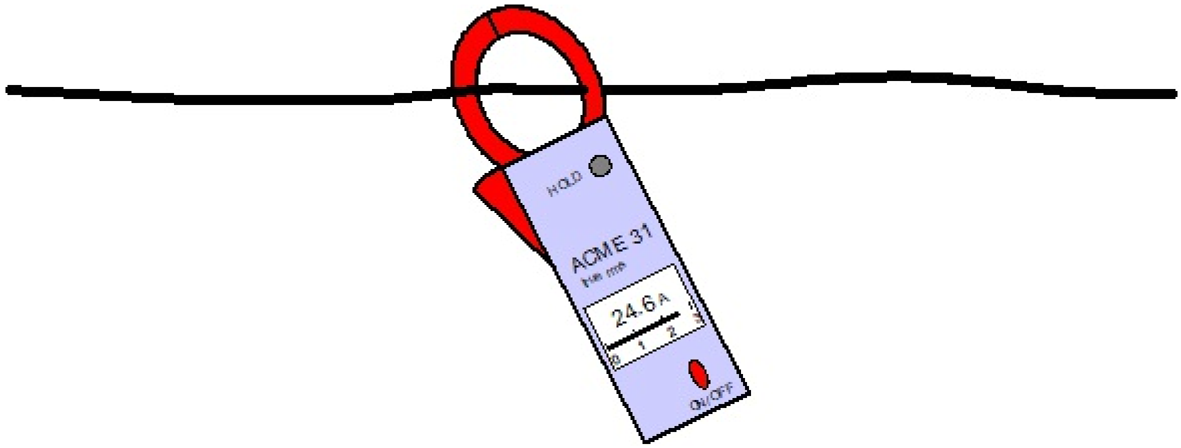

Figure 214.4 A clamp-on ammeter can be used to measure the electrical current in amperes flowing in a wire.

It is important to know how to properly use a clamp-on ammeter. Refer to Figure 214.5 for the proper method of measuring current in an ac circuit. Place **only one** of the circuit wires through the jaws of the clamp-on ammeter. The current in one of the circuit wires is flowing in the opposite direction of the current flowing in the other wire. If both wires pass through the jaws of the clamp-on ammeter the magnetic field of the one wire will cancel the magnetic field of the other, and the ammeter will register zero amperes. When clamping the meter around all of the wires of a circuit the reading should be zero. If the reading is not zero then current is returning to the source by some path other than the circuit wires.

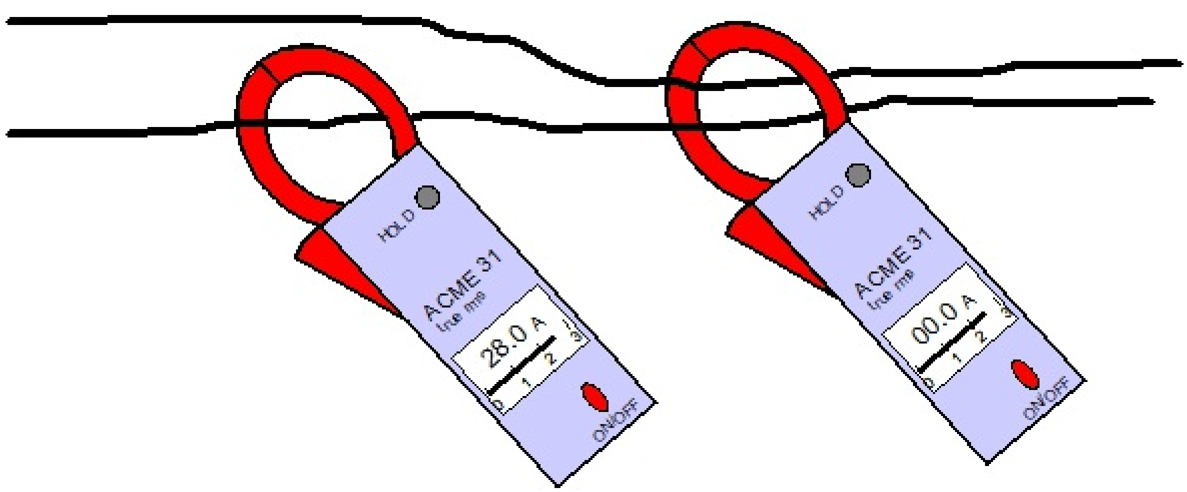

Figure 214.5 Place only one of the circuit wires through the jaws of the clamp-on ammeter.

Sometimes the current flowing in the circuit wire is so small that the needle of the clamp-on ammeter barely moves. You can trick the meter. All the meter senses is magnetic field. The meter has no way of compensating for the number of times the wire is looped through the jaws of the meter. Looping the wire through the meter jaws two times doubles the strength of the magnetic field sensed by the meter. The actual current flow in the circuit is the reading on the ammeter divided by the number of loops of wire through the meter jaws. When a current reading is less than 20% of the ammeter range, the wire sometimes can be looped through the meter jaws several times to get the reading high enough to be determined accurately by the ammeter. This method of increasing accuracy of a current measurement is illustrated in Figure 214.6.

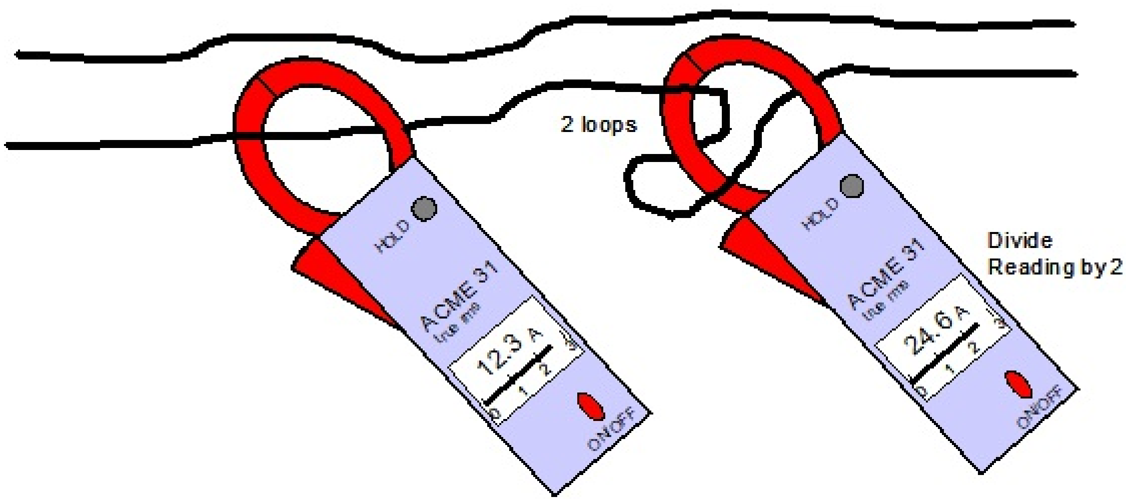

Figure 214.6 When the wire is looped through the ammeter jaws two times, the ammeter will read double the actual current flowing in the circuit.

Measuring dc Current: The clamp-on ammeter will not measure current in a direct current (dc) circuit because the magnetic field around the wire is static and not in motion. The magnetic field must be in motion for it to be detected by the sensor coil of a clamp-on ammeter. To make a direct current measurement the circuit current must flow through the meter. The multimeter can be used for this purpose provided the circuit current does not exceed the maximum dc current rating of the meter.

To make a dc current reading first open the circuit at the point where the current measurement is desired. Polarity is important with a dc current measurement. Connect the red lead to the positive end of the connection and the black lead to the negative end of the connection. This may not always be obvious and if the meter does not show a reading with the first connection reverse the leads and try another measurement. Figure 214.7 shows a simple dc circuit with a multimeter used to measure the dc current.

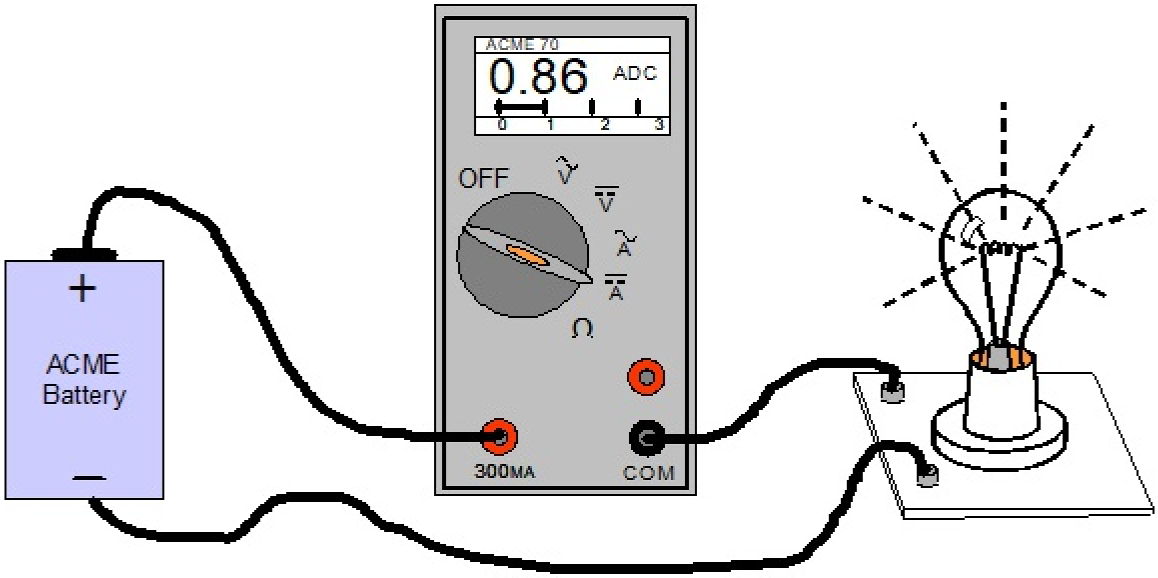

Figure 214.7 When making a measurement of dc current make sure the current will not exceed the limit of the meter and connect the red lead to the positive end of the point of connection.