Meters and Measuring

Test instruments and measurements are the basis to get things working. If your circuit does not work or your receiver stops, the first approach should be to check the supply. You need a meter to measure the supply voltage or current.

Moving coil meters are in universal use and their measuring range can be extended by adding external resistors. Any meter used for measurements (a multi-meter) is not complete without an ohms range.

Loading of circuits under test is one of the important factors to consider when making measurements.

The success of any electronic or radio project is to make it work. Meters and other test instruments are required for this purpose.

Meter movements

Most common meters use a **moving coil**. This comprises a small, light coil of wire mounted in the field of a permanent magnet. A DC current through the coil sets up a small magnetic field which causes the coil to rotate by the motor principle. This in turn tightens a spring and the coil will only rotate a certain amount, until the force produced by the current equals the force in the spring. A pointer is attached to the moving coil, and moves over a calibrated scale.

(*This is the reverse operation of a generator. The difference is that a DC input current to the coil produces a mechanical rotation of the coil in the magnetic field.*)

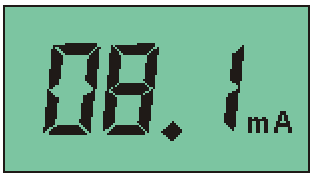
The deflection of the pointer is proportional to the current, or more exactly, to the average value of the current. The moving-coil movement responds only to DC currents. It will only respond to AC if it has been rectified.

Multimeters

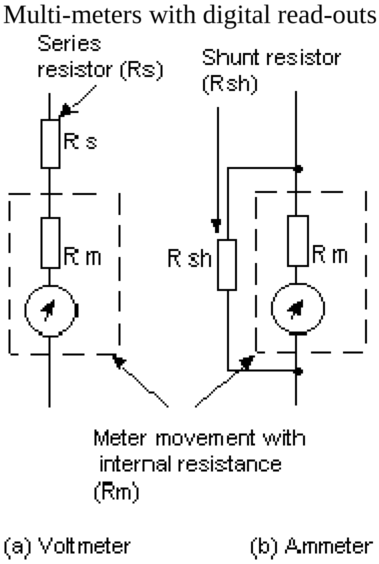
The movement probably found most often in meters used by amateurs is the moving coil. This is used in the multimeter for current and for voltage measurement.

To measure AC with a moving-coil meter requires the addition of a bridge rectifier. Although such a meter reads the average value, the scale is usually calibrated for RMS values of a sine wave. This scale is correct only for sine waves. For any other waveform there will be a different relationship between average and RMS values, and therefore a different indication for the same RMS value.

Some rectifier circuits use capacitors to give a peak reading. This reading is correct for all waveforms and the peak value is quite useful. (See another entry in this Guide for information about RMS and for peak, RMS and average values.)



Multi-meters with digital read-outs use integrated circuits with a liquid crystal display (LCD) consisting of seven segment numbers. The unit of measurement can also appear on the display.



Measurement of voltage and current

The moving-coil movement can be configured to measure both current and voltage. This is the basis of the multimeter, typically using a sensitive movement with a full-scale deflection produced by a current of 1mA or less.

This diagram shows voltmeter and ammeter circuits. Rm represents the "internal resistance" of the moving coil movement,

A voltmeter circuit: To read different voltage values a resistor is put in series with the meter. This is known as a series multiplier resistor and can be calculated using the usual Ohm's Law relationships.

The higher the resistance value of the series resistor, the higher the voltage that can be read by the meter.

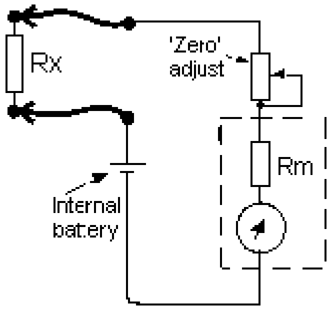
When meters are used in high voltage situations care must be taken to avoid accidental shock.

An ammeter circuit: To read different current values a resistor of a low value is put in parallel with the meter, shown in the diagram as Rsh (Shunt resistance). The shunt resistor bypasses the extra current that the meter cannot carry. For example, to measure 500 mA on a 1 mA meter the shunt resistor would have to carry 499 mA leaving 1 mA to produce a full-scale deflection (fsd) on the meter. The lower the value of the parallel (or shunt) resistor the higher the current that can be read on the meter.

For example, if a meter of 100 ohms resistance and a full scale deflection of 1 mA is required to measure 500 mA, a shunt must be provided to carry the excess 499 mA current away from the meter. Using Ohm's Law, you can work out the value of the shunt resistor required. Shunt resistors have very low resistance values and usually have to be made for the particular application.

Resistance measurements

Apart from voltage and current the other most useful function for a meter is to measure resistance. This diagram shows the circuit of an ohmmeter.



In its simplest form this is a battery in series with a variable resistance (zero adjust). When the two probes (shown with arrows) are directly shorted together (Rx = 0) the battery current is adjusted until the meter reads full-scale.

So if the circuit under test is a short-circuit (a continuity check) the meter reads full-scale or zero ohms.

If there is some resistance in the circuit (shown in the diagram as Rx) the meter will receive less current and only a partial deflection of the needle will result. The higher the resistance the less deflection or *lower* reading. The scale is non-linear with the higher resistances crammed at the lower end of the scale. To minimise this effect, several resistance ranges are built into the meter circuit.

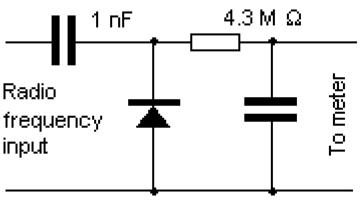
Loading on a circuit

When using a voltmeter one must always keep in mind that the meter will draw some current from the circuit under test. If the meter current is high compared to the currents in the circuit then the meter will load the circuit and consequently the readings will be inaccurate. To reduce loading the circuit, the meter should draw as little current as possible from the circuit.

The loading accuracy of a meter is expressed in *ohms per volt*. In simple terms it means that a 1 mA meter needs 10 000 ohms in series with a 10 V source to produce 1 mA fsd in the meter. The sensitivity is then 1000 ohms per volt.

So a 50 µA meter will require 200 000 ohms in series with 10 V to produce a 50 µA fsd in the meter or 20 000 ohms per volt.

In high-resistance, low-current, circuits, the higher the meter input resistance the more accurate the reading will be. Digital multimeters can put a very small load on the circuit under test.

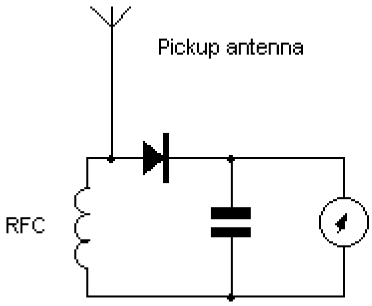


Some meters are affected if used near an operating transmitter because of the RF energy present in that environment.

RF voltage probe

This diagram shows a simple circuit that can be used to make RF measurements. This is a rectifier and RF bypass network. Keeping lead lengths short will also help to get useful readings up to about 200 MHz.

Field strength meters

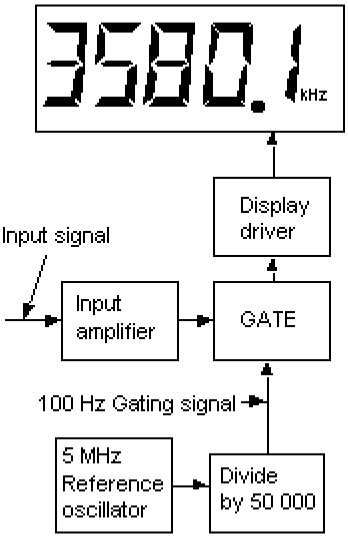


A field strength meter is an indicating device. It is used to indicate the relative intensity of a radiated field. It is useful for checking and adjusting directional antennas. This diagram shows a circuit of a field strength meter in its simplest form with a pickup antenna, connected to a rectifying diode with a meter indicator.

If the RFC (Radio Frequency Choke) is replaced by a tuned circuit the device can be used as an absorption wavemeter. The frequency measurement accuracy of the device is low, but the device has one useful feature in that it will respond mainly to the frequency to which it is tuned, and not to harmonics.

Frequency counters

Frequency measurement is a frequent requirement by the radio amateur. Many amateur transceivers have digital dials making frequency measurements of RF signals easy and accurate. The frequency of RF signals may also be measured by using a frequency counter. The diagram shows the block diagram of a frequency counter.



The reference oscillator is a stable crystal oscillator with its output signal being divided down in frequency to give the timing required for frequency measurements. An input amplifier, gate, and a display system completes the counter.

An input signal's frequency is measured by opening the gate for an exact time, thus allowing a preset number of cycles through to be displayed. For example, if the gate time is set to 10 milliseconds, and the number of cycles passed to the counter was 35 801 the input frequency displayed would be 3580.1 kHz .

Digital meters

The principle of many digital multimeters is similar to the concept of a frequency counter, but in the digital multimeter the period of measurement is determined by the input voltage or current. An analog-to-digital converter is used to convert the input voltage or current to a timing signal for the counting process. With the exception of the range switching, the circuitry of a digital multimeter is usually contained in a large scale integrated circuit.

RF power measurements

An RF power meter is an RF voltmeter calibrated to measure the voltage across a fixed (normally 50 ohm), resistor load. The resistor load is designed to dissipate the maximum power reading of the power meter, which for amateur use would be 120 watts or so. The resistor is large and carefully constructed to ensure that any stray capacitances and inductances are kept to a minimum so that a wide frequency range can be covered with accurate power measurements.

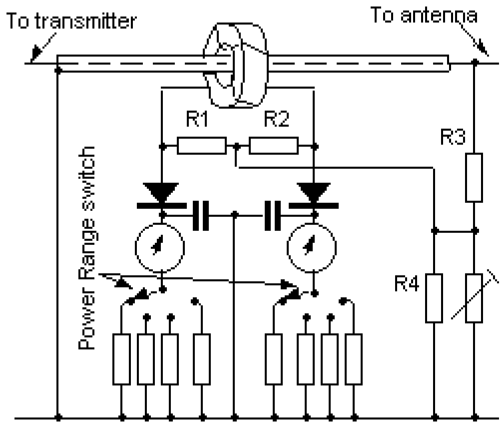
RF current measurement

The **hot wire meter** can measure AC at radio frequencies directly by using the heating effect of a current to lengthen a wire, the lengthening being used to move a pointer. The hot wire meter can be used at RF, but has many disadvantages. It is generally replaced by **thermocouple meters** that use a thermocouple and a moving-coil movement.

Voltage Standing Wave Ratio (VSWR) measurement

The forward and reverse power sent to an antenna are an essential measurement of the effectiveness of the antenna system. If no reverse energy shows on the meter it means that all the power sent to the antenna is radiated. Two common types are available. Sampling is achieved by using a current transformer.

The device is frequency independent so may be calibrated to measure power over a wide frequency range. This diagram shows a circuit of a frequency-independent directional wattmeter.



Power Ranges are
1 W, 10 W, 100 W,1 kW

The short piece of co-axial transmission line passes through the centre of a toroidal transformer. The co-axial cable is earthed at one end only. It forms the primary of a current transformer with the toroidal winding as the secondary.

The output from the toroidal transformer secondary winding is split into two equal parts by resistors R_1 and R_2. This output is then compared to a voltage sample obtained by direct connection to the centre conductor of the co-axial transmission line by the resistors R_3 and R_4. The connection between the two sampling resistor circuits results in the sum and difference voltage being available at the ends of the toroidal transformer secondary winding.

The sum (forward power), and the difference (reflected power), can be indicated on the two meters. Note the range switching for different power levels.

Transmitter off

Sometimes an *SWR Bridge*, an *Antenna Tuner*, and a *Dummy Load*, are combined into the one box. Sometimes the two SWR meters are built into one instrument - with *cross-needles*.

The cross-over point of the two needles can be read directly as the SWR value off a separate scale on the face of the meter. Each separate needle indicates the forward and reflected power on its own arc-scale. It must be remembered that all these scales are non-linear.

The knobs on the Antenna Tuner are carefully adjusted using a steady carrier as the transmitted signal until the SWR reading is 1. These adjustments ("tuning up") should be made quickly and with care to avoid interfering with other stations.

An example of a cross-needle meter is seen in the photograph. The transmitter output power is adjusted for 100 watt in the forward direction for each part of the display. Observe the change of position of the needle cross-over points. In practice, the "Antenna Tuner" controls are adjusted for minimum reflected power shown on the meter.

Other test methods

Do not overlook your computer as a test instrument, and a very flexible one too. There are many programs written to run in Windows, with a sound-card, and which provide useful test facilities. Many programs are available by free download from the internet. Spectrum analysers, audio signal generators, and many more, are available and suitable for amateur radio purposes.