Bob's TechTalk #13
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Ohm's Law Part III of IV

Ohm's Power Law:

Last month we looked at Thevenin's theorem and how it made solving more complex circuit problems easier. This month we'll look at Ohm's power law; this law fits so closely with the Ohm's law we studied in the past two articles that it is often included and called the "six forms of Ohm's law" (actually there are twelve!). Let's list the three forms of Ohm's law we know so far. They are:

$$E = I \times R \qquad (1)$$
$$I = E / R \qquad (2)$$
$$R = E / I \qquad (3)$$

Ohm's power law introduces a new term, power, often symbolized by a P or W (for watts); we'll use W. Ohm's DC power law *states that the power in watts dissipated in a load (or resistance) is equal to the voltage across the load times the current flowing through the load*. In equation form it is simply:

$$W = E \times I \qquad (4)$$

Let's do a simple problem. What is the power dissipated by a one-ohm resistor when one volt is across it? The problem gives us the voltage but we need to know the current through the resistor. Using Ohm's law (2) it can be calculated as one amp. Thus the power dissipated by the resistor is:

$$W = E \times I = 1 \times 1 = 1 \text{ watt.}$$

Now, let's raise the voltage across the one-ohm resistor to two volts; you might expect the power to double, but be careful. Calculating the current again we find the current is now two amps, so the power is now:

$$W = E \times I = 2 \times 2 = 4 \text{ watts.}$$

Similarly, if we change the current through the resistor to 2 amps, the voltage across the resistor will increase to 2 volts and the power will be 4 watts. When you change the voltage or current through a fixed resistor the power dissipated by the resistor changes by the square of the voltage or current change. In equation form:

$$W = E \times E / R \text{ or } W = E^2 / R \qquad (5)$$
$$W = I \times I \times R \text{ or } W = I^2 \times R \qquad (6)$$

You now have seen the classic "six forms of Ohm's Law". Many ways have been developed to remember them - wheels, mnemonics, etc. I've never bothered with any of them nor have I made an effort to memorize the six equations; instead I've only memorized equations (1) and (4). From those two it is simple manipulation to get the ten others.

Getting Ohms Law in the Form You Want:

When I started this series I promised to not get into math too heavily. I'm going to renege on that promise a little in this section. Feel free to skip it, but it is really very simple, and once you master it you will find that you don't need to memorize as much for that test you're taking, or that problem you're solving. The trouble with memorizing is that, if you don't use it occasionally you'll forget it. Here's how to find all twelve when you only know the two basic equations (1 and 4).

Notice that between these two equations all four items: voltage (E), current (I), power (W) and resistance (R) appear (voltage and current appear in both!) You must know the value of two of the items to find either of the other two. Since each of the Ohm's Law equations only has three items in it, there is one item you don't care about. What you want to do is end up with a formula that has the two known items on one side of the equal sign (usually the right side) and the unknown item you're looking for on the other side (usually the left side). If the three items of interest are all found in either of the two equations (1 or 4) then you only need that equation. If the equation isn't already in the form mentioned above, divide both sides of the equation by the item you know that is on the longer side of the equation (the side with two items). For example, let's say we know the values for E and I and want an equation to calculate R:

$$E = I \times R \qquad (1)$$

We want to get this into the form where R is alone on one side of the equation. 'I' is the item that we know that is on the longer side of the equation so we'll divide both sides of the equation by 'I' like so:

$$E / I = I \times R / I \quad \text{or} \quad E / I = R \times I / I$$

Since I / I equals one, the 'I's on the right side cancel out and we get:

$$E / R = I$$

Swap the left and right sides to get equation (2), which is the one we want.

If the three items we want in our equation appear only when we look at both equations, the process is similar but has additional steps. First, determine the item that you **<u>don't</u>** need and arrange either of the equations it appears in so that it appears by itself on one side of the equal sign; this is just what we did above. As an example, we want the equation to solve for resistance (R), and we know the power (W) and voltage (E). The current (I) is the item that we don't need. I'll randomly use equation (4) and arrange it to solve for 'I' (the other equation could just as easily been chosen):

$$W = E \times I \ (4)$$

Dividing by 'E'

$$W / E = E \times I / E \text{ or}$$

$$I = W / E \qquad (7)$$

Now, substitute the equation we just solved into the other equation:

$$E = I \times R$$

$$E = (W / E) \times R$$

And rearrange it so 'R', the unknown item you want to solve for, is alone on one side of the equation. This is done similarly except, since there is a dividing term ('E' in this case) you multiply both sides by the dividing term. Let's simplify it now; first multiply both sides by 'E':

$$E \times E = (W / E) \times R \times E \text{ or}$$

$$E \times E = W \times R \times (E / E)$$

Remember - any value divided by itself is one so:

$$E \times E = W \times R \qquad (7)$$

Now to isolate R just divide both sides by 'W':

$$E \times E / W = R \quad \text{or:}$$

$$R = E \times E / W$$

Which can be written as:

$$R = E^2 / W.$$

When solving a couple of the equations you will end up with a "squared" term in the answer. One such case is when you want to know the voltage and have the power and resistance. This is identical to the previous example up to where we rearrange the terms. Starting with equation (7) above, we want now to isolate 'E' to one side of the equation

$$E \times E = W \times R$$

$$E^2 = W \times R$$

Now just take the square root of either side:

$$E = (W \times R)^{1/2}$$

Here are all twelve forms of Ohm's law. See how many you can derive from the two main equations (underlined):

$\underline{E = I \times R}$	$E = W / I$	$E = (W \times R)^{1/2}$
$I = E / R$	$I = W / E$	$I = (W / R)^{1/2}$
$R = E / I$	$R = E^2 / W$	$R = W / I^2$
$\underline{W = E \times I}$	$W = E^2 / R$	$W = I^2 \times R$

73, from AF6C

This article is based on the TechTalk article that originally appeared in the February 2010 issue of RF, the newsletter of the: Orange County Amateur Radio Club - W6ZE.