Ham Radio License Course

Discovering the Excitement of Ham Radio

ARRL The national association for AMATEUR RADIO®

SCARS Tech License Course – Week 3

Electrical Components and Circuits

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Technician License Course

Chapter 3

Lesson Plan Module – 3a

Electricity

Fundamentals of Electricity

- Radios are powered by electricity and radio signals are a form of electrical energy.
- A basic understanding of how we control electricity allows you to better install and operate your radio.

Fundamentals of Electricity

- Electrical charge can be positive or negative.
  - Opposite charges attract each other
- Electrical current is the flow of *electrons*.
  - Electrons are negatively-charged atomic particles, usually surrounding an atom's positively-charged nucleus of protons (positive) and neutrons (neutral – no charge)
  - Electrons move in response to an *electromotive force* and can move independently of atoms

Basic Electrical Concepts

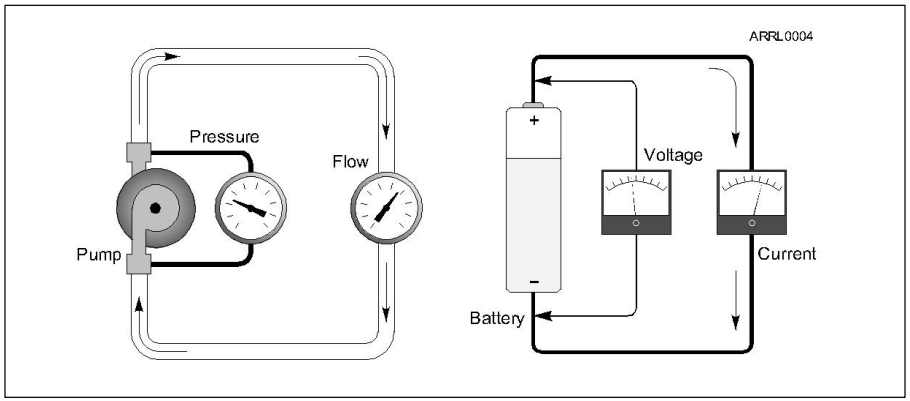
- Current: the movement of electrons, measured in *amperes* (A) by an ammeter, and represented by *I* in formulas
- Voltage: the amount of electromotive force (emf), also called electrical potential, measured in *volts* (V) by a *voltmeter*, represented by *E* or *V* in formulas

Basic Electrical Concepts

- Resistance: the opposition to the movement of electrons, measured in *ohms* (Ω) by an *ohmmeter* and represented by R in formulas.
- Resistance is like friction and turns electrical energy into heat when current flows.
- *Conductors* permit current flow (low resistance) and insulators block current flow (high resistance).

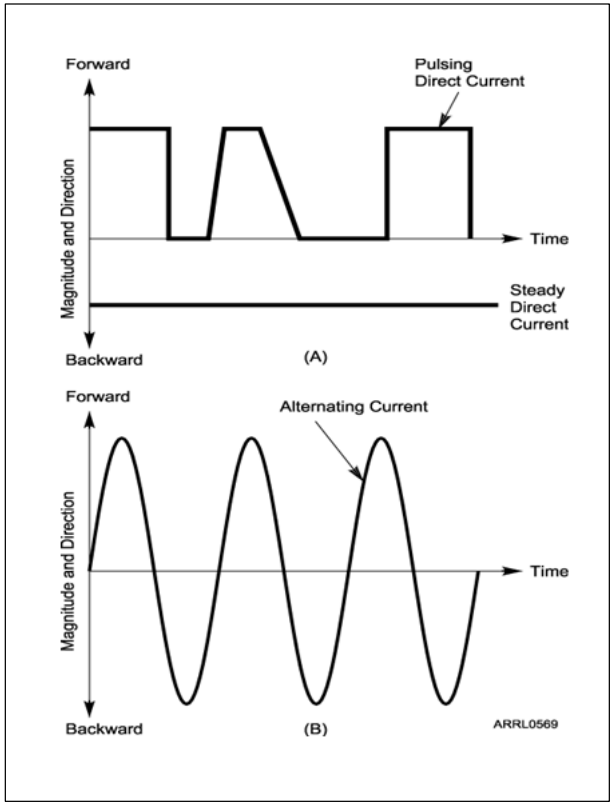
Basic Electrical Concepts

- The flow of water through a pipe is a good analogy to understand the three characteristics of electricity and how they are related.



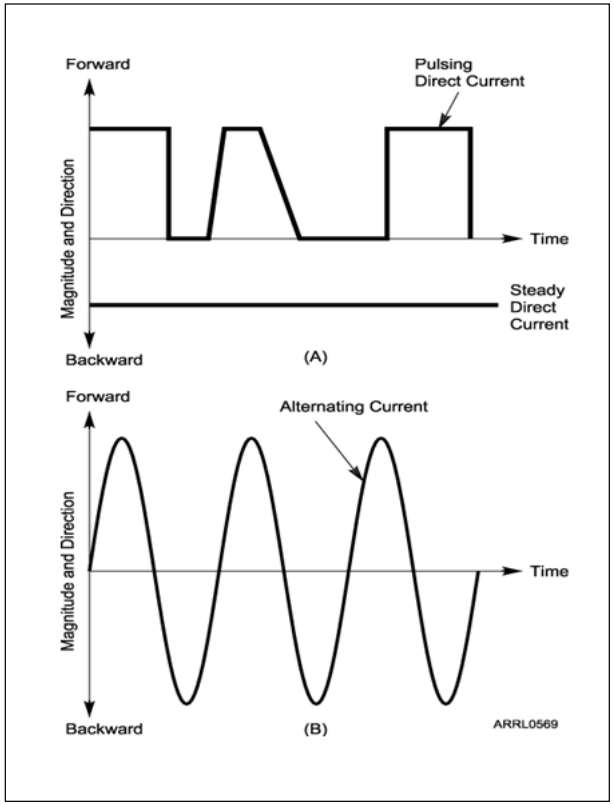
The Two Kinds of Current

- Current that flows in only one direction, is called direct current (dc).
  - Batteries are a common source of dc.
- Current that flows in one direction then in the opposite direction is called alternating current (ac).
  - Household current is ac



The Two Kinds of Current

- AC current reverses direction on a regular basis
  - Each process of reversing is a *cycle*.
  - The number of cycles per second is *frequency*, measured in hertz (Hz).
- 1 Hz = 1 cycle per second

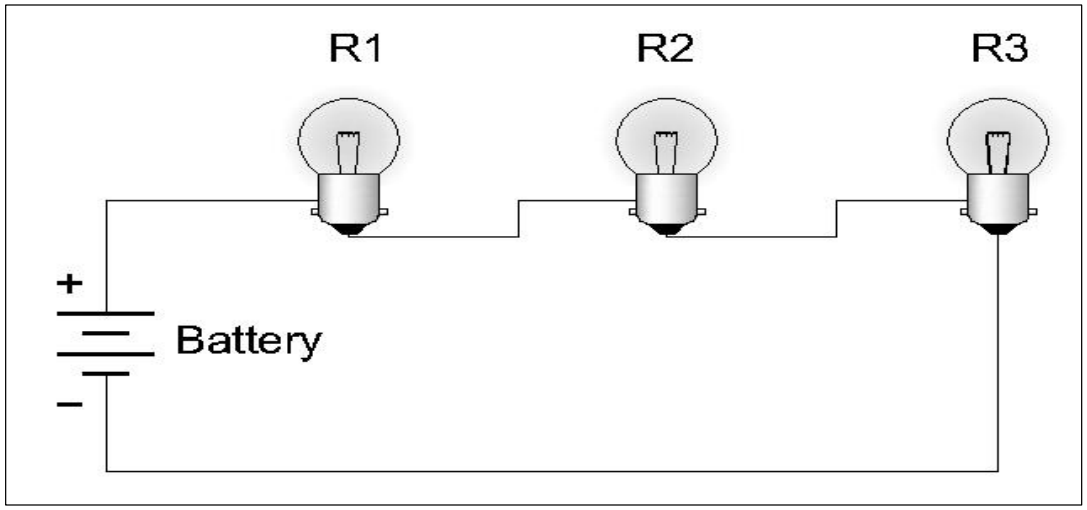


The Electric Circuit: An Electronic Roadmap

- For current to flow, there must be a path from one side of the energy source to the other side of the source – this path is called a *circuit*.
  - There must be a pipe (conductive path) through which the water (current) can flow.
- There are two types of electric circuits.
  - Series and parallel

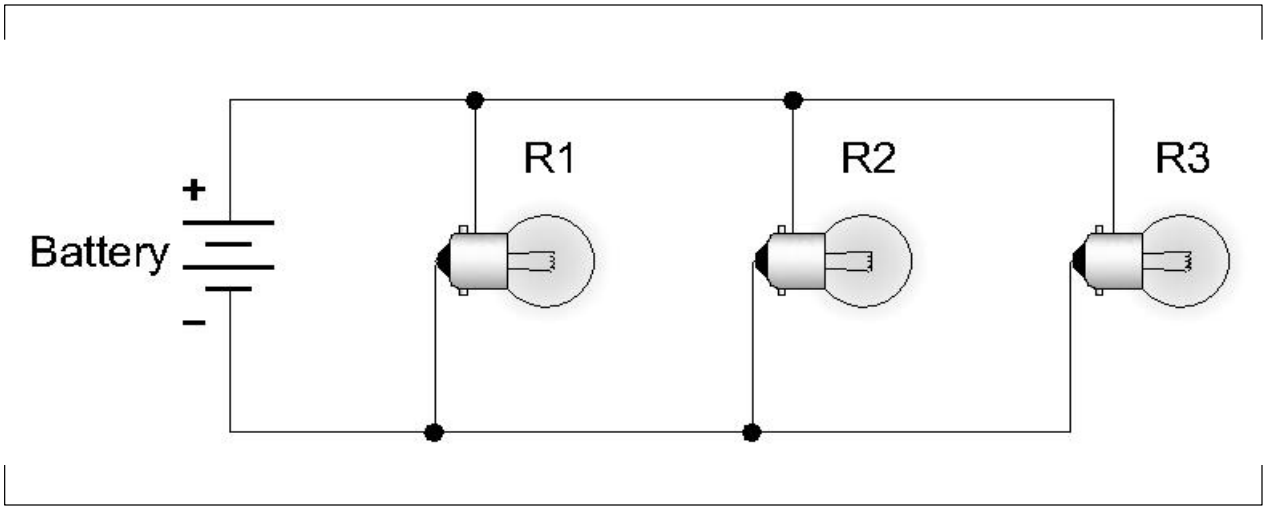
Series Circuits

- Series circuits provide one and only one path for current flow



Parallel Circuits

- Parallel circuits provide multiple paths for current flow.



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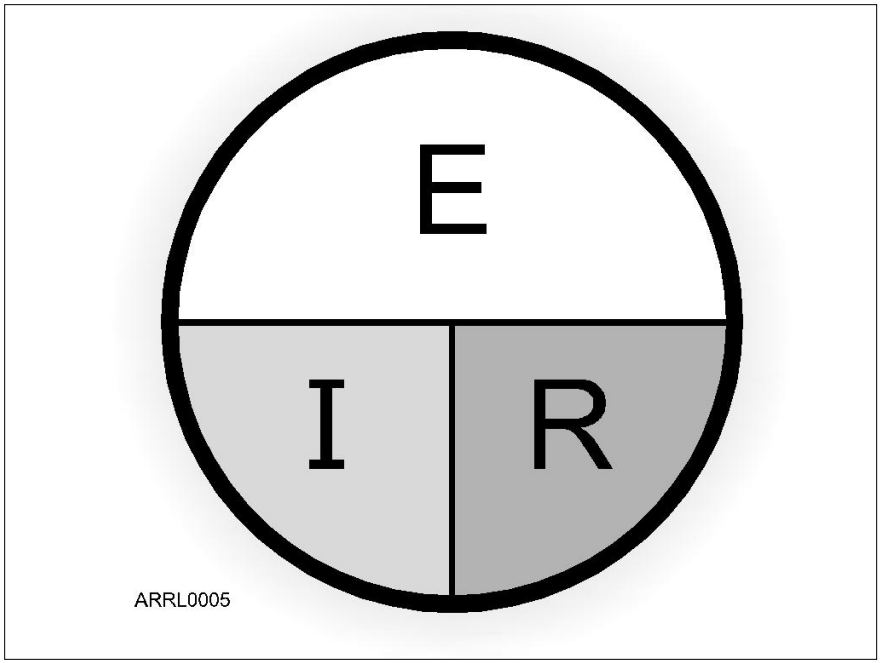
Chapter 3

Lesson Plan Module – 3b

Ohm's Law, Power and the Metric System

Ohm's Law



- E represents voltage
  - Units – volts (V)
- I represents current
  - Units – amperes (A)
- R represents resistance
  - Units – ohms (Ω)

$R = E / I$

$I = E / R$

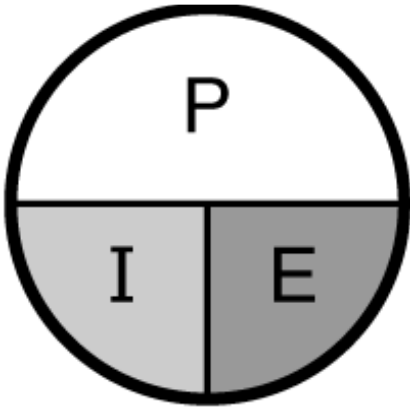
$E = I \times R$

Power - Electrons Doing Work and Expending Energy

- Any time energy is expended, power is consumed.
- Electrons moving through resistance expend electrical energy and consume power.
- Power is the rate at which energy is consumed.
- Power is measured in units of watts (W).

Power Equation

- Power is calculated as the product of voltage and current
  P = E x I
  E + P / I
  I = P /E



- Like Ohm's Law, if you know two of the values, you can calculate the third.

Metric Prefixes

Table 2-1
International System of Units (SI)—Metric Units

Prefix	*Symbol*	*Multiplication Factor*
Tera	T	10^{12} = 1,000,000,000,000
Giga	G	10^{9} = 1,000,000,000
Mega	M	10^{6} = 1,000,000
Kilo	k	10^{3} = 1000
Hecto	h	10^{2} = 100
Deca	da	10^{1} = 10
Deci	d	10^{-1} = 0.1
Centi	c	10^{-2} = 0.01
Milli	m	10^{-3} = 0.001
Micro	μ	10^{-6} = 0.000001
Nano	n	10^{-9} = 0.000000001
Pico	p	10^{-12} = 0.000000000001

Electrical Units

Table 3.1
Electrical Units and Their Namesakes

Unit	*Measures*	*Named for*
Ampere	Current	Andree Marie Ampere (1775 – 1836)
Coulomb	Charge	Charles Augustin Coulomb (1736 – 1806)
Farad	Capacitance	Michael Faraday (1791 – 1867)
Henry	Inductance	Joseph Henry (1797 – 1878)
Hertz	Frequency	Heinrich Hertz (1857 – 1894)
Ohm	Resistance	George Simon Ohm (1787 – 1854)
Watt	Power	James Watt (1736 – 1819)
Volt	Voltage	Alessandro Giuseppe Antonio Anastasio Volta (1745 – 1827)

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Chapter 3

Lesson Plan Module – 3c

Electrical Components

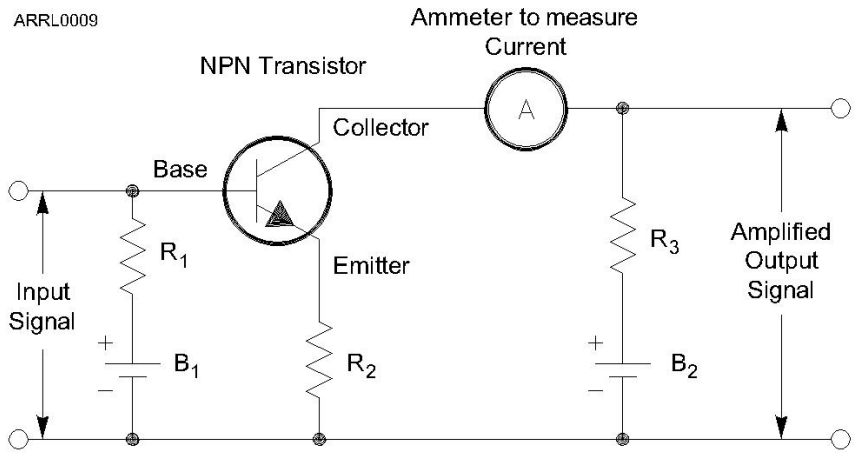
Electronics – Controlling the Flow of Current

- To make an electronic device (like a radio) do something useful (like a receiver), we need to control and manipulate the flow of current.
- There are a number of different electronic components that are used to do this

Schematic Diagrams

- We can draw pictures of electronic components forming circuits, such as for the parallel and series circuit examples. This is too cumbersome for most circuits.
- Schematic diagrams use symbols with different components, each having a different symbol.

Schematic Diagrams



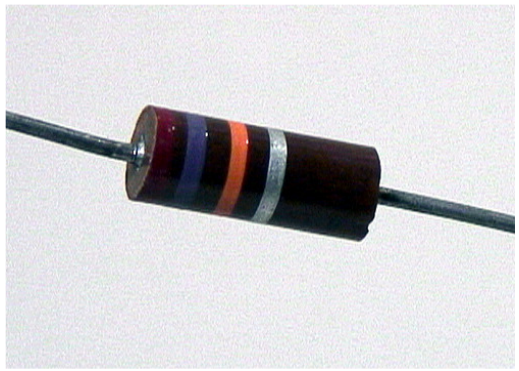
The lines and dots on schematics represent electrical connections between the components.

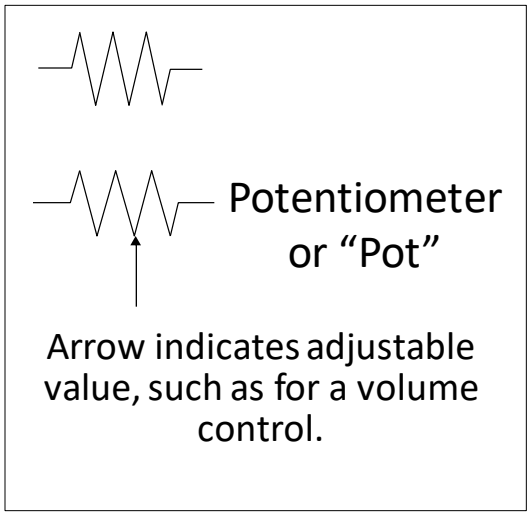
The Resistor

- The function of a resistor is to restrict the flow of current.
- Schematic symbol
- Remember Ohm's Law:

  I = E / R

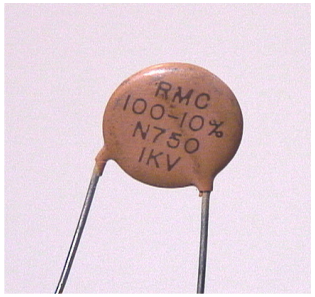
  E = I x R

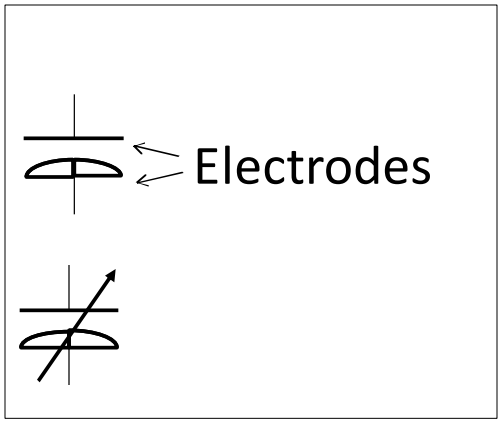




The Capacitor

- The function of a capacitor is to store electrical energy – called *capacitance*.
- Schematic symbol
  - Acts like a battery
  - Stores energy in an electric field created by voltage between the electrodes with insulating dielectric material between them

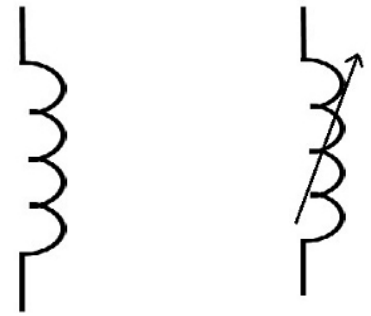




The Inductor

- The function of an inductor is to store magnetic energy – called *inductance*.
  - A coil of wire around a *core* of air or magnetic material like iron or ferrite
  - Stores energy in a magnetic field created by current in the wire

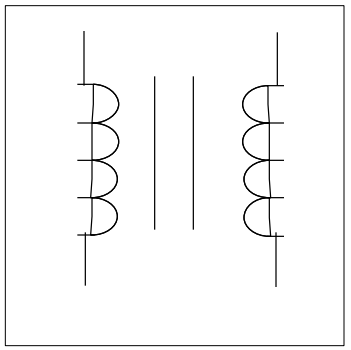
- Schematic symbol

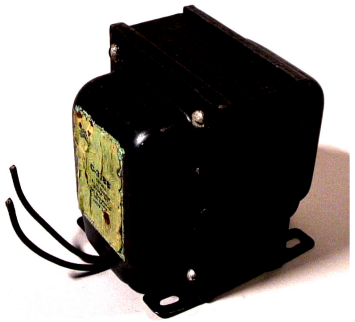


The Transformer

- A pair of inductors sharing a common core
  - Also share their magnetic field
  - Used to transfer energy from one circuit to another without a direct connection
  - Changes the ratio of voltage and current

- Schematic symbol





Electrical Units

- Each type of component has a value measured in specific units:

- Resistors > resistance > ohms (Ω)
- Capacitors > capacitance > farads (F)
- Inductors > inductance > henrys (H)

Component Designators

- Each schematic symbol has a *designator* to denote which component it refers to. For example, the 10th resistor in a circuit is R10.
- Resistors (R), capacitors (C), inductors (L).

Indicators and Displays

- Indicators communicate status
  - ON/OFF, ready/stand-by, left/right
  - LEDs, light bulbs, symbols, audio tones
- Displays communicate values or text
  - Numeric values, warnings, messages
  - Digital and analog meters, LCD screens

Reactance

- Capacitors and inductors store energy, rather than dissipating it like resistors.
- Energy storage creates an effect called *reactance* (symbol *X*) that acts like a resistance in opposing the flow of ac current.

- Capacitors create *capacitive reactance (X_C)*
- Inductors create inductive reactance *(X_L)*
- The effects of each are complementary

Impedance

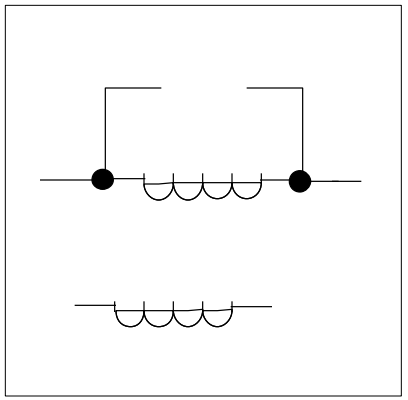
- The combination of resistance (*R*) and reactance (*X*) is called impedance, represented by the symbol *Z*.
- Impedance represents a circuit's opposition to both ac and dc currents.

Resonance

- A component's reactance depends on frequency: X_L increases with frequency while X_C decreases.
- At the frequency for which a circuit's X_L and X_C are equal, their effects cancel. This is the circuit's *resonant frequency*.
- At *resonance*, a circuit has only resistance, which affects ac and dc current equally.

Resonant or Tuned Circuit

- Capacitors and inductors connected together create a *tuned circuit*.
- When X_L and X_C are equal, the circuit is *resonant*.
- If C or L are adjustable the resonant frequency can be varied or tuned.



Semiconductor Components

- Made of material like silicon that are “OK” conductors but not as good as metals.
- Impurities added to semiconductors create material with more than usual electrons (*N*-type) and fewer than usual (*P-type*) electrons.
- Structures of N and P material can control current flow through the semiconductor.

The Diode

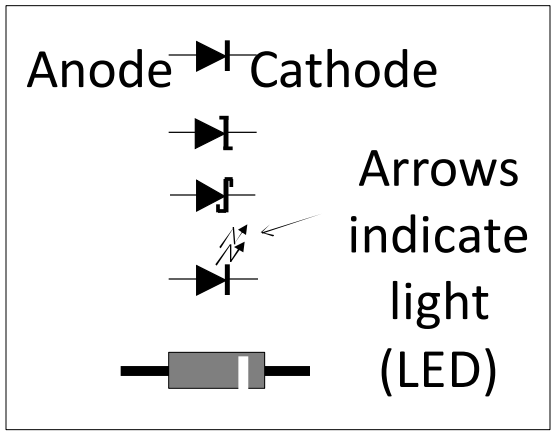
- Allows current to flow in only one direction.

- Two electrodes: *anode* and *cathode*

- AC current is changed to varying pulses of dc – called *rectification*

- Diodes used to change ac power to dc power are called *rectifiers*

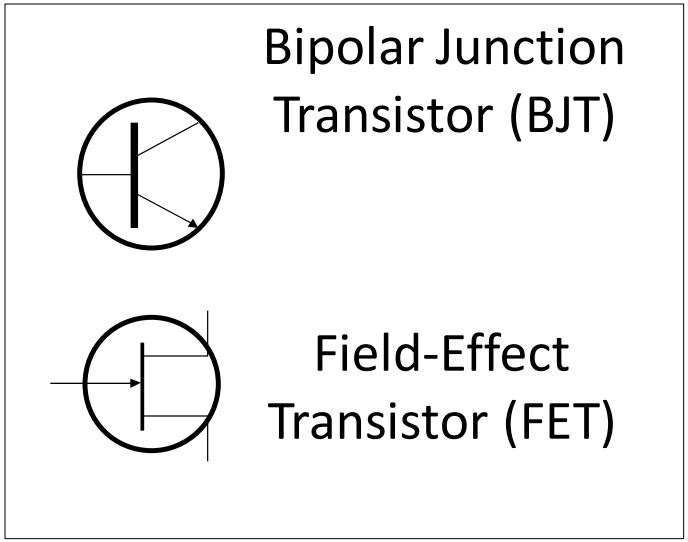
- Schematic symbol
- Designator (D or CR)



The Transistor

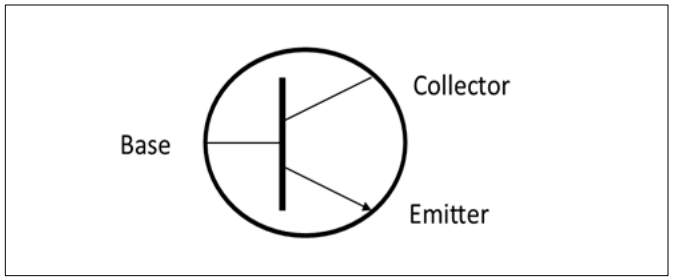
- The function of a transistor is to control large signals with small ones.
  - An "electronically controlled current valve"
  - When used as an amplifier a transistor produces *gain*
  - Transistors can also be used as a switch

- Schematic symbol
- Designator (Q)



The Transistor

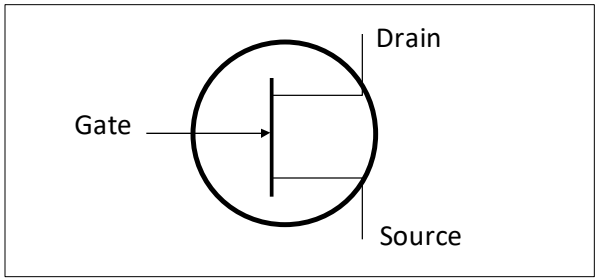
- The Bipolar Junction Transistor (BJT) has three layers of N or P material connected to electrodes:



- Depending on the arrangement of layers, a BJT is either an NPN or PNP transistor.

The Transistor

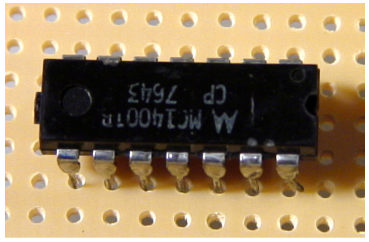
- The Field-Effect Transistor (FET) has a conducting path or channel of N and P material connected to the drain and source electrodes.



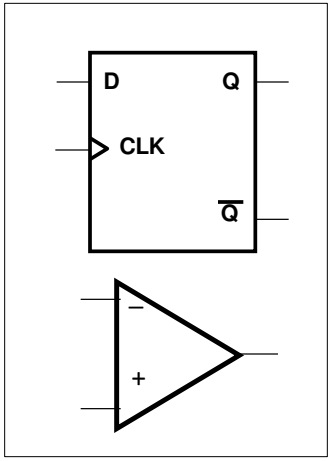
- Voltage applied to the gate electrode controls current through the channel.

The Integrated Circuit

- The integrated circuit is a collection of components contained in one device that accomplishes a specific task.



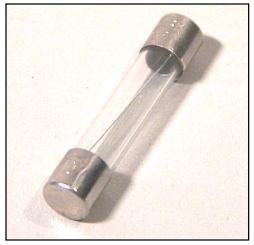
- Schematic symbol
- Designator (IC or U)

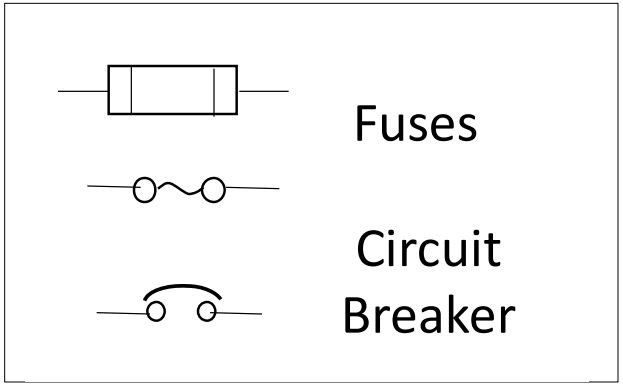


Protective Components

- Fuses and circuit breakers are designed to remove power in case of a circuit overload.
  - Fuses blow – one time protection
  - Circuit breakers trip – can be reset and reused
  - Always use proper rating

- Schematic symbol
- Designator (F or CB)

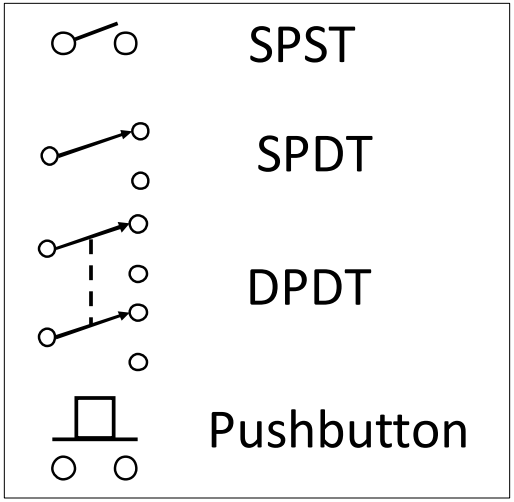




Switches

- Switches are used to interrupt or allow current to flow.
- Each circuit controlled by the switch is a *pole*
- Each position is called a *throw*

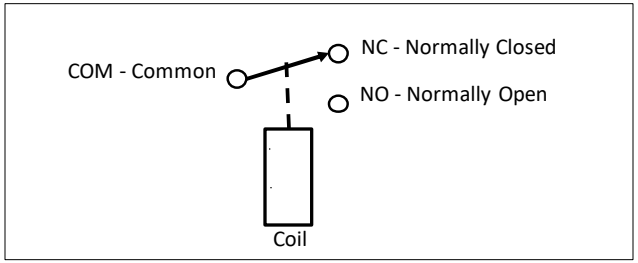
- Schematic symbol
- Designator (S or SW)



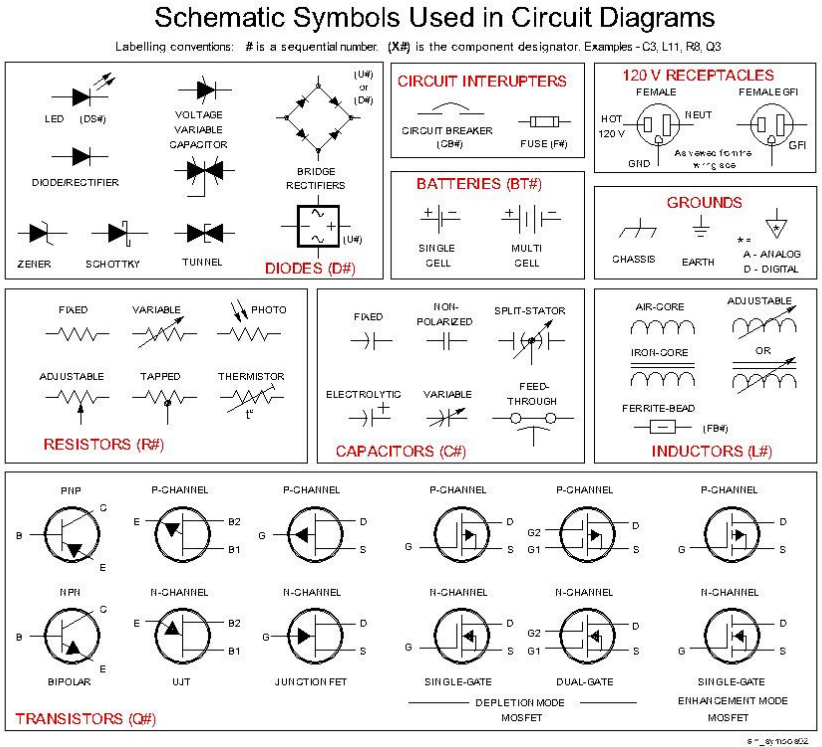
Relays

- Relays are switches activated by current in a coil (electromagnet)
- Relays use the same pole/throw names as switches
- The moving switch is called the *armature*
- *Contacts* are named by when they are connected

- Schematic symbol
- Designator (K or RLY)



Other Circuit Symbols



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Chapter 3

Lesson Plan Module – 3d

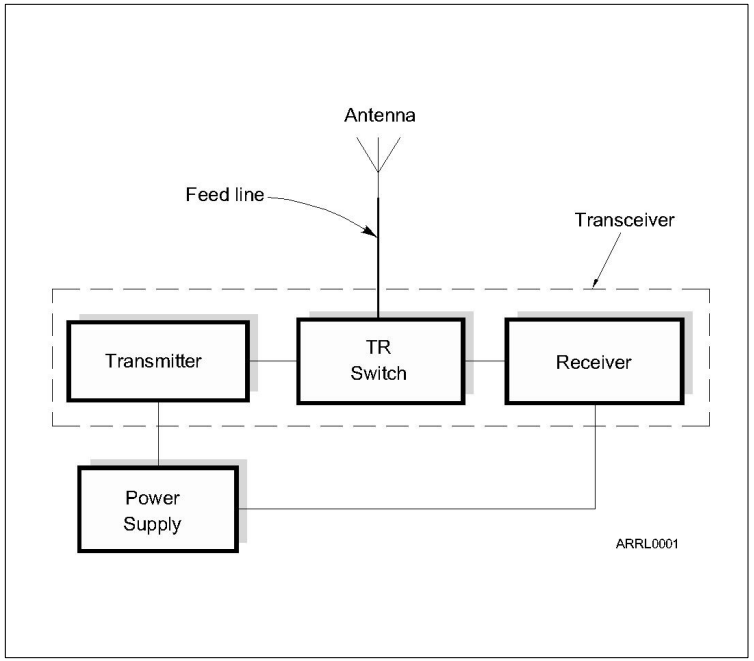
Types of Radio Circuits

The Basic Transceiver

- Combination of “transmitter” and “receiver”

- Abbreviated “XCVR” (X = trans)

- Antenna switched between transmitter and receiver by the TR switch



Transmit/Receive (TR) Switch

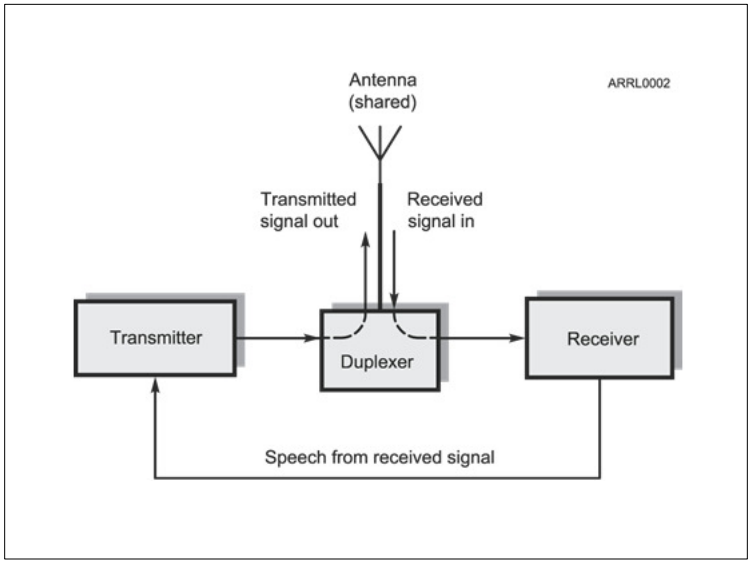
- TR switch allows a single antenna to be switched to the transmitter when sending and to the receiver when receiving.
  - In a transceiver, the TR switch is inside the unit and operates automatically.
  - Transceivers cannot transmit and receive at the same time like a repeater.

The Basic Repeater

- Relays signals from low-power stations over a wide area

- Simultaneously re-transmits received signal on the same band

- TR switch replaced with duplexer which allows antenna to be shared without switching



What Happens During Radio Communication? (Review)

- Transmitting (sending a signal):

- Information (voice, data, video, commands, etc.) is converted to electronic form.

- The information in electronic form is added to a radio wave.

- The radio wave carrying the information is sent from the station antenna into space.

What Happens During Radio Communication? (Review)

- Receiving:

- The radio wave carrying the information is intercepted by the receiving station's antenna.
- The receiver extracts the information from the received wave.
- The information is then presented to the user in a format that can be understood (sound, picture, words on a computer screen, response to a command, etc.).

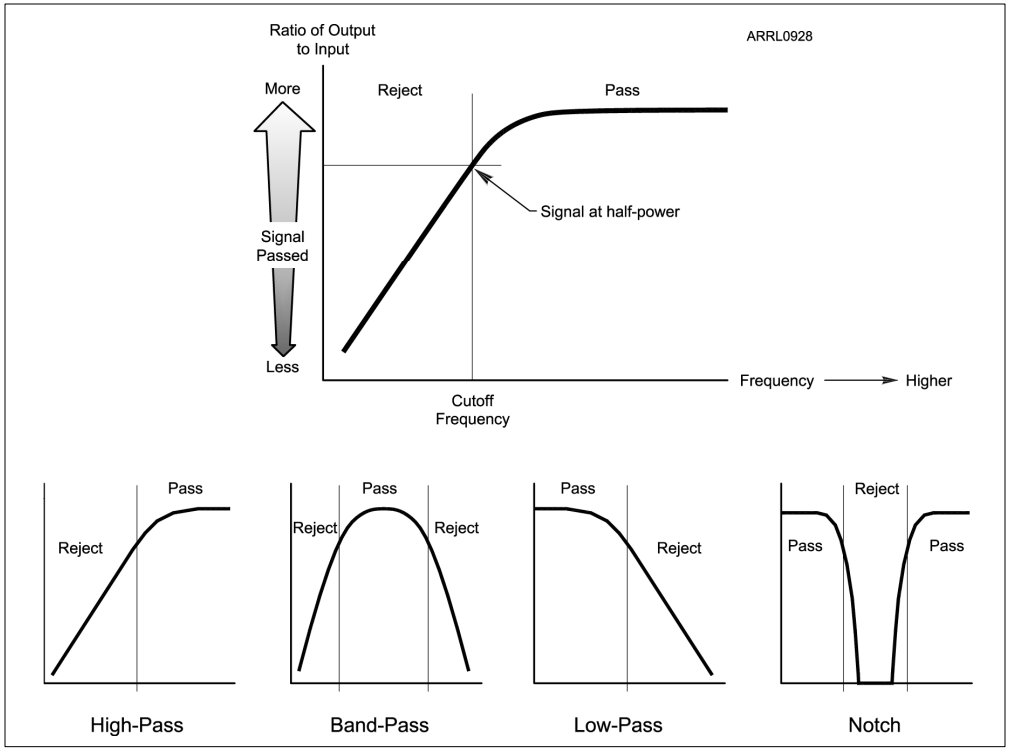
What Happens During Radio Communication? (Review)

- Adding and extracting the information can be simple or complex.
- This makes ham radio fun…learning all about how radios work.
- Don't be intimidated. You will be required to only know the basics, but you can learn as much about the "art and science" of radio as you want.

Filters

- Circuits that act on signals differently according their frequency.
- Filters can reject, enhance, or modify signals.

Types of Filters



Adding Information - Modulation

- When we add some information to the radio wave (the carrier), we modulate the wave.

- Morse code (CW), speech, data

- Different modulation techniques vary different properties of the wave to add the information:

- Amplitude, frequency, or phase

Adding Information - Modulation

- Modulator and demodulator circuits

- Modulators add information to an RF signal, demodulators recover the information

Changing Frequency - Mixers

- Signal frequencies can be changed by combining with another signal, called *mixing*
  - Also referred to as *heterodyning*
- Two signals are combined in a *mixer*
  - Generates *mixing product* signals
  - Sum and difference of the input signals
  - Shifts frequency by adding or subtracting
- Different than a *multiplier* which multiplies a signal's frequency by some integer, usually 2 or 3

Sensitivity and Selectivity

- Two essential tasks for a receiver:
  - Hear a signal and hear only one signal
- *Sensitivity* is a measure of how well the receiver can detect weak signals
- *Selectivity* is a measure of the receiver's ability to discriminate between signals
- *Preamplifiers* make a receiver more sensitive
  - Preamplifiers added between antenna and receiver

Transverter

- Short for “transceiving converter” (XVTR)
- Converts a transceiver to operate on another band
  - Usually to a higher frequency
  - External mixers shift frequency
- Typical examples
  - HF SSB/CW at 28 MHz converted to/from 222 MHz
  - VHF SSB/CW at 144 MHz converted to/from 10 GHz

End of Week 3

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