Electronics (General)

Ohm’s Law

$$I = \frac{V}{R}$$

$$V = IR$$

$$R = \frac{V}{I}$$

Multimeter

DMM - Digital Multimeter

When measuring voltage you measure volts **across** a component or battery. The meter uses a high resistance so very little current is able to go through the meter.

When measuring current you measure the amps **through** the meter, in other words you metter is part of the circuit. In order to be part of the circuit without having much of an impact the meter uses very low resistance.

Wires

Thin wire can potentially handle high voltage, but not high current. If you are holding an insulated wire and it feels very hot, you are likely running too much current through that wire and therefore should be using a larger diameter wire. Otherwise you are risking a potential fire. Also, through the heat the wire is generating you are losing energy/power.

Units

V = volt - same (V) in equations, although sometime (E)
Kva = kilovolts
A = amp - in equations respresented with I
mA = milliamps
Ω = ohm - use “ohm” where symbol is not available, in equations represented with R
kΩ = kiloohm - use kiloohm when symbol is not available

W = watt - use P for Power in equations
kW = kilowatt
C = coulomb

Note: The symbols are uppercase (except for the prefix, eg mA), but when using the names (volt, kilovolt, amp, milliamp, ohm, kiloomb, etc) they begin with lowercase

Analogies

Voltage - think of voltage as pressure, similiar to pressure in a water line.

Current - think of current as the rate of flow (messure in amps)

Coulomb - is the volume, the rate of flow over time (C=1A*1S)

Resistance - a restriction to the flow. There needs to be enough pressure (volts) to overcome this restriction to allow the current to flow, but the amount of current that flows will be restricted.

With Ohm’s Law if you have a pressure of 1 volt, a resistance of 1 ohm your current is going to be 1 amp. If the resistance is .5 ohm (less resistance) then your current is going to be 2 amps. If your resistance is 2 ohms (more resistance) then your current is going to be .5 amps. Example in a different scale: if you have 1 volt, and kΩ1 (kiloohm) (1000 ohms), your current is going to be 1 mA (milliamp) (0.001 amps).

The pressure analogy is well illustrated if you use a variable power supply to charge a battery. If the variable power supply is at the same volage (pressure) as the battery there will be no current flowing (0A). But as you increase the volts (pressure) on the power supply it pushes against the battery and the current increases (amps increase). If it is lower then the battery attempts to push back to the power supply, which will result in the power supply showing a negative current.

AC vs DC

Direct current flows in one directions (conventionally from possitive to negative, although technically the electrons flow from negative to postive). Represented on an oscillascope by a straight line.

Alternating current cycles back and forth from positive to negative. Represented as a sine wave on an oscillascope. In general the value (eg 120V) is the RMS (root mean square) value, not the peak value of the wave.

AC is often converted to DC, but it is much more efficient to transmit AC over distance. The losses over a piece of wire over distances is far greater with DC. You can also generate much higher voltages with AC. Long distance lines use high voltage, with low current, which is transformed before the endpoint.

DC can be more dangerous, because it will contract your muscles so you hold on to the wire, whereas AC will tend to throw you back.

The 110V used in the US is safer than the 220 used in Europe. The current is roughly the same (typically 15A to 20A in households). The tradeoff is that you have less power in a US than Europe. Although US has seperate 220 circuits for applicances that need higher power. One cycle in US is 60mHz in US, 50MHz in Europe.

Relationship of Voltage, Current, and Power

General

With higher currents you need thicker conductors to avoid excessive heat, but with voltage you can potentially have high voltage through a thin conductor as long as the curren is low (which will depend on the load/resistance).

Power

Power is expressed in Watts (W or watt)

Power formula:

$$P = \text{work done per unit time} = \frac{QV}{t} = IV$$

where

Q is electric charge in coulombs

t is time in seconds

I is electric current in amperes

V is electric potential or voltage in volts

Expressed in watts:

W = IV - amps times voltage

Power equates to **work**, the function that your circuit is meant to perform (a light, a motor, a broadcast, a display, a processor, etc)

When evaluating a power need you need to decide on the appropriate ratio between volts and watts. This is often determined by the needs of other components in the circuit which have certain voltage and current requirements.

Example different circuits with the same power requitement (24W), but different volt/amp ratios:

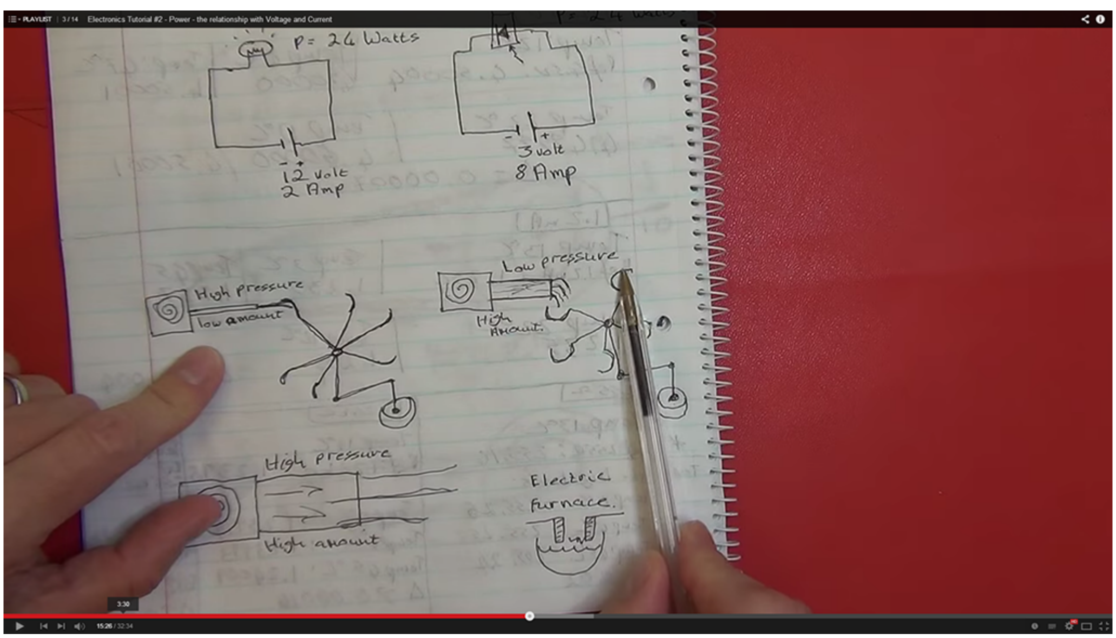
- 120V *.2A = 24W (.2A = 200mA)
- 12V * 2A = 24W
- 6V * 4A = 24W
- 3V * 8A = 24W
- 2V * 12A = 24W

Illustrated example of power, current, and voltage compared to water and pipe sizes

To accoumplish the same work amount

- High pressure through a small pipe = limitted flow (current)
- Medium pressure through a medium pipe = medium flow (current) - not illustrated below.
- Low pressure through a big pipe = high flow (current)

When you have both high pressure and a big pipe you are going to have a very large flow (current) - more work accomplished than the three examples above that perform the same amount of work with different ratios of pressure and current,



Current

The current is the rate at which a certain amount of electrons pass a given point. It is defined as 1A = 1C * 1S (amp, coulom, second). Current is generally measured in terms of amps rather than coulombs.

Coulomb - is the charge transported by a constant current of one ampere in one second. It is equal to the charge of approximately $6.241 * 10^{18}$ electrons, or inversely one electron has a charge of $1.602 * 10^{-19}$.

Load

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Hyperlink["Wikipedia", "http://en.wikipedia.org/wiki/Electrical_load"]
Wikipedia
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If an electric circuit has a well-defined output terminal, the circuit connected to this terminal (or its input impedance) is the load. (The term ‘load’ may also refer to the power consumed by a circuit; that topic is not discussed here.)

Load affects the performance of circuits that output voltages or currents, such as sensors, voltage sources, and amplifiers. Mains power outlets provide an easy example: they supply power at constant voltage, with electrical appliances connected to the power circuit collectively making up the load. When a high-power appliance switches on, it dramatically reduces the load impedance.

If the load impedance is not very much higher than the power supply impedance, the voltage will drop. In a domestic environment, switching on a heating appliance may cause incandescent lights to dim noticeably.

Impedance

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Electrical impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied.

In quantitative terms, it is the complex ratio of the voltage to the current in an alternating current (AC) circuit. Impedance extends the concept of **resistance** to AC circuits, and possesses both **magnitude** and **phase**, unlike resistance, which has only magnitude. When a circuit is driven with direct current (DC), there is no distinction between impedance and resistance; the latter can be thought of as impedance with zero phase angle.

Components

Resistors

Note that when using small resistor values < 100 ohms it is easy to exceed the power requiremens of that resistor. Since P = V*I and I = V/R, if you have a 100 Ohm resistor with 6 Volts applied you have a current (I) of 6/100=0.06A, and 6V * 0.06A = .36 watts, which exceeds the a 1/4 watt resistor (a 1//2 would be ok here). This becomes even more pronounced with even smaller resisance amounts such as 10 ohms. To get around this you can put the resistors in parrallel which reduces the resistance, but in the case of two resistors in parallel doubles the wattage requirement. So if you had two 200 ohm resistors in parallel, you woud still get the same 100 ohm resistance $(1/200 + 1/200)^{-1}$, but with 1/2 watt of power capability. Four 1/4 watt resistors in parallel will give you a total of 1 watt.

Capacitors

The function of a capacitor is to store an electrical charge. It is useful as a filter, and for passing AC and blocking DC.

When a DC voltage is applied to a capacitor it begins to charge. As the charge accumulates on the plates there is current flowing in the system. But as the capacitor gets charge the current is reduced, and when it is fully charged the current becomes zero.

When measuring resistance between the leads of a capacitor it will show infinite resistance, hence a capacitor will block DC current. However, when AC current is applied it will pass (rather than resistiance, it is called reactance)

The unit of capacitance is the Farad (F), but typical capacitors are in the microfarad (10^{-6}F), nanofarad (10^{-9}F), and picofarad (10^{-12}F).

When connecting capacitors in Series the total capacitance is determined by $(1/C_1 + 1/C_2 \ldots)^{-1}$, similar (and inversely) to how resistance is found in parallel.

When connecting capacitors in Parallel the total capacitance is the sum of the individual capacitances.

A capacitor has a breakdown voltage, the voltage limit that can be applied to a capacitor.

Inductors (Coils)

A coil is a copper wire wound in a spiral. They are inductors which is measured in the Henry (H). The more turns the coil contains, the stronger its characteristics become.

If a coil is wound around and iron rod, or ferrite core, the inductance of the coil will be greatly increased.

Self inductance is a measure of a coil's ability to establish and induced voltage as a result of a change in its current.

In some sense Inductors are like capacitors, but opposite in behavior. A capacitor will block DC, but allow AC to pass. An inductor will block AC, but allow DC to pass.

Inductors can be used to change frequencies.

Coils are used inTransformers - in which case the change in current of one coil affects the current and voltage in the second coil. This phenomenon is called Mutual inductance, which is also measured in henries.

Coils are used in Relays - in which case a magnetic field is induced that affects the the relay switch (opening and closing).

Coils are used as electromagnets

Coils are used for resonance, in which a coil is combined with a capacitor in which the impedience changes with the frequency of the voltage. These tuning circuits can be used to select a particular radio or television station.

From Wikipedia:

An inductor, also called a coil or reactor, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil. When a current flows through it, energy is stored temporarily in a magnetic field in the coil. When the current flowing through an inductor changes, the time-varying magnetic field induces a voltage in the conductor, according to Faraday's law of electromagnetic induction, which opposes the change in current that created it.

An inductor is characterized by its inductance, the ratio of the voltage to the rate of change of current, which has units of henries (H). Inductors have values that typically range from 1 μH (10–6H) to 1 H. Many inductors have a magnetic core made of iron or ferrite inside the coil, which serves to increase the magnetic field and thus the inductance. Along with capacitors and resistors, inductors are one of the three passive linear circuit elements that make up electric circuits. Inductors are widely used in alternating current (AC) electronic equipment, particularly in radio equipment. They are used to block the flow of AC current while allowing DC to pass; inductors designed for this purpose are called chokes. They are also used in electronic filters to separate signals of different frequencies, and in combination with capacitors to make tuned circuits, used to tune radio and TV receivers.

Diodes

Diodes only allow current to flow in one direction, in the case of DC applying a positive voltage to the anode the current flows from anode to cathode.

Uses

- They are used as **Rectifiers** to convert AC to DC
- They are used as **Switches** in some applications
- They are used as **Voltage Regulators**
- They are the electrical equivellent of valves, in fact they used to be called valves

There are two main types of ordinary diodes

- Signal diodes: which pass small currents of 100mA or less
- Rectifier diodes: which can pass large currents.

Other types of diodes include LEDs and Zener Diodes. Zener Diodes are often used as voltage regulating diodes. A varactor (varicap) diode allows you to have variable capacitance.

When you apply a positive voltage to the anode (the P side of PN semiconductor material) it is **forward biased** with low resistance and current will flow. If you provide a positive voltage to the cathod (the N side of the PN semiconductor material) it is **reverse biased** with high resistance and no current will flow.

Below the cut-in voltage (typically .7V in semiconductor material) the current will be very small. Once the cut-in voltage is reached the current increases significantly an the current can become very large.