Use Those Surplus Meters

Find out what's inside that meter, and how it can be used.

by J. Frank Brumbaugh KB4ZGC

Junk boxes all over the world hold panel meters with all kinds of scales, most of which provide no clues to the characteristics of the internal movements. If the capabilities of these meters could be determined easily, many would be dusted off and placed in useful service in power supplies and test gear. This article will describe some simple and easy methods that any ham can use to identify the electrical parameters of most types of panel meters, and show how to tailor them to his or her exact requirements.

Meter Varieties

Disregarding the oddball meters which were originally intended for use in military equipment for exotic purposes, most common panel meters are of two basic types: iron-vane and D'Arsonval. Typical of the iron-vane movement are the small, black metal-cased meters such as those manufactured by Shurite and a few other companies. The D'Arsonval movement is a moving coil movement and is used in the more expensive, and accurate, panel meters, as well as in analog VOMs and other types of electronic equipment.

The iron-vane meter is neither very sensitive nor very accurate, and in most cases its function is clearly indicated by the scale on the meter. This meter is often used on automotive battery chargers and in AC line voltage measurement.

The d'Arsonval—moving coil—movement is usually found in meters which at least look expensive, in black or white or clear plastic cases. Occasionally the case may be metal, usually painted black, and a few may be hermetically sealed. Almost every such meter can be identified and placed in service to measure either voltage or current or both (with switching) of practically any value.

Some surplus panel meters, especially those made originally for WWII and more recent military equipment, and many more removed from commercial gear and manufactured under such well-known names as Simpson, Westinghouse, Marion, etc., contain essential information on their faces. For now, ignore the main scale and look at the very small type at the bottom of the meter face, usually on one or both sides of the movement, visible through a cutout in the center. Either the DC resistance, the full-scale DC current, or both may be printed there.

The many small square and edgewise panel meters in plastic cases now available from mail order parts dealers for about $2 are usually 100 µA, 200 µA, 500 µA, or 1 mA movements. However, be aware that these ratings are nominal, not exact, and these inexpensive meters may not have a linear response, regardless of any scale printed on them. These meters are available in left- or right-handed zero and center zero. They were made originally as tuning meters in commercial AM/FM and stereo equipment for home use, and as power and S-meter service in citizen band transceivers.

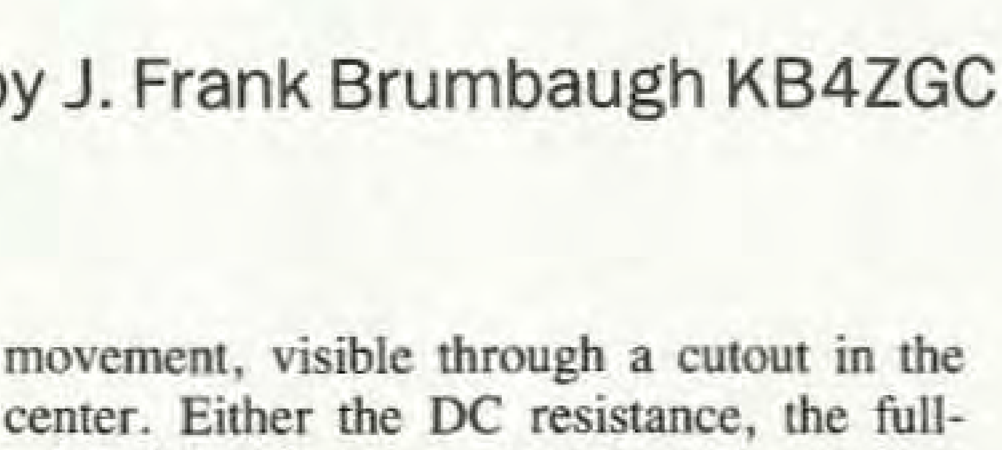

Figure 1. Test setup for measuring full-scale current.

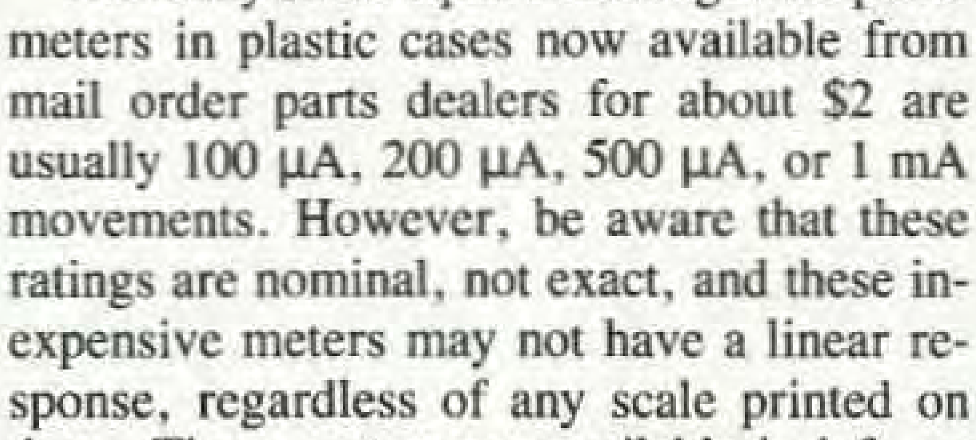

Figure 2. Suppressed zero, expanded-scale voltmeter.

Even if the DC resistance and/or full-scale current is printed on the meter face, there may be internal shunts or multiplier resistors. Therefore, I recommend that the actual full-scale current be measured before doing anything else. This is covered later in this article, as is the easy way to measure the meter's DC resistance.

Meter Disassembly

CAUTION: If you have to make any internal modifications, the meter must be partially disassembled. Use extreme care and the proper tools in taking the meter apart. Equivalent care must also be used in reassembly. Be very careful not to lose any tiny screws! Replacements may be impossible to locate.

Surplus military and commercial meters in black metal or plastic cases are usually held together by three small flathead screws around the circumference of the rear portion of the meter case, near the rear panel. Surplus commercial meters in white or clear plastic cases are usually held together with strips of cellophane tape, but a few may be cemented together with plastic adhesive. Hermetically sealed meters, easily identified by the glass-to-metal seals around the rear terminal studs, cannot be disassembled without destroying them. However, these meters are very accurate, and the printed scale(s) are indicative of their intended use. Use them as-is, or sell them at the next hamfest.

If the meter is held together with screws, use a jeweler's screwdriver of the proper size to remove them, being careful not to distort or burr the screw slots. Put the screws in a safe place so they will not be lost. With one hand, grasp the terminal posts on the rear of the meter and, holding the case firmly in the other hand, gently pull the meter movement from the case.

If the meter is in a plastic case held together with strips of tape, carefully strip the tape off and discard it.

If the meter case has been glued together it *may* be possible to break the seal by carefully cutting through the joints with a sharp knife. This may or may not work, and cutting or prying with a knife may cause the plastic case to crack or break, rendering the meter unusable. However, if you have to disassemble this type of meter, it must have been unusable as-is and thus would not be a great loss. Attempting to take this type of meter apart is not recommended, except as a last resort.

Modifying the Meter

The only internal modification that I suggest for panel meters is the elimination of shunts and series resistances so that the basic meter movement is available at the external terminals.

Shunts will be connected between the positive and negative terminals. Usually they look like a coil of wire, a resistor, or, in some cases, a piece of printed circuit board. This latter shunt is generally found in very large DC ammeters.

Multiplier resistors may resemble ordinary resistors or small coils of wire. These normally will be connected from the positive meter terminal to an insulated tie-point near the meter coil at the base of the needle. The simplest way to eliminate the effect of the multiplier resistor is to shunt it with a fine wire (AWG 30 or finer), *very carefully* soldering this shorting wire to both ends of the multiplier resistor. If there is room to clip the resistor out, it can be replaced with a short piece of fine wire. Note: In some meters it may be necessary to remove either the meter face or the rear panel to gain access to internal components.

If the meter face must be removed, use a small jeweler's screwdriver of the proper size to extract the two tiny screws holding the meter face to the internal structure. Save these screws, and any small meter needle stops which were attached under the screw heads. Then carefully, without bending the needle, slide the meter face towards the top of the meter and off.

When a new or modified scale is to be placed on the meter to replace the original scale, removing the face first will make this modification easier.

To remove the rear panel of the meter, carefully remove the nuts from both terminal studs passing through the rear of the meter. Save these nuts and any washers or solder lugs that come off with them. Very carefully remove the rear panel from the terminal studs. Note: If you anticipate using shunts or multipliers with the meter, I suggest that you use them externally, *not* placed inside the meter case. Used externally, meter shunts and multipliers can be trimmed or changed at any time if you want to use the meter for a different function.

Meter Reassembly

If the meter face or rear panel has been removed, replace them in the reverse order to that used in removing them. Use the same hardware and tools, and be extremely careful not to bend or break anything. If needle stops were found under the face mounting screws, be sure to replace them in the same positions they had previously occupied.

Meters held together with screws must have the movement inserted into the case so the screw holes match perfectly and the meter face is positioned properly when viewed from the front through the protective glass. **Caution**: Make certain that the slot on the front of the movement slides accurately over the stud on the zero adjust, if the meter is equipped with one.

Before fastening the screws holding the meter together, hold the meter in one hand while adjusting the position of the zero adjust screw on the front of the meter. It *must* be possible to move the needle both above and below scale zero with less than 180 degrees movement of the zero adjust screw.

If the needle cannot be moved as just described, remove the movement from the case. Look into the case from the rear and rotate the zero adjust screw to position its stud at the bottom of the case and on the vertical center line. Then, carefully align the slotted extension on the bottom front of the movement into a vertical position so it will slip properly over the zero adjust stud when the meter is again put together.

Slide the movement back into the case, making sure that the screw holes on top of both components match up when the movement is fully seated into the case *without rotating* either component in a way that will affect matching the screw holes.

Check proper seating by again rotating the zero adjust screw so the needle can be moved both above and below the scale zero. Then replace the three screws holding it together and set the needle to scale zero.

Commercial plastic-cased meters seldom have zero adjust capability, and thus are simpler to reassemble. Replace the face if it has been removed, and the rear section, as described above. Finally, use cellophane tape to hold the meter case together.

Many small, square plastic meters don't come with a means of mounting them to a panel. There is sufficient space near the lower corners of these meters to drill small holes from the front panel through the rear of the case to clear 4-40 machine screws. **Caution:** Drilling these holes will leave plastic shavings and chips inside the case. These must be removed to prevent them from lodging in the movement or under the needle and preventing the meter from operating properly. Use great care when removing these chips and shavings so the moving coil and needle are not bent or broken.

Table 1. Copper Wire Table

AWG	Ohms Per Inch
14	0.0002
16	0.0003
18	0.0005
20	0.0008
22	0.0013
24	0.0021

Table 2. Fractions of One Inch

Decimal	Linear
0.0625	1/16
0.1250	1/8
0.1875	3/16
0.2500	1/4
0.3125	5/16
0.3750	3/8
0.4375	7/16
0.5000	1/2
0.5625	9/16
0.6250	5/8
0.6875	11/16
0.7500	3/4
0.8125	13/16
0.8750	7/8
0.9375	15/16

Determining Meter Resistance

Although the methods for measuring the DC resistance of meter movements described in the *ARRL Handbook* and other publications are quite accurate, they are rather complex. The advent of the digital multimeter (DMM) has made such involved methods obsolete. With the DMM on the ohms scale, meter resistance can be safely and accurately measured directly, as simply as measuring an ordinary resistor.

Fortunately, the voltage and current available at the test prods of a DMM set to measure resistance are too low to damage even a 50 μA meter. While most DMMs will pin the needle on a 50 μA movement, the meter will not be damaged. Usually, a 100 μA meter will indicate about three-quarter scale when it is being measured with a DMM. Caution: Use only a DMM to measure meter resistance directly. An analog VOM measuring ohms can provide enough current to destroy a valuable meter.

The range of resistances to be expected will probably be between about 50 and 5,000 ohms. Higher resistances are usually, but not always, found in more sensitive meters. Resistances outside this range suggest internal components such as shunts (very low resistance) or multiplier resistors (high resistance). In these instances, first check the primary scale printed on the meter face. It may indicate the range of current or voltage for which you have an immediate or future use. If this is true, no further action is necessary.

Determining Full-Scale Current

If full-scale current in microamperes or milliamperes is not printed along the lower edge of the meter face, you will have to measure this. Because of the very fine wire used in the moving coil of d'Arsonval meters, basic movement current is limited to about 25 mA, although most surplus meters are usually 1, 5, or 10 mA. This makes these meters more valuable for use as DC voltmeters and ammeters, as well as in ham-oriented equipment of all kinds.

Refer to Figure 1, which illustrates the test setup for measuring the full-scale current of unknown meter movements. Although a DMM is preferred because of its accuracy, an analog VOM can be used for this measurement. Set the meter to indicate DC current, and the 50k ohm potentiometer to maximum resistance. Apply voltage—I suggest using a flashlight battery—and slowly decrease the resistance of the pot until the needle on the unknown meter is at full scale. Read the current on the DMM or VOM. This value is the full scale current required by the unknown meter. Note: Both the DC resistance and full-scale current should be marked on a label attached to the meter. This information will be needed when calculating shunts or multipliers.

Calculating Voltage Drop Years ago it was almost always safe to assume that any basic meter movement of the d'Arsonval type was a "50 millivolt movement." No longer.

To discover the amount of DC voltage required to produce a full-scale indication on the meter, you'll have to make a very simple Ohm's law calculation. The full-scale current and DC resistance have already been measured so you can determine the voltage drop by the formula: E = IR, where E = volts across the meter; I = full-scale current in amperes; and R = DC resistance in ohms. This value should be marked on each meter. It will be required in making shunts to allow greater current to be measured.

Voltage Multiplier Resistance

A DC current meter in series with a resistor becomes a voltmeter and the scale is calibrated in volts. It is necessary to know the full-scale current of the meter in order to choose the proper series resistance. Because the voltage drop across the basic meter movement is only a few millivolts, it can be ignored and the value of the multiplier resistor determined from the full-scale current required by the meter and the maximum voltage required to be measured. Again, a simple Ohm's law calculation will tell you what you need to know: R = E/I, where R = multiplier resistor in ohms; E = maximum voltage to be measured in volts; and I = full-scale current of the meter in amperes.

A special application is a *suppressed zero, expanded scale voltmeter*. This allows spreading a narrow voltage range over the entire meter scale, a voltage range which is referenced to a point above ground. For instance, you might want to monitor the +13.8 VDC from a regulated power supply which powers a modern transceiver. If an ordinary voltmeter, which measured from zero to, perhaps, +15 VDC were used, any voltage variation around the +13.8 volt point would hardly be visible on the normal panel meter. An expanded scale voltmeter, which would measure only the 5 volt spread between 10 and 15 volts, would enable even small variations of the +13.8 VDC to be seen.

The properties of zener diodes, available from a few to a few hundred volts, form the magic ingredient which allows such a narrow voltage range to be easily monitored. The zener diode establishes the voltage equivalent to scale zero on a low voltage meter, and the meter will not indicate a voltage lower than the conducting point of the zener diode chosen in each application.

Figure 2 illustrates a typical suppressed zero, expanded scale voltmeter which monitors only the range between +10 and +15 VDC. The values given are for a 5 mA meter and uses a 10 volt zener diode to establish the voltage at which the meter (which, with its multiplier resistance, becomes a 5 volt meter) starts to conduct. This example illustrates the simplicity of the application and you can adjust for just about any voltage monitoring application that most hams might need. **Caution**: Be sure to consider both the current-carrying capacity and power dissipation maximum of the zener diode used in any application where this type of voltmeter is to be used. If the zener diode should develop a short, it is likely that the meter movement would be damaged and the needle "wrapped around the pin."

Current Shunts

A DC current meter shunted by a small resistance becomes an ammeter capable of indicating greater current than the basic meter movement. The new scale is calibrated in amperes or milliamperes, depending on the application. A shunt to allow the meter to measure higher current is very simple both to calculate and to make from common copper wire. The voltage drop across the meter, the maximum current to be measured, and good old Ohm's law again are all that are required to calculate shunt resistance: R = E/I, where R = reputed shunt resistance in ohms; E = voltage drop across the meter, in volts; and I = maximum current measured in amperes.

Table 1 gives the value of ohms per inch of copper wire sizes from AWG 14 through AWG 24. These values have been rounded off to four decimal places. These values are very small so I suggest using a calculator to determine the length of wire in the shunt.

To determine the length of copper wire needed for the shunt, choose a wire gauge that seems reasonable for the maximum current to be measured. As a guide, remember that AWG 22 is suitable for 5 or 6 amperes, and AWG 16 is sufficient for 20 or 25 amperes. Smaller wires (higher AWG numbers) may be used for lower current values, and vice versa. Larger wire sizes make shunts self-supporting. Smaller wire sizes for shunts should be wound on forms such as 1 watt resistors.

Calculate the shunt as follows: L = RS/RW, where L = length of wire in inches and decimal fractions; RS = required shunt resistance in ohms; and RW = resistance of one inch of chosen gauge wire (from Table 1). The required length of shunt wire will seldom be in an exact number of inches. Use Table 2 to convert decimals to fractional equivalents.

As an example, assume that the meter movement has a voltage drop of 50 mV at full scale and that 20 amperes is the maximum current to be measured, the current equivalent to full-scale on the meter. In this case, AWG 16 wire will be used to make the shunt. Therefore: L = 0.0025/0.0003, so L = 8.3333 inches (8-1/3 inches).

Referring to Table 2, 0.3333 inches is closer to 5/16 than 3/8, so this is added to the eight inches, giving a total length of wire of 8-5/16 inch for the 20 ampere shunt.

Now all those meters gathering dust in junk boxes can be easily revived and given a purpose in life. Don't let them hide in dark corners. Clean them up, check them out, and put them to work in the ham shack. And, be sure to bypass the terminals of each meter with a 0.01 μF disk capacitor to prevent stray RF from causing erroneous meter indications. 73

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