Newcomers' Notebook

Ohm's Law in practice

Figuring out meter shunts and multipliers without fears or tears

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Sooner or later, you will need to use a panel meter to show current or voltage relating to the working of a circuit or piece of equipment. Here's how to get that meter to show what you want. A practical, everyday use of Ohm's law, explained simply without complex mathematics.

Figure 1. Analogue panel meters come in a variety styles. These are moving coil meters having a pointer that moves over a scale to show a value in response to current flow.

Analogue panel meters are ubiquitous. Square, round and edgewise shapes, as seen in **Figure 1**, meet different needs. Even the march of digital electronics, liquid crystal displays and specialised ICs has not pushed them off the inventories of electronics stores.

The most common analogue panel meter is the moving coil meter (MCM), sometimes known as a moving coil current meter (MCCM) or permanent magnet moving coil meter (PMMC). In some quarters, it's known as a moving coil galvanometer. Never mind the acronyms and multisyllable terms, let's keep it simple.

We can thank a Frenchman, Jacques-Arsène d'Arsonval, for pioneering development of the moving coil meter that first saw the light of day in 1882. Later, many others refined and improved the moving coil meter. For many years, they were called d'Arsonval meters.

Figure 2 illustrates the general makeup of a moving coil meter. A coil of fine, insulated wire is mounted on a shaft between jewelled bearings, sitting within the shaped poles of a permanent magnet. The core within the coil is of soft iron, concentrating the magnetic field. The coil is positioned by 'control' springs that are connected to each end. The current being measured passes through the coil which experiences a twisting force, or torque. The shaped pole pieces provide a radial field through the coil, thus giving constant torque, whatever the coil's position, while the springs oppose the torque. The coil turns by an amount directly related to the current flowing, which the pointer indicates on a scale.

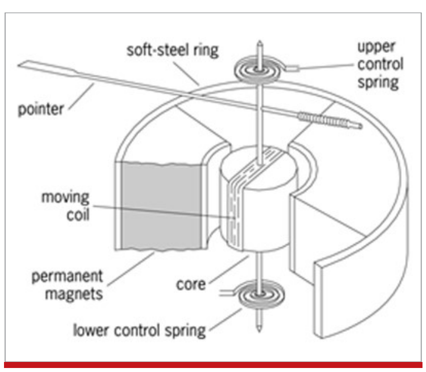


Figure 2. The workings of a moving coil meter, showing all the salient parts.

If you look closely at the square and round meters in **Figure 1**, you can see parts of this marvel of physics and engineering.

Getting to know a meter

The coil in a moving coil meter has a given resistance for its particular design, set out in the maker's or supplier's specifications. The value of that resistance will determine the current at which the pointer reaches full-scale deflection (FSD). The meter in **Figure 3** here, that reads 30 volts FSD, has a specified resistance of 30 kohms. From Ohm's law, the current flowing through the meter at full scale can be found this way:

I meter = E meter / R meter
= 30 / 30,000
= 0.001 amps,
or 1 milliamp (mA)

Now we know that when we are using this meter only 1 mA flows through it when it reads 30 V.

Figure 3. This panel meter is manufactured to read voltage over the range from 0 V to 30 V.

A voltmeter measures the potential difference, or voltage, between two points in a circuit. A current meter measures the current flowing in a circuit. Panel meters are produced to measure one specific current or voltage range.

When circumstances require a different current or voltage to be measured, the meter can be adapted by applying Ohm's law and connecting resistors to change the meter range. The resistors applied are called shunts or multipliers. A shunt is a resistor connected across the meter. A multiplier is a resistor connected in series with the meter.

Behold, the multiplier!

Take the example where we want the meter of **Figure 3** to read 0 to 50 V. Knowing the specifications of the meter, we need to connect a multiplier resistor in series with it, but what value?

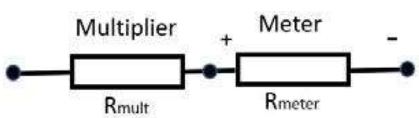


Figure 4. With a multiplier resistor (Rmult) in series with the Figure 3 panel meter, you can have it read to 50 V.

From **Figure 4**, as the meter 'drops' 30 V across its internal resistance at FSD, the multiplier resistor must 'drop' 20 volts. The current flowing at FSD is 1 mA, so the value of Rmult can be found from Ohm's law, like this:

Rmult = 20 V / 0.001 A
= 20,000 ohms, or 20k

In practical terms, you would connect two 10k resistors in series as your multiplier resistance. The meter scale would be recalibrated to read 0 – 50 V.

Figure 5. Common 1 mA FSD panel meters like this can be put to a lot of uses.

Now, the shunt!

With a panel meter like that in **Figure 5**, it may have a specified coil resistance of 1500 ohms. To use this meter to measure 100 mA, you would need to connect a shunt resistor to 'bypass' all but 1 mA of the current, i.e. 99 mA (0.099 amps). **Figure 6** illustrates the principle.

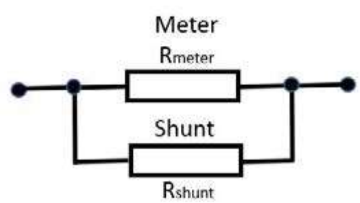


Figure 6. The shunt resistor bypasses an amount of current, effectively increasing the FSD value of the meter.

Emeter = Imeter x Rmeter
= 1/1000 amps x 1500 ohms
= 1.5 volts

Rshunt = 1.5/0.099
= 15.15 ohms

In practical terms, a 15 ohm resistor connected across the meter would do the job.

Read it right

Analogue meters are subject to parallax errors when being read. This is caused by the apparent position of the meter scale relative to the meter pointer, which is slightly above the scale, and the viewing position of the person reading the meter.

To overcome parallax error, the meter must be viewed directly face-on to the scale (90 degrees to the plane of the scale plate).

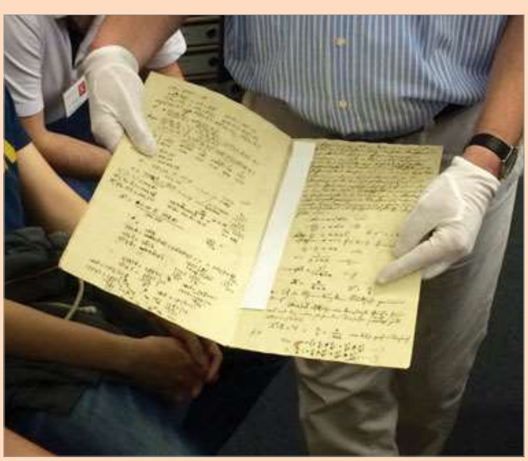
New technology

The continued miniaturisation and lower cost of electronic components and equipment led to better ways to make displays and measurements. In turn, this also led to greater accuracy than achievable with analogue meter scales. Some examples include:

- digital meter displays with back light
- digital multimeters (DMMs) that fit in your pocket
- multimeters with inductance and capacitance functions
- auto-ranging DMMs
- true-RMS reading DMMs.

If you have a topic you would like to nominate to be covered in a future instalment of Newcomers' Notebook, email Jules at jp.bqt@bigpond.net.au

Have fun and stay safe.



It all began here!

The first record of Ohm's law is found in his own lab book, held today at the archives of the **Deutsches Museum** (wikimedia.org), the "German Museum of Masterpieces of Science and Technology" in Munich, Germany. It claims to be the world's largest museum of science and technology.