CHAPTER 2

Basic Electronics & Theory

(The rules behind all those little things)

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Math Formulas

- Often we'll get one formula, and to find an answer it will mean rearranging it.
- Symbols used are:
  - \+ Addition - Subtraction
  - * Multiplication / Division
- Consider solving for B:

4 = B * 2

Rearrange and

B = 4 / 2 = 2

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Math Formulas (2)

- More examples solving B:

  A = B + C "rearrange"

  A – C = B + C – C

  A – C = B or

  B = A - C

- And another one….

  A = B / C

  A * C = B / C * C

  A * C = B

  B = A * C

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Metric Prefixes

Metric prefixes you'll need to know ...

1 Giga (G) = 1 billion = 1,000,000,000
1 Mega (M) = 1 million = 1,000,000
1 kilo (k) = 1 thousand = 1,000
1 centi (c) = 1 one-hundredth = 0.01
1 milli (m) = 1 one-thousandth = 0.001
1 micro (u) = 1 one-millionth = 0.000001
1 pico (p) = 1 one-trillionth = 0.000000000001

... and a few you might want to know ...

1 Tera (T) = 1trillion = 1,000,000,000,000
1 hecto (h) = hundred = 100
1 deci (d) = 1 tenth = 0.1
1 nano (n) = 1 one-billionth = 0.000000001

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Metric Prefixes

The prefix enables us to reduce the amount of zeros that are used in writing out large numbers.

For example…

Instead of saying that the frequency of a signal is 1,000,000 Hz
(Hz = Hertz, or cycles per second)

We say it is 1 Megahertz (MHz) or 1,000 kilohertz (kHz)

The prefix enables us to write the number in a shorter form

This becomes especially useful when we need to measure or record very large or very small values

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Metric Prefixes

Mega = one million = 1,000,000

Let's go back and look at large frequencies again

1,000 Hz = 1 kHz
"One thousand Hertz equals one kilohertz"

1,000,000 Hz = 1 Mhz
"One million Hertz equal one megahertz"

How many kilohertz are in one megahertz?

1000 kHz = 1 MHz
"One thousand kilohertz equals one megahertz"

If a radio is tuned to 7125 kHz, how do we express it in megahertz?

1000 kHz = 1 MHz || 7125 kHz = 7.125 MHz

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Metric Prefixes

Mega = one million = 1,000,000

Another frequency problem: your dial reads 3525 kHz. What is the same frequency expressed in Hertz?

1 kHz = 1000 Hz || 3525 kHz = 3,525,000 Hz

(Notice that since we have to add three zeros to go from 1 kHz to 1000 Hz, we must also do the same to go from 3525 kHz to 3,525,000 Hz.)

Your displays shows a frequency of 3.525 MHz. What is that same frequency in kilohertz?

1 MHz = 1000 kHz || 3.525 MHz = 3525 kHz

(See how the 1 became 1000? To go from megahertz to kilohertz, you multiply by 1000. Try multiplying 3.525 MHz by 1000 to get your frequency in kilohertz.)

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Metric Prefixes

Giga = one billion = 1,000,000,000

Remember, kilo equals one thousand, and mega equals one million

One billion Hertz is one gigahertz (GHz).

You are transmitting on 1.265 GHz, what is your frequency in megahertz?

1 GHz = 1000 MHz || 1.265 GHz = 1265 MHz

These prefixes make it easier to express the large and small numbers commonly used in radio and electronics

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Metric Prefixes

Milli = one one-thousandth = 0.001

If you were to take an ammeter (a meter that measures current) marked in amperes and measure a 3,000 milliampere current, what would your ammeter read?

1,000 mA = 1 A || 3,000 mA = 3 A

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Metric Prefixes

Now lets say, on a different circuit, you were using a voltmeter marked in volts (V), and you were measuring a voltage of 3,500 millivolts (mV). How many volts would your meter read?

1,000 mV = 1 V || 3,500 mV = 3.5 V

How about one of those new pocket sized, micro handheld radio you're itching to buy once you get your license? One manufacturer says that their radio puts out 500 milliwatts (mW) , while the other manufacturer's radio will put out 250 milliwatts (mW). How many watts (W) do these radios really put out?

1000 mW = 1 W || 500 mW = 0.5 W

1000 mW = 1 W || 250 mW = 0.25 W

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Metric Prefixes

Micro = on one-millionth = 0.000001

Capacitors usually have very small values. A one-farad capacitor is seldom used in commercial electronics.

Usually, capacitors have values in the range of thousandths of a farad to trillionths of a farad

Micro and pico are the opposite end of the scale compared with kilo, mega, and giga… they indicate very small values

If a capacitor has a value of 500,000 microfarads, how many farads would that be?

Since it takes one million microfarads to equal one farad...

1,000,000 uF = 1 F || 500,000 uF = 0.5 F

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Metric Prefixes

Pico = one one-trillionth = 0.000000000001

What if a capacitor has a value of 1,000,000 picofarads? One picofarad is one trillionth of a farad. One picofarad is also one millionth of a microfarad. So it takes one million picofarads (pF) to equal one microfarad (uF):

1,000,000 pF = 1 uF

It takes one trillion (i.e. one million-million) picofarads (pF) to equal one farad (F):

1,000,000,000,000 pF = 1 F

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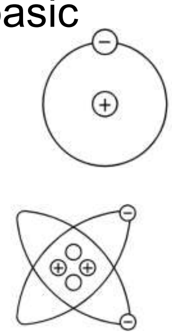
Atomic Theory

- In high school, we learned that the basic elements of matter are:
  - The atom
    - Protons (+)
    - Electrons (-)
    - Neutrons (nothing/neutral)
  - Electrons move nearly randomly in layers around the nucleus (made of Protons and Neutrons)



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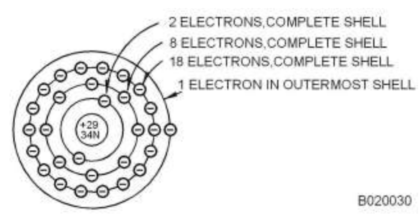
Atomic Theory (2)

- Electrons live in layers around the nucleus
  - The 1st 3 layers hold 2, 8, and 18 electrons, matching 28 protons. This is VERY stable.
  - For copper, it has 29 electrons. The one on the outside is referred to as a valence electron, and more easily dislodged than those in layers that are full
  - Valence electrons can be dislodged by heat and energy



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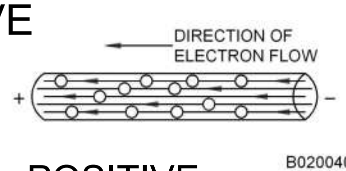
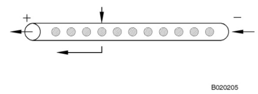
Electron Flow

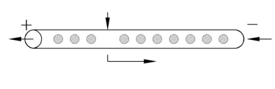
- Electrons have a NEGATIVE charge, so are attracted to POSITIVE charges
  - They flow from NEGATIVE to POSITIVE
  - When an electron is pushed out the positive end, another must reappear at the negative
  - Moving electrons to the left is called "electron current flow"





"Hole" Flow

- One can also think of the electron moving over, creating a "hole", into which another electron can move
  - As the electrons move left, toward positive, the "hole" moves right
  - This is alternate perspective is called "conventional current flow", and originated long ago before a better understanding of atomic theory was developed (BE: before electrons)



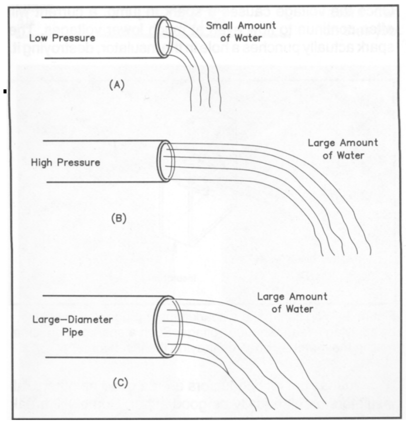
Current, Voltage, Resistance

Water flowing through a hose is a good way to imagine electricity. Water is like **Electrons** in a wire.

Flowing electrons are called **Current**

Pressure is the force pushing water through a hose – **Voltage** is the force pushing electrons through a wire

Friction against the hose walls slows the flow of water – **Resistance** is an impediment that slows the flow of electrons



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Two Types of Current

- **Direct Current** (**DC**)
  - Flows in only one direction **from negative toward positive** pole of source
- **Alternating Current** (**AC**)
  - Flows back and forth because the poles of the source alternate between positive and negative

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Conductors & Insulators

Electricity flows easily through some materials. These materials are called **conductors**. Most conductors are metals, and some of the best conductors are

gold, silver, aluminum and copper

Some materials resist or prevent the flow of electricity through them. These **insulators** include such materials as

glass, air, plastic, and porcelain

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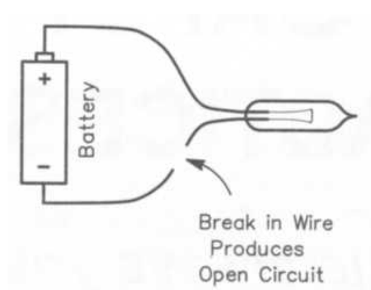
Open Circuit

In an **open circuit** no current flows. A break or open in a DC circuit makes it impossible for electrons to complete a journey from negative to positive poles, so nothing flows.

For example, when a switch in a circuit is turned off, it creates an open circuit by creating a break or opening in the circuit, and current stops flowing. When it is turned on, the "path" from negative to positive poles is completed and current flows.



You probably figured that since there are "open circuits" that there are probably also "closed circuits". Well, a closed circuit is when the switch is closed and current is allowed to flow through the circuit.

A fuse is a device that is used to create an open circuit when too much current is flowing.

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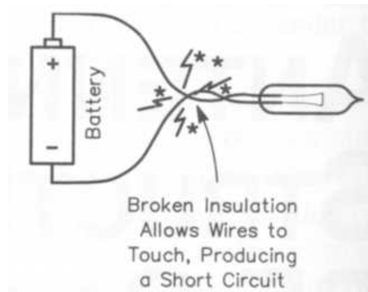
Short Circuit

A **short circuit** usually occurs when the intended path of electron flow is abruptly shortened, often by crossing uninsulated wires or touching other components together.

Since a circuit usually has some resistance, and the power wires or touching components that "short out" have little resistance, current will tend to flow through the path of least resistance... the location of the short circuit.

Less resistance at the same amount of voltage results in greater current flow, which can damage components not designed for it.



What is the best way to stop a short circuit from doing damage (because it is drawing too much power from the source)?

A fuse. Fuses are designed to work up to a certain amount of current (e.g. 1 amp, 15 amps, etc.)

When the maximum rated current is exceeded, the wire within the fuse burns up from the heat of the current flow, breaking the circuit and creating an open circuit… no more current flow.

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Resistors

- Fixed resistors come in different power ratings (1/4w, up)
  - Some can handle very high power levels, being either fixed value (grey) or variable (brown)
- Adjustable resistors are called “variable resistors”.
  - Some have built-in switches (i.e. Power on/off volume controls)

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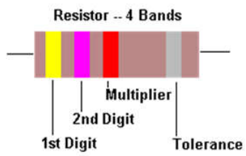
Resistor Fundamentals

Resistor Colour Codes & Tolerances



Band Color	Digit	Multiplier	Tolerance
Black	0	1	---
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	---
Blue	6	1,000,000	---
Violet	7	10,000,000	---
Gray	8	100,000,000	---
White	9	---	---
Gold	---	0.1	±5%
Silver	---	0.01	±10%
None	---	---	±20%

0	1	2	3	4	5	6	7	8	9
Bad	**Booze**	**Rots**	**Our**	**Young**	**Guts**	**But**	**Vodka**	**Goes**	**Well**
Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White

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Resistor Fundamentals

The color code chart is applicable to most of the common four band and five band resistors. Five band resistors are usually precision resistors with tolerances of 1% and 2%. Most of the four band resistors have tolerances of 5%, 10% and 20%.

The color codes of a resistor are read from left to right, with the tolerance band oriented to the right side. Match the color of the first band to its associated number under the digit column in the color chart. This is the first digit of the resistance value. Match the second band to its associated color under the digit column in the color chart to get the second digit of the resistance value.

Match the color band preceding the tolerance band (last band) to its associated number under the multiplier column on the chart. This number is the multiplier for the quantity previously indicated by the first two digits (four band resistor) or the first three digits (five band resistor) and is used to determine the total marked value of the resistor in ohms.

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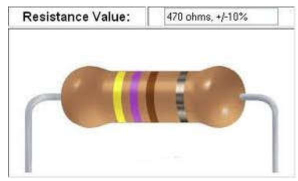
Resistor Fundamentals

To determine the resistor's tolerance or possible variation in resistance from that indicated by the color bands, match the color of the last band to its associated number under the tolerance column. Multiply the total resistance value by this percentage.

Example of a 4-Band Resistor

Colours:	Band 1 (Value):	YELLOW (4)
	Band 2 (Value):	VIOLET (7)
	Band 3 (Multiplier):	BROWN (1)
	Band 4 (Tolerance):	SILVER (10%)
Value:	Resistance:	470 Ohms
	Preferred Value:	470 Ohms (10%)
	Tolerance:	10%



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Multimeter Tool

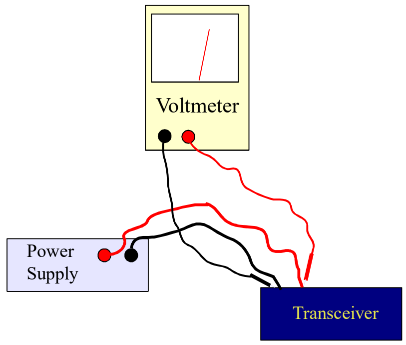
Multimeters will measure Voltage, Current and Resistance.

Be sure it is set properly to read what is being measured.

If it is set to the ohms setting and voltage is measured the meter could be damaged!

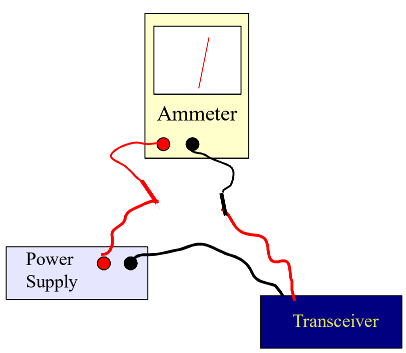
Measuring Voltage

Potential difference (voltage) is measured with a voltmeter, the voltmeter is connected to a circuit under test **in parallel with the circuit**



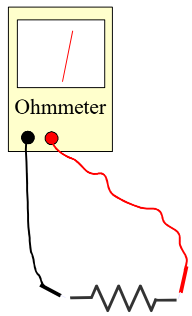
Measuring Current

The instrument to measure the flow of electrical current is the ammeter. An ammeter is connected to a circuit under test **in series with the circuit**



Measuring Resistance

The instrument to measure resistance is the ohmmeter. An ohmmeter is connected to a circuit under test **in parallel with the circuit**



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Hands-on Team Work

- Using a Multimeter measure:
  - Set to Resistance:
    - Record the values of each resistor
    - Determine the value from the colour code
    - Are the values the same?
  - Set to Voltage:
    - Record the values across each cell
    - Record the values across both cells together
    - Is the voltage across both cells what you expect?

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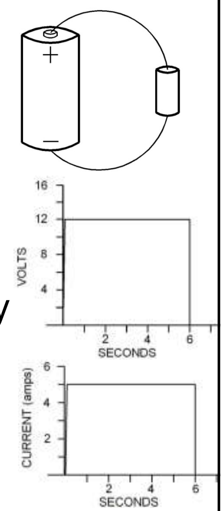
DC Voltage

- When a battery is connected to a load (i.e. Resistor)
  - Voltage and Amperage in the circuit rises quickly to a constant level
  - Remains in this state until the battery wears down (electromotive force is consumed)



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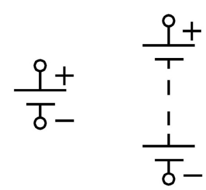
Batteries: Series



- When batteries are connected in series, the total voltage is the SUM of the battery voltages
  - Example: 3 9-volt cells are in series – the voltage at the probes is 27 volts

- The amperage delivered is the maximum current of the lowest capacity cell
  - If all cells can deliver 1 ampere individually, then together they deliver 1 ampere at 27 volts

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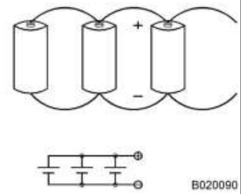
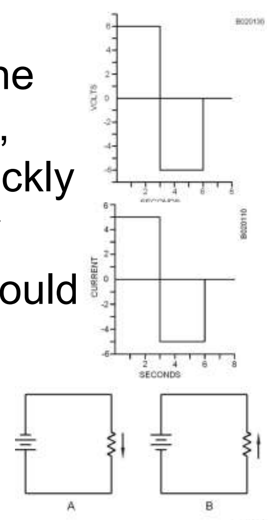
Batteries: Parallel



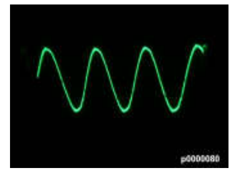
- When batteries are in parallel, the voltage is the common voltage
  - Three 9-volt batteries in parallel give 9-volts
- The difference is that the amperage from the batteries is additive
  - If 1 cell can deliver 1 amp, then 3 cells in parallel will deliver 3 amps, but still at the common voltage

Switching around polarities

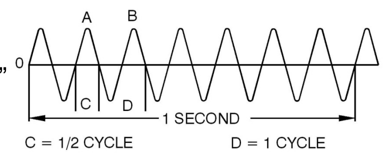


- If we were to suddenly switch the terminals around on the battery, then the voltage would drop quickly and then have opposite polarity
- At the same time, the current would suddenly stop, then reverse its direction

AC Voltage



- Switching around quickly is what happens for AC (wall power, which is 110-120 volts)
  - The number of cycles measured over time (in seconds) defines the cycle rate
  - Our wall power switches back and forth 60 times a second (called 60 cycles per second, or **60 Hertz**)
  - The speed of cycles is a “frequency” and we will use this later when talking about radio “waves”



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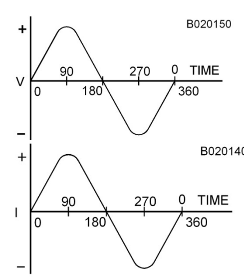
Generators creating AC

- As the generator runs, it creates voltage and current over time.
  - You can think of the voltage and current as relative to the spin of the generators armature in degrees of a circle



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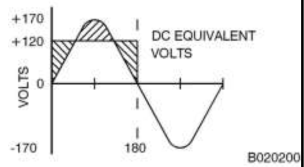
Comparing AC to DC

- Wall power is typically called 120 Volts AC
  - BUT, the peak voltage is not 120v, but is really about 170v (169.68v)



- Because of the under-runs in voltage at the start and end of each half-cycle, this higher value is required for equivalence
  - For mathies/engineers, the area under the AC curve, is equal to the area of the DC square, delivering the same effective voltage and current

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How to compare AC and DC

- In order to calculate the equivalent AC voltage compared to a DC source we use the "root mean square" formula:
  - Formulas: $\mathbf{E_{rms} = 0.707 \times E_{peak}}$ <u>OR</u>
    $\mathbf{E_{peak} = 1.414 \times E_{rms}}$
- Just as we used a Multimeter (or Volt-Ohm Meter VOM) in our hands-on session, we recommend you get this very useful tool as one of your FIRST purchases.

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