

1) Resistors

- a) By far and away, the majority of the parts on most circuits that are color coded are resistors. Resistors can be made out of carbon, wire, and other substances not quite so familiar. 99.99999% of the resistors you will see in your electronics career will be made of carbon or wire, and 99% of these will be carbon. It is probably wise to concentrate on the qualities and performance of carbon resistors since that is the predominant component in almost every circuit.
- b) Resistors have two main electrical qualities -- RESISTANCE (measured in ohms with shortcut symbol the Greek letter omega Ω) and allowable POWER (measured in watts). Both are a function of how the resistor is made.
- c) If you have a pencil lead (carbon) and attach leads to it, you will be able to measure a specific resistance from one end of the pencil to the other. If you make the lead SHORTER or FATTER, the resistance will go DOWN. This leads us to an equation that you need to have seen once, but not necessarily memorized or become familiar with. It goes like this: $R = (\rho * L) / A$ That is, the RESISTANCE (R) is equal to the "specific resistivity" (ρ) of the material times its length, all divided by the cross-sectional area. This equation is the mathematical equivalent to what I said, the shorter and fatter you make it, the lower the resistance.
- d) But all carbon is not created equal. Bituminous coal will not have the same "p" as anthracite. A #2 pencil lead will not have the same "p" as a #4. By varying the amount of impurities in the carbon, the resistor manufacturer can keep the same physical size for a whole BUNCH of resistance values. On the other hand, physical size pretty much determines how much heat a resistor can take, so (for example) all values of resistance (ohms) for quarter-watt resistors will be the same physical size.
- e) The last electrical quality a resistor has is TOLERANCE. If you go and take a 270 ohm resistor from the shelf, what are the odds of it being EXACTLY 270.000 ohms. Nearly zero. The manufacturing process is good, but it is not that good. So, we wind up telling the customer that you can buy a 270 ohm resistor, and it will be CLOSE to 270 ohms. How close? Within the marked TOLERANCE on the resistor. For example a 5% tolerance on a 270 ohm resistor lets it wander from plus 5% (13.5 ohms) to minus 5% and still be within specifications. If you were to measure this resistor with an ohmmeter, you would expect to see values between 256.5 and 283.5 ohms for a resistor within specified tolerance. Common tolerances today are 10%, 5%, 2%, and 1%. Of course, as you proceed from left to right in this sequence, the price goes up accordingly. 5% resistors are worth about a half a cent (500 millicents). 1% resistors are worth about 5¢ apiece.
- f) Nor can you go out and buy just any old value of resistor. Why, for example, would a manufacturer want to make a 260 Ω 5% resistor when the 270 Ω resistor encompasses this value. Resistor manufacturers have standardized the values that they will manufacture and sell. The 5% values (and 10% values in **bold**) you can buy are as follows:
- i) 1.1 **1.2** 1.3 **1.5** 1.6 **1.8** 2.0 **2.2** 2.4 **2.7** 3.0 **3.3** 3.6 **3.9** 4.3 **4.7** 5.1 **5.6** 6.2 **6.8** 7.5 **8.2** 9.1
- g) And all decimal multiples of these values up through 22 M Ω (22 Million Ohms, or more properly 22 Megohms).

- h) Some things to remember about resistors:
 - i) The current through a resistor is in phase with the voltage applied across the resistor.
 - ii) The reactance of the resistor is the same as the resistance of the resistor (for almost all practical purposes). A resistor's value does NOT change appreciably with frequency.
 - iii) Resistors can be used as heaters, voltage dividers, and current limiters.
 - iv) Resistors can be used in conjunction with capacitors and inductors as time constants, filters, and for wave shaping

2) Quotation about resistors (Globalspec)

- a) "Resistors are electrical components that oppose the flow of either direct or alternating current. They are used to protect, operate, or control circuits. Voltages can be divided with the use of resistors. In combination with other components, resistors can also be used to make electrical waves into shapes most suited to the designer's requirements. Resistors can have a fixed value of resistance, or they may be variable or adjustable within a certain range. Typically, resistor values are expressed in ohms, a unit of resistance. Materials of construction for resistors include carbon composition, carbon film, ceramic composition, metal alloy, metal film, metal oxide, thick film, thin film, and wire. Common lead types include axial leads, gull-wing leads, J-leads, radial leads, screw terminals, and tab terminals. Resistors without leads are also available.
- b) Performance specifications to consider when searching for resistors include resistance range, tolerance, power rating, continuous operating voltage, temperature coefficient, configuration, and operating temperature. Power rating is the maximum power supported by the resistor. Resistors can be operated at any combination of voltage and current as long as the power rating is not exceeded, and provided that neither the current rating nor the voltage rating is exceeded. Typically, power rating is measured in watts (W) and released as heat energy. Continuous operating voltage is measured in volts (V). The temperature coefficient of resistance (TCR) parameter measures the rate at which the nominal resistance value changes as a function of temperature. TCR for resistors is expressed in parts-per million (ppm) per degree Celsius, or ppm/C. .
- c) Physical specifications for resistors include mounting style and package type. Mounting styles include surface mount technology (SMT) and through-hole technology (THT), as well as bolt-on (chassis) and panel-mounted methods. Surface mount components are a direct response to cost reduction efforts that center around improved printed circuit board (PCB) production. Automatic or robotic pick and place equipment can pick and place surface mount devices (SMD) on a PCB with both speed and accuracy. Typically, the pad on the circuit board is coated with a paste like formulation of solder and flux. Unlike SMDs, through-hole resistors connect to a printed circuit board by inserting a terminal or lead through a hole in the board and soldering it to the opposite side. Bolt-on or chassis-style resistors use a metal-to-metal connection for maximum heat dissipation. Panel-mounted variable resistors use a threaded shaft with a bushing."

1) Ohm's Law

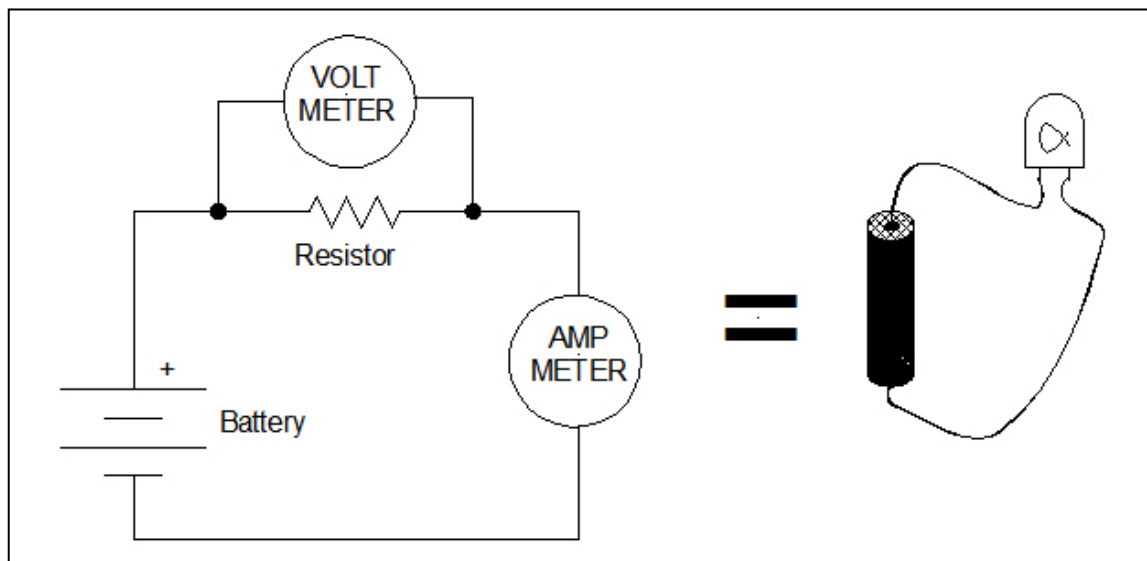
a) Georg Simon Ohm, professor of physics at the University of Munich (Germany) began experiments with Alessandro Volta's newfangled voltage pile and Oersted's experiments with wire wrapped around a compass and came up with a relationship between the two electrical quantities. He said:

i) If a component is placed across a battery of V volts and it causes a current of I amperes, then the component has a resistance of R ohms, where

(1) $R = E/I$ or using simple algebra,

(2) $E = I * R$ and

(3) $I = E/R$

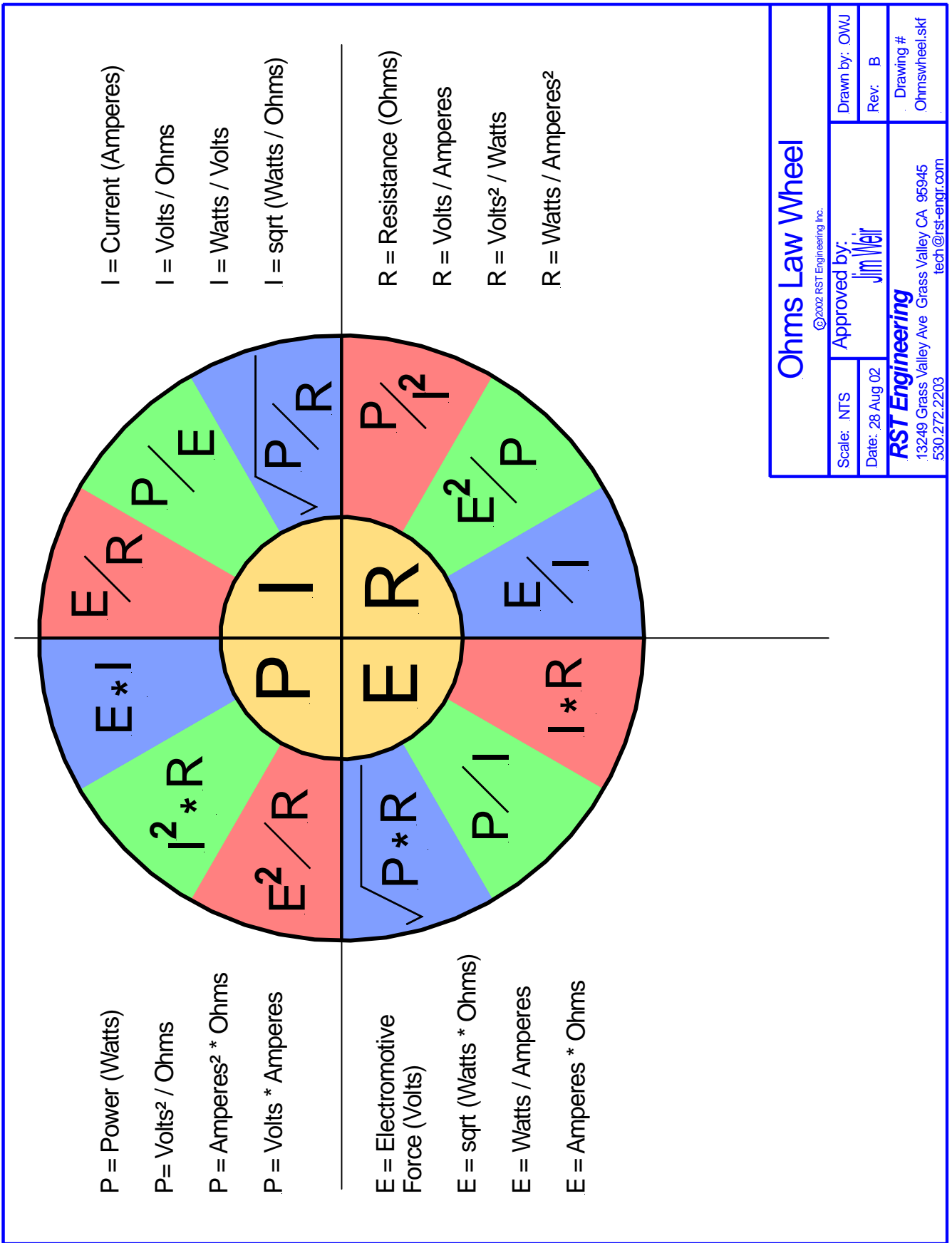


ii) Let's see now, I have math equations I'm going to be using all my career, perhaps I should make a

spreadsheet

for them? See ohmslaw.xls in the spreadsheet files. **DON'T WORRY ABOUT W or P RIGHT NOW. We'll take care of that next class.**

iii) See the next page for a graphic representation of this law.



Ohms Law Wheel

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Scale: NTS	Approved by:	Drawn by: OWJ
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