The power and the glory of Ohm's Law, and the wonder of components in series and parallel

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Way back in 1827, a German physicist, Georg Ohm (1789-1854), published a paper on his electrical experiments. The result is Ohm's Law and the identification of electrical resistance that bears his name.

His research found that every electrical component, or indeed any item, has a 'natural resistance' to electrical current flow. This natural resistance means that all these items that conduct electricity will dissipate some form of energy as heat measured in Watts, which naturally, is and named after James Watt (1736-1819).

Two other electrical units are tied-up in Ohm's Law - the volt and the Amp (aka 'ampere' in formal terms).

The volt is named after the Italian physicist Alessandro Volta (1745–1827), while the amp is named after André-Marie Ampère (1775–1836), a French physicist and mathematician.

While studying for your amateur licence, Ohm's Law along with the related power formulae, would be one of the first topics covered. Fortunately, we don't need to get drawn into the mathematics of the three physicists of yesteryear as the connection between the volt, resistance and power can be explained without complex mathematics such that we can use it every day. See **Figure 1** as a reminder.

But what makes the Ohm, Volt, Watt and Ampere the same here in Australia as it is in any other country?

All these units are defined by the International System of Units, known by the international abbreviation SI. Under the SI, there are seven base units and 22 derived units. The four units covered in this article are listed under the SI.

- **Ampere** (A) A base unit calibrated by the flow of a quantity of electrons over time.
- **Volt** (V) A derived unit from the potential to move one Ampere.
- **Watt** (W) A derived unit from the rate of work.
- **Ohm** (Ω) A derived unit based on the Volt and Ampere (Ohm's Law).

The SI web site in Wikipedia is worth a visit to explore how many of the measurement units are derived (enter: International System of Units).

Back to the triangle, use a finger to cover the unit you want to calculate and the position of the remaining two units gives the formula. Example: If we want to know the current, cover the I, which leaves 'E over R' (E divided by R).

So, the current flowing in a circuit pushed by 12 Volts DC through a 10 Ω lamp would be

I = 12 VDC / 10 Ω = 1.2 A

Using the PIE formulae, what energy is dissipated by the 10 Ω lamp above?

P = 1.2 A x 12 VDC shows that the resistor dissipates 14.4 W.

I think this is the wattage of an incandescent parking light in a car.

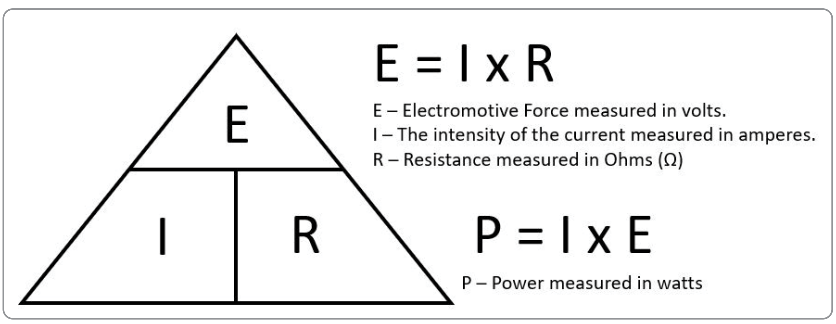

Figure 1. *The Ohm's law triangle illustrates the relation between voltage, current and power.*

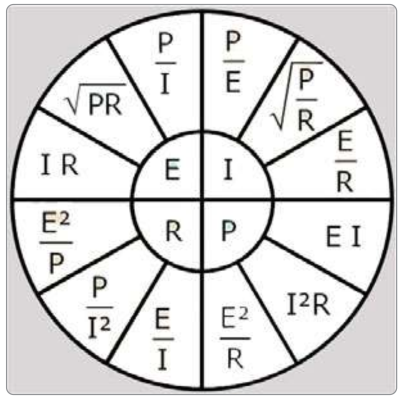

Figure 2. *The Ohm's Law Wheel – a very useful thing to keep around the workbench.*

Using a combination of the triangle and the PIE formulae, most calculations related to DC voltage, current, resistance and power in our hobby environment can be done easily.

Going further

There are more complex formulae to calculate the power from resistance, voltage and current. These can be seen in the Ohm's Law Wheel at **Figure 2**. I have a copy on my quick reference sheet that I use in the shack. A copy of the reference sheet can be downloaded from my website, here: *www.julesworkshop.net/amateur%20radio.html*. It's the top link.

The Ohm's Law wheel can be handy. For example: if there is a 10 Ω resistor dissipating 10 Watts, what is the DC voltage across the resistor and what current is flowing through the resistor?

Answers are: 10 V and 1 A. Use the wheel to see how these results are obtained.

Series and parallel

Components in series or parallel would be one of the first topics when studying to upgrade your licence. Knowing how to calculate the impact these configurations have is important.

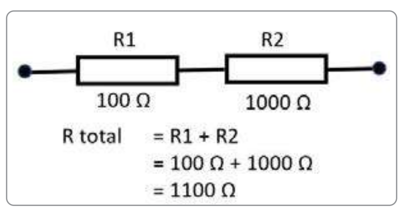

Figure 3. *Calculating the value of two resistors in series.*

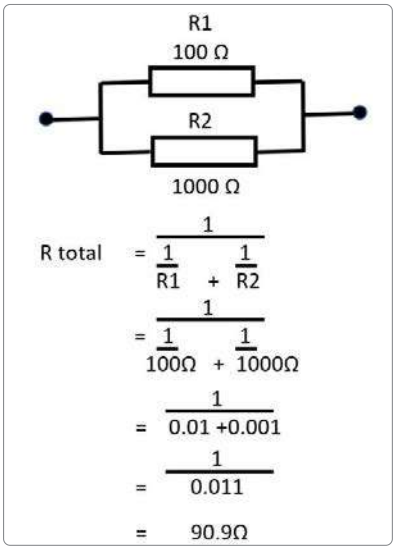

Figure 4. *Calculating the value of two resistors connected in parallel.*

The arithmetic is simple, so just take it one step at a time. Also, ensure you are working with the same prefix in the description. Do not mix, for example, M-ohms (megohms) with k-ohms (kilohms).

Resistors in series

The current path for series resistors travels through one resistor then the other. Calculate total resistance in series by adding the resistances. In **Figure 3**, R2 is the greater value resistor and will have the largest impact in restricting the current flow.

Resistors in parallel

The current path for parallel resistors will split proportionately through the resistors. In **Figure 4**, R1 is the smaller value resistor and hence will have the larger current flow through it. As the relationship of the resistors to each other is proportional, the reciprocal of the resistor values is derived then added.

Do not be daunted by the calculation, just start with the bottom division at each level and work up as shown. The resulting value will always be less than the smallest resistor value.

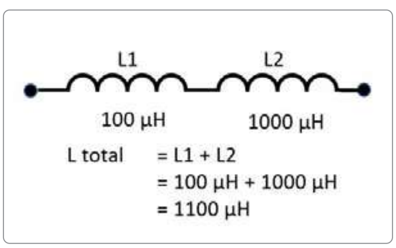

Figure 5. *Calculating the value of inductors connected in series.*

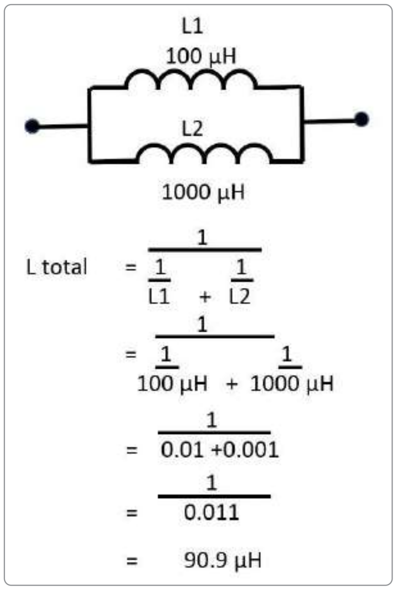

Figure 6. *Calculating the value of inductors connected in parallel.*

The same method works for calculating the values of other basic components connected in series or parallel.

Inductors in series

Inductors in series are calculated the same way as resistors in series – just add them, as in **Figure 5**.

Inductors in parallel

Again, the same calculation method applies as for resistors. See **Figure 6**. The result will always be less than the smallest value inductor.

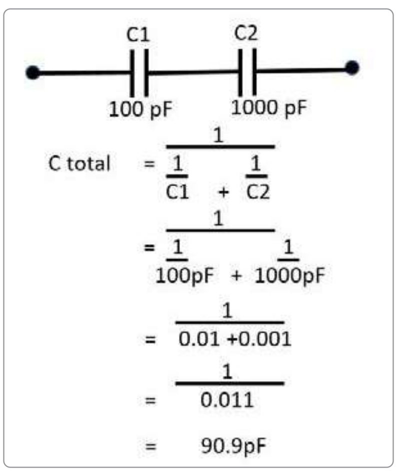

Figure 7. *For calculating the value of capacitors connected in series, the method is the same as for resistors in parallel.*

Capacitors in series

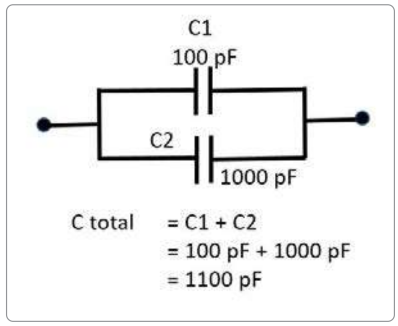

Figure 8. *Capacitors in parallel – simples – just add the values!*

Just when you thought you had everything sorted, along come capacitors just to throw a spanner in the works. The calculations are the same as before, just flipped!

So, the calculation for capacitors in series is the same as resistors in parallel. The result will always be less than the value of the smallest value capacitor, as in **Figure 7**.

Capacitors in parallel

The method of calculation for capacitors connected in parallel, is the same as for resistors in series. **Figure 8** shows how.

Try out a few calculations for yourself and the formulas will not be so daunting as you may have originally thought.

Memorisation

Memorising formulae can be helped by a mnemonic or a 'ditty'. There are several such reminders to help remember the resistor colour code (Google them). I remember the power formula $P = I^2 \times R$ as follows: *Twinkle twinkle little star, power equals I-squared R (I^2R).*

It never ceases to amaze me the number of people working in electrotechnology that do not have a fundamental understanding of the basics. When understood, circuit theory – for which this topic forms the foundation – makes it possible to comprehend all the more advanced subjects encountered in electrical and electronics.

Have fun and stay safe.