BASIC ELECTRICAL MEASUREMENTS

By David Navone

Just about every component designed to operate in an automobile was designed to run on a minimum 12 volts. When this voltage, V, is applied across a resistance, R, a current, I, will flow in the closed circuit. Measuring the voltage across a load really presents no problem for most installers - simply place the probes of a volt meter across the load and read the answer. The current in the loop can also be measured, and since Ohm's law tells us that V = IR, the resistance can be easily calculated.
See Figure A.

It has been our experience that determining the current flowing from a supply into a load and back out of that load into the supply is not exactly straightforward for many installers. Whenever a problem occurs in a system, the power source needs to be checked. Overloading a power supply by drawing too much current in a load will surely cause the power supply to fail. I've often heard installers state that their particular load was drawing 10 amps only later to find out that this figure was indicative of the fuse in the circuit and NOT of the current flowing in the loop. (Fuses are usually for short circuit protection and do not necessarily represent the actual current.) How then can current be accurately measured?

And finally, we have the quantity of resistance. For a given voltage, the amount of resistance in a circuit determines exactly how much current will flow through that circuit. But how do we measure resistance? Many installers think that resistance can be measured just like voltage and current. Well, let's begin with voltage and work our way down this list.

Measuring Voltage

The ideal voltmeter draws no current and has a very high input impedance. In the old days, we were happy if our voltmeters exhibited 10,000 ohms/volt. Modern DVMs (Digital Volt Meters) often have input impedances of over 100 Megohms (l00,000,000 ohms). See Figure B.

Voltmeters read across the circuit or load under test. This means that typical readings are taken with the circuit in operation. In fact, it would be meaningless to measure the voltage across a load that was not in operation because the result should be zero volts. Right? There is, however, validity in measuring the open circuit supply voltage as well as the supply potential when under load. This measurement will tell us just how much the load is effecting the supply.

Forty years ago, the mechanical D'Arsonval meter movement was the accepted standard. With this type of meter, higher voltages created greater meter movements. Various voltage scales were simply voltage dividers that permitted the same meter action to be used for many different ranges.

When measuring transient waveforms, the D'Arsonval movement tended to average the voltages and provide a good representation of the actual potential. Modern DVMs do not work in this manner and tend to display varying numbers when evaluating complex waveforms as the samples are flashed across the display.

Measuring alternating current (AC) with the D'Arsonval movement required little more than passing the signal through a rectifier and then reading the DC value. However with DVMs the signal is typically fed into integrated circuits (ICs) known as Analog to Digital converters (A-Ds). With AC, many values are commonly calculated, including: peak-to-peak, average and rms. Remember, when working with AC, it is important to know what value the meter is actually reading.

Measuring Current

The ideal current meter (ammeter) has zero input impedance. In fact, it should represent a short circuit. An ammeter is always placed in series with the circuit to be measured. This is why an ammeter with a very low input impedance is desirable - so that it will have a minimal effect on the circuit under examination. See Figure C.

Ammeters work by measuring the voltage dropped across what is known as a shunt resistor. Clip on ammeters work on a slightly different principle, but, they can be accurate to within approximately 2% and are easy to use.

To measure the current flowing in a particular closed circuit, the circuit must first be broken and the ammeter must be connected in series. When the circuit is reactivated, current will flow through the ammeter's shunt resistor causing a voltage drop across the resistor. This voltage drop is then displayed on a voltmeter that is calibrated in amps.

It is important to use a fuse in series with the shunt resistor whenever the amount of current is largely unknown. The fuse will protect the shunt resistor from damage in the event the current range is exceeded. Seasoned installers will always set the ammeter to its highest current range, and then progressively move down the scale until the proper range is found. See Figure D.

Measuring Power

To measure power, both the voltage across the circuit and the current flowing through the circuit must be known. This does not usually present us with too much of a problem for steady state DC, but with the varying phase relationship between the current and the voltage in AC circuits, accurately measuring the power can be a little tricky. Typically power meters are used with frequencies under 1000 Hz.

With two meters, the measurement of power in DC circuits can be straightforward. See Figure E. Turn-on triggering circuits have long been a sore subject in a few brands and models of components. For instance, if the input resistance of a turn-on sensing circuit is too high, then just about any stray voltage can activate the circuitry. On the other hand, if the input resistance is too low, excessive current will flow in the circuit and possibly overload the source.

Almost always the source of turn-on current is a semiconductor device with limited output capability. In some extreme cases the amount of current available at the "electric antenna turn-on output" was found to be less than 50 mA. Now remember, semi-conductor devices are usually associated with a voltage drop of their own. This means that there will normally be less than the input voltage available at the output of a transistor-switched device. Don't forget that as the voltage goes down, the current must increase to perform a given amount of work.

When installers try to connect loads, such as a typical automotive 12 VDC, 30-Amp rated contact, automotive relay, the current requirement of the relay's coil often exceeds the 50 mA limit. The result can be a burned trace on the deck's PC board, a "blown" resistor, or a damaged semi-conductor device.

Measuring the power consumed by the load would have made this problem trivial, but how many installers ever bother? Instead, many decks were returned to the factory for repairs. (In this particular case, most of the decks were retro-fitted with high current Darlington switches capable of driving several automotive relays.) See Figure F.

Another problem here is when several components are connected in parallel to a single turn-on lead. Does it make good engineering sense to design several amperes of current to be sourced from a deck? Anyway, the point is to check the load requirements of a circuit before connecting it to what may, or may not, be an unlimited source of power. The obvious solution would be to use a solid state switch or relay as a buffer between the deck's turn-on output and the inputs of the rest of the components.

Measuring Resistance

Resistance measurements are done internally in the meter by using a battery to supply current to the resistance under test. The current flowing through the resistance is then measured by its associated voltage drop and the result is displayed as resistance by the meter. It is very important that the battery supply is the only current flowing through the resistance under test. If outside currents happen to flow though the resistance, then the meter cannot accurately measure the resistance under test.

There have been a few occasions in car audio in which exceedingly low resistance measurements have been published. We're talking on the order of .001 ohms. These measurements were supposedly meant to qualify various ground points on the chassis of a car. But since we usually experience noise only when the engine is running, then shouldn't we be making our measurements at the same time? With ground currents flowing all over the chassis of a car, such readings are totally useless because the circuit under test was active and not totally passive. Resistance must be measured with no current flowing except the current from the VOM (Volt Ohm Meter). This is a fact of life for us car audio installers.

Taking accurate low resistance readings in a car is a difficult task. Although it can be done, the accepted engineering method is to use the resistance between any two points on the car as the shunt resistor and then to measure the voltage drop across the resistance with something like a laboratory-grade amplifier. But who really cares? As soon as the engine is started, ground currents will begin flowing all over the car. These currents often wreak havoc with our car audio components and are the real source of our problems. For instance, taking many low resistance readings (.001 ohms or so) with the engine off is of little help in removing alternator whine from a component with poor power supply isolation.

And on the other hand, with the engine running there can be no serious resistance readings taken on the chassis of the car because current will be flowing. Over the last 15 years, many installers have "debugged" their systems by taking resistance readings with the engine running. I can even remember a couple of guys that discovered "negative resistance." It seems that their meters were moving in negative direction because the circuit under test was active rather than passive. Totally meaningless readings.

Another source of aggravation for the novice installer has to be the measurement of a resistor that is soldered into a circuit. Unless one end of the resistor is un-soldered, that resistor just may be connected to other resistors, or capacitors. By the way, charged capacitors in parallel with resistors always make for interesting resistance readings. At A2TB we have had installers call with reports of changing resistance values on the order of factors of 1000. Resistance must be measured with no current flowing -except the current provided by the measuring system itself.

Types of Meters

From a practical standpoint, a couple of good analog meters of the type manufactured by Simpson or Triplett work just fine for most installation applications. We highly recommend picking up a meter like this at a swap meet or garage sale. The shunt fuses are easily accessible and the ranges are clearly defined. I recently visited an alarm shop that had customized their meters by installing circuit breakers on the test leads and then shorted across the shunt fuse receptacles. Replacing a shunt fuse with a circuit breaker is not a good idea because it can severely alter the accuracy of the reading.

DVMs have long caused problems for some installers. The problem is that the input impedance of such devices is often so high (so as to not effect the circuit under test), that useless numbers rapidly flash across the display. We have had installers call in with reports of alternator induced voltage spikes on the order of 200 volts. That may be true, but such spikes do not necessarily mean that the alternator has bad diodes or that the alternator is going to explode and ruin the entire electrical system of the car. The response of an analog meter would not let quick spikes register a meter movement. It is important to know the limitations of your test equipment.

One last thought on meters for use in car audio applications would be cost. Over the years, we've lost many meters. It is far better to lose a moderately priced meter than an expensive full featured meter. We'll cover more on this subject in future issues.

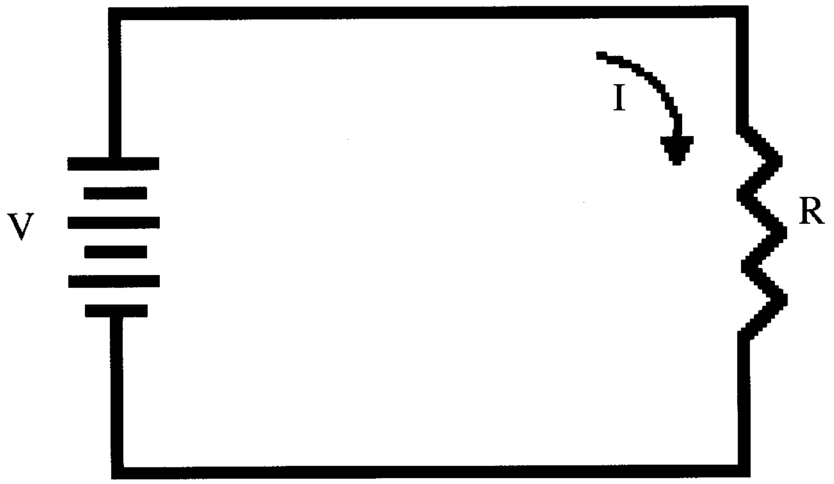

Figure A. Ohm's Law V = IR

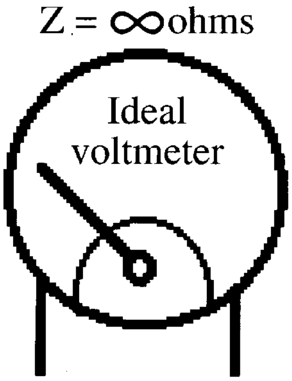

Figure B. The ideal voltmeter
has an infinitely high input impedance.

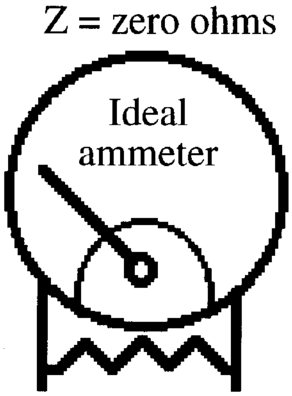

Figure C. The ideal ammeter
has a zero input impedance.

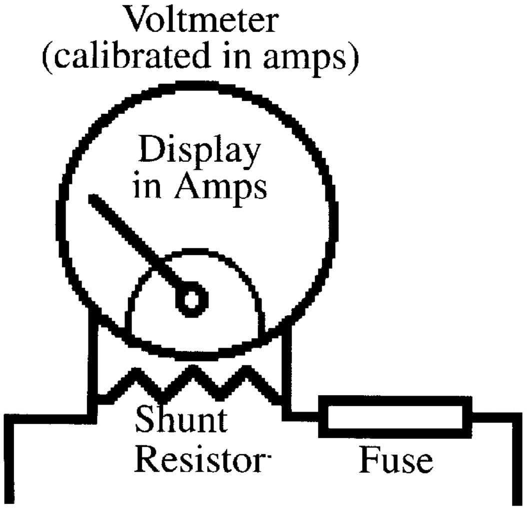

Figure D. Typical ammeter setup.

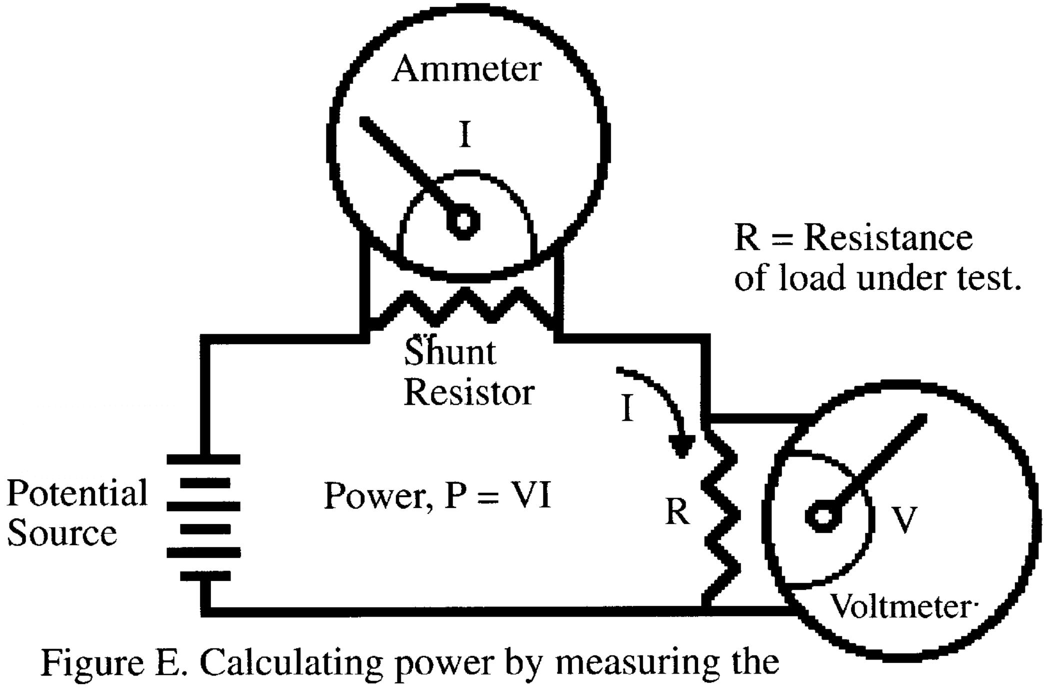

Figure E. Calculating power by measuring the voltage, V across the load and the current I flowing through the load.

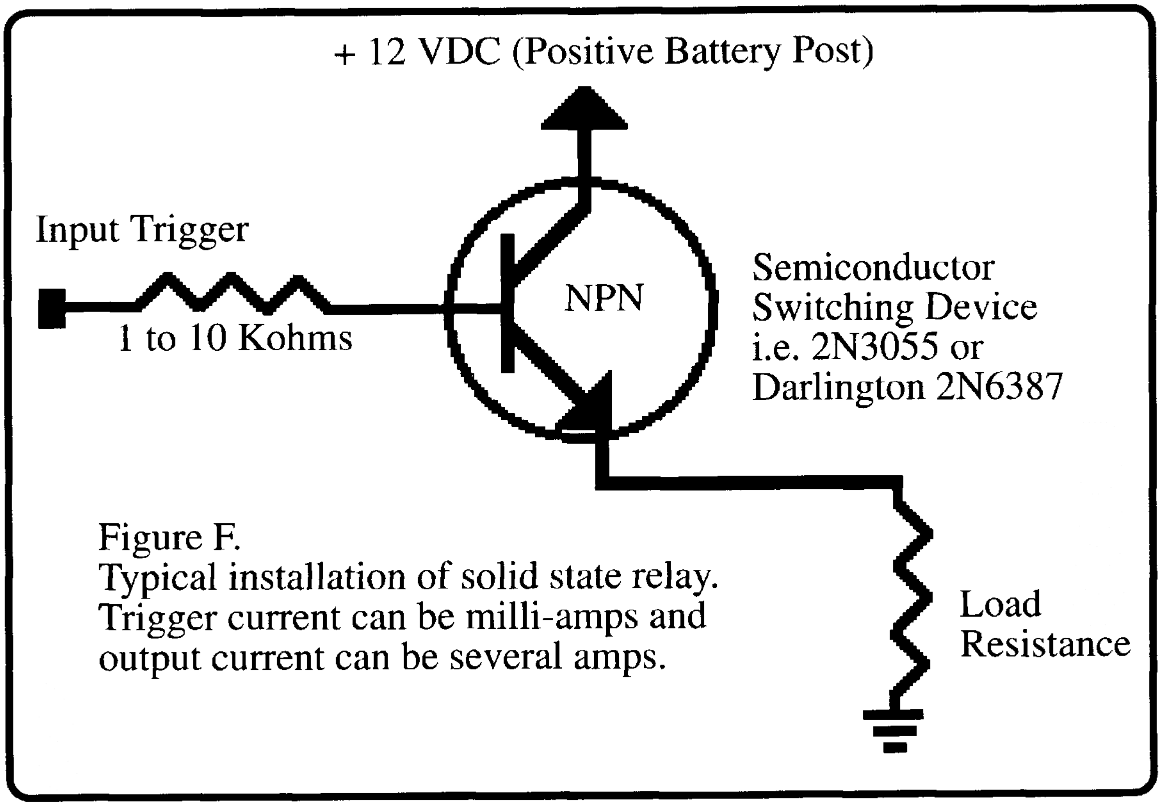

Figure F.
Typical installation of solid state relay.
Trigger current can be milli-amps and output current can be several amps.