# A note about course content, speed

- Class slides are meant to be an overview
  - We'll cover as much of the content as possible
  - Covering all topics in detail would take a semester-long class
  - Fastest route: memorization of questions/answers
- Recommendations:
  - Read the chapter(s) we're covering each week
  - Also review the relevant questions
    - In the ARRL book, look for notes like **[T7C06]** for relevant questions
    - In https://hambook.org, questions are included in the text
    - RECOMMENDATION: read the question, read ONLY the correct answer to associate the question with the answer

# 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 |

***NOTE***

$$10^{-1} = \frac{1}{10}$$

$$10^{-2} = \frac{1}{100}$$

$$10^{-3} = \frac{1}{1000}$$

# Ohm's Law: E=IR

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

R = E / I
I = E / R
E = I x R

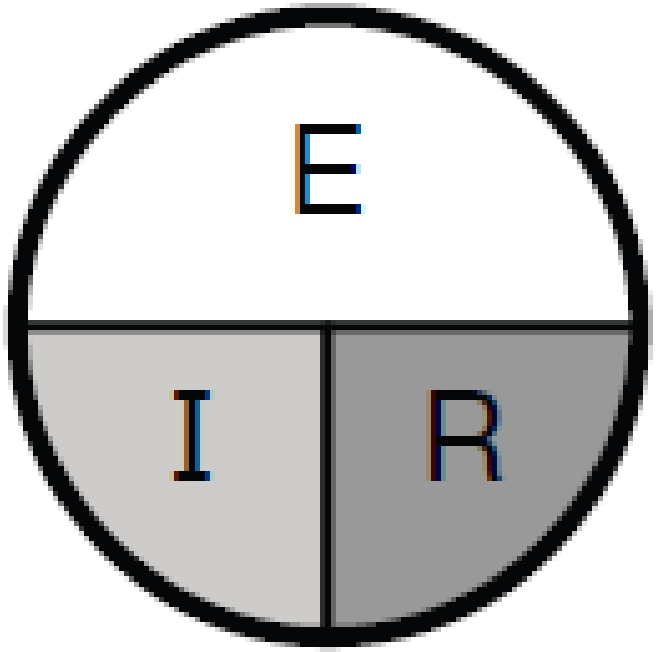
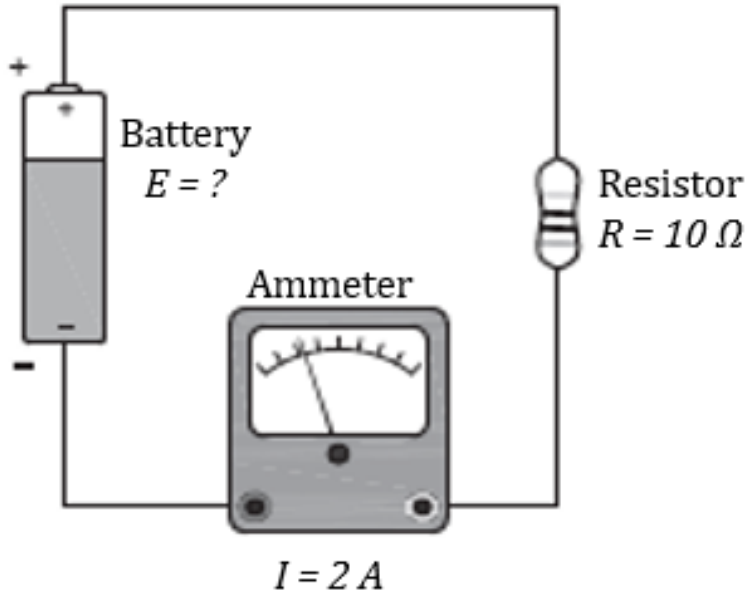



Figure 3.5A —If you know any two of the quantities, the equation to find the third — just cover up the unknown quantity. The positions of the remaining two symbols show if you have to multiply (side-by-side) or divide (one above the other).

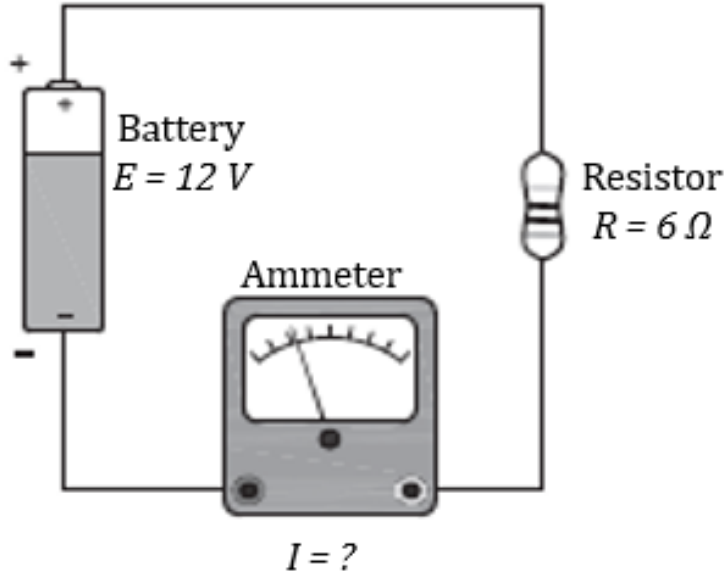
# Examples of how to use Ohm's Law




Given I = 2 Amperes
R = 10 Ohms

Find: E (voltage)

E = I × R = 2 × 10 = 20 Volts
Voltage Equals 20 Volts




Given E = 12 Volts
R = 6 Ohms

Find: I (current)

I = E / R = 12  6 = 2 Amps

Current Equals 2 Amperes

# More Ohm's Law Examples

What is the resistance of a circuit in which a current of 3 amperes flows when connected to 90 volts?

$$R = E / I = 90\ V / 3\ A = 30\ \Omega$$

What is the current in a circuit with an applied voltage of 120 volts and a resistance of 80 ohms?

$$I = E / R = 120\ V / 80\ \Omega = 1.5\ A$$

What is the voltage across a 2-ohm resistor if a current of 0.5 amperes flows through it?

$$E = I \times R = 0.5\ A \times 2\ \Omega = 1\ V$$

# Power

- *Power*, represented by the symbol P, is the rate at which electrical energy is used
  - Measured in *watts* (W)
- A device that consumes or dissipates power is referred to as a *load*

$$P = I \times E$$
$$E = P / I$$
$$I = P / E$$

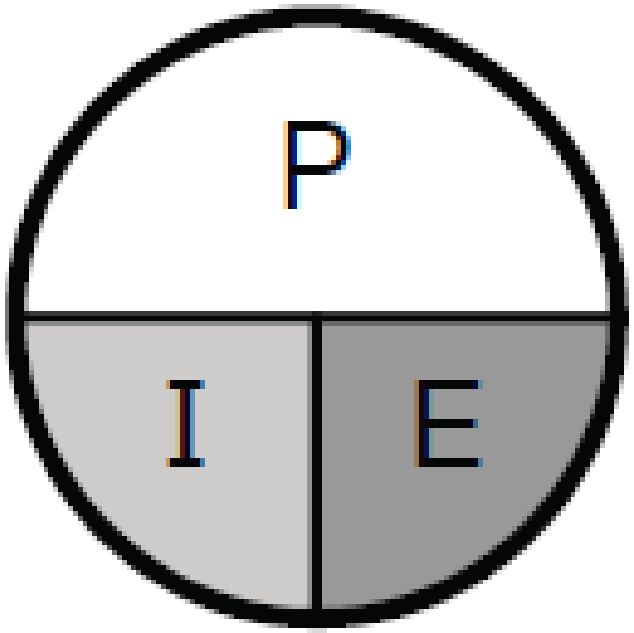



Figure 3.5B — Simple diagram to help remember the Ohm's Law. If you know any two of the quantities, the equation to find the third — just cover up the unknown quantity. The positions of the remaining two symbols show if you have to multiply (side-by-side) or divide (one above the other).

# Example Power Calculations

How much power is delivered by a voltage of 13.8 volts DC and a current of 10 amperes?

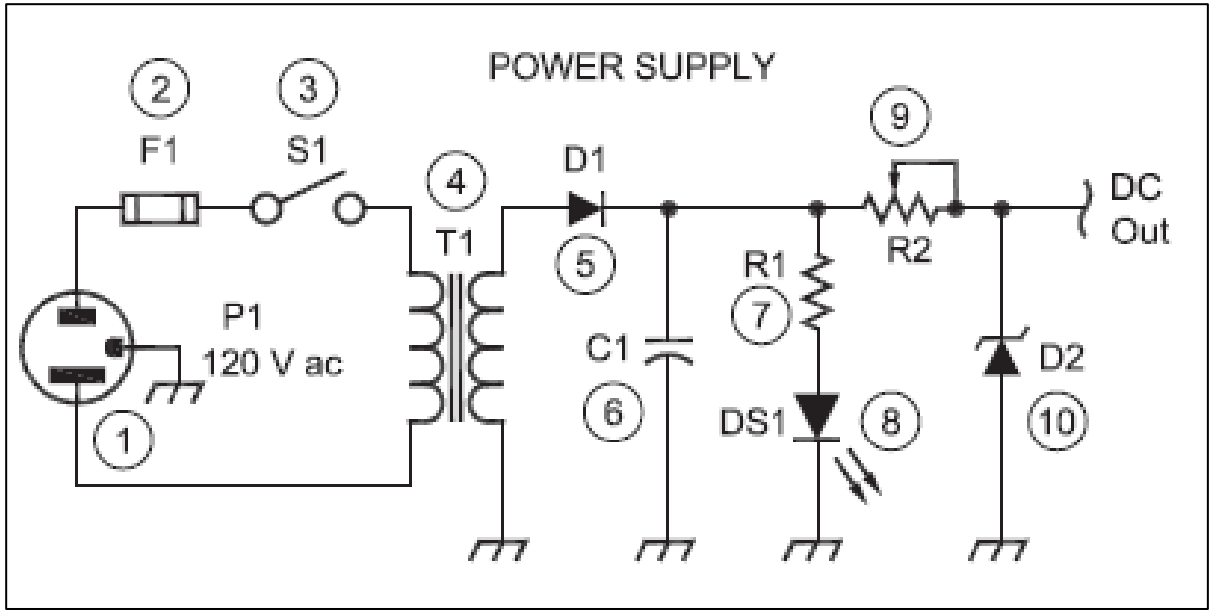
$$P = E \times I = 13.8\ V \times 10\ A = 138\ W$$

How much current is required to deliver 120 watts at a voltage of 12 volts DC?

$$I = P / E = 120\ W / 12\ V = 10\ A$$

# Components and Units

- Components in electrical circuits performs functions such as storing or using energy, routing current, or amplifying signals
- The three most basic types of electronic components are ***resistors***, ***capacitors*** and ***inductors***
- ***Schematic diagrams*** are a convenient shorthand for complex circuits




*More on schematics later …*

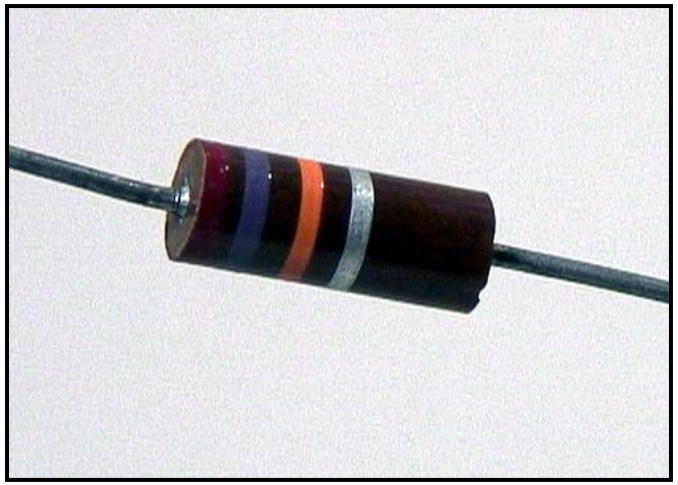
# Resistors

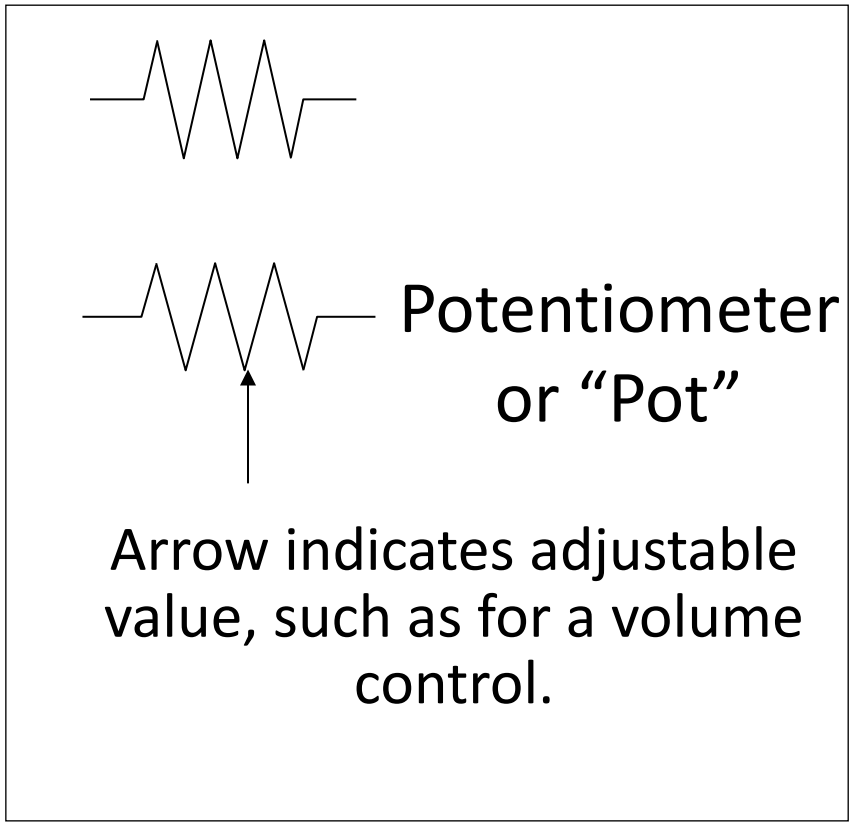
- Function: To restrict the flow of current, like a valve in a water pipe
- Resistance measured in ohms (**Ω**)
- Remember Ohm's Law (R = resistance)

$$I = E / R$$

$$E = I \times R$$

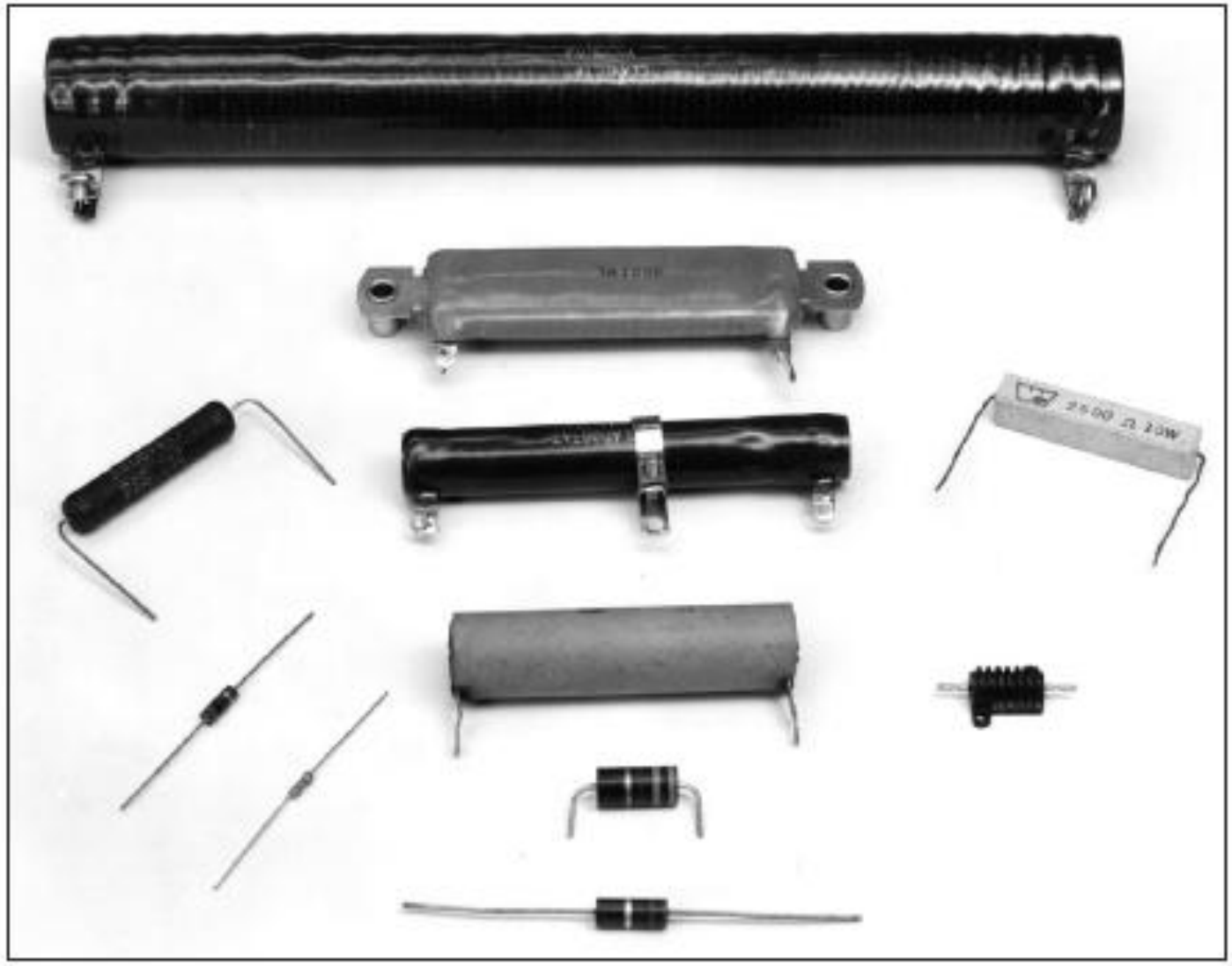
$$R = E / I$$






Resistor Schematic

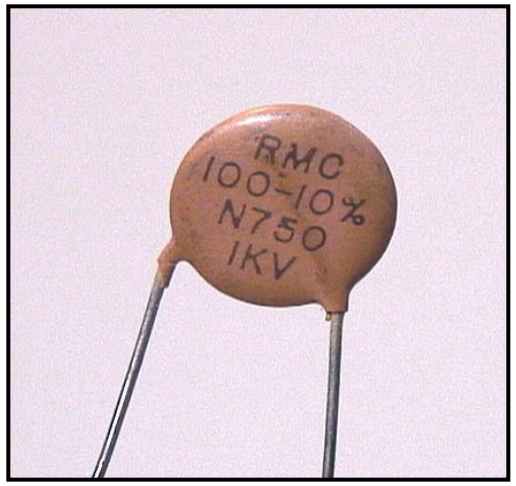
# Large Variety of Resistors!

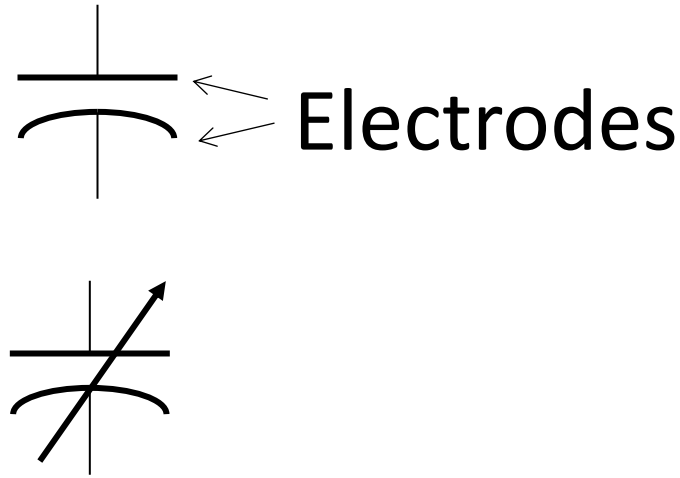


# Capacitors

- The function of a capacitor is to store electrical energy – called *capacitance*
  - Capacitance measured in *farads (F)*
- Acts like a short-term battery

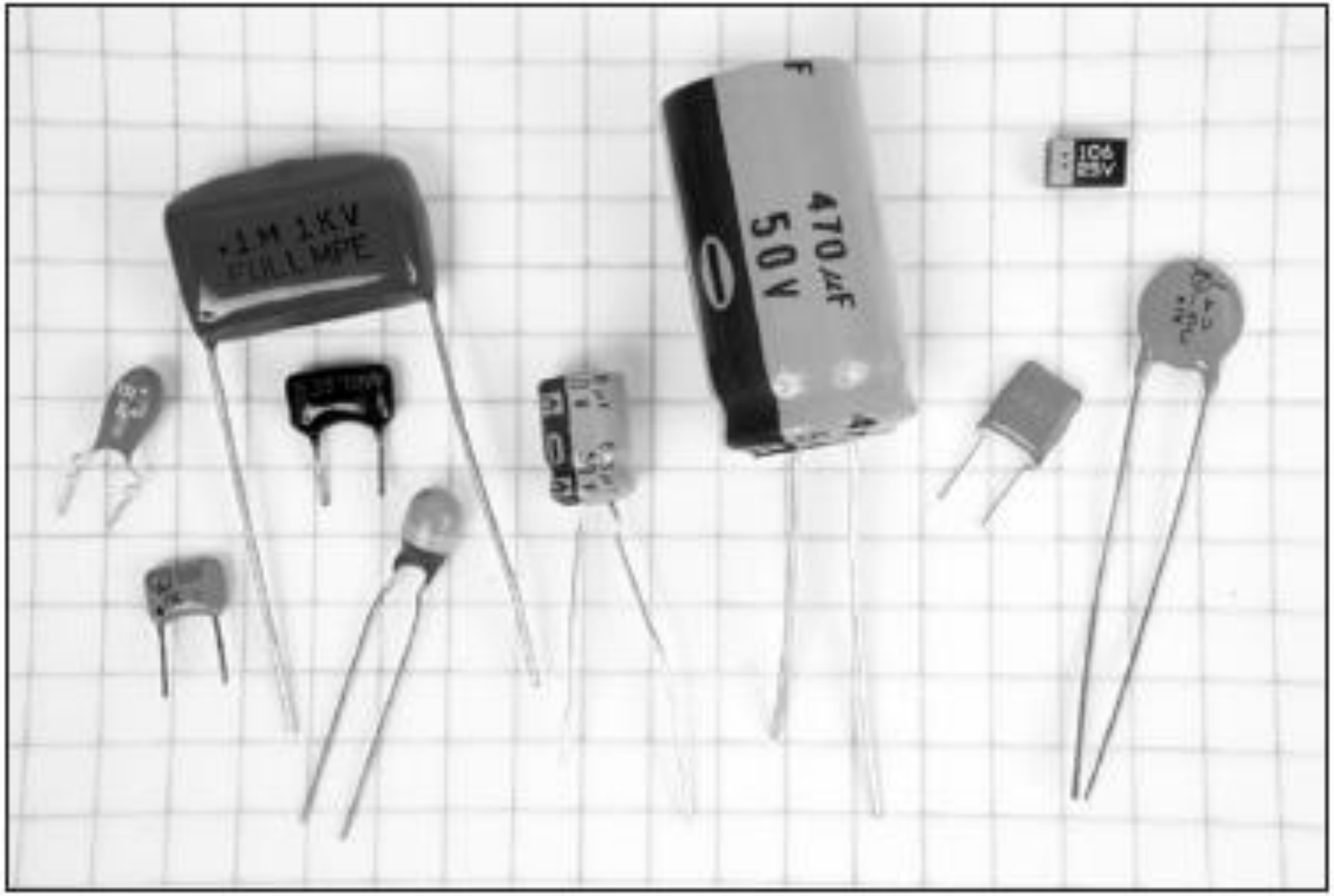
*Stores energy in an electric field created by voltage between the electrodes with insulating dielectric material between them*



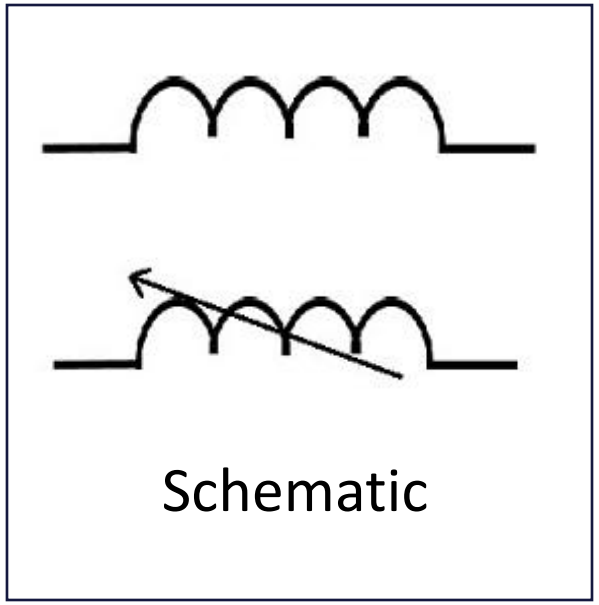

Schematic

# Large Variety of Capacitors!



# Inductors

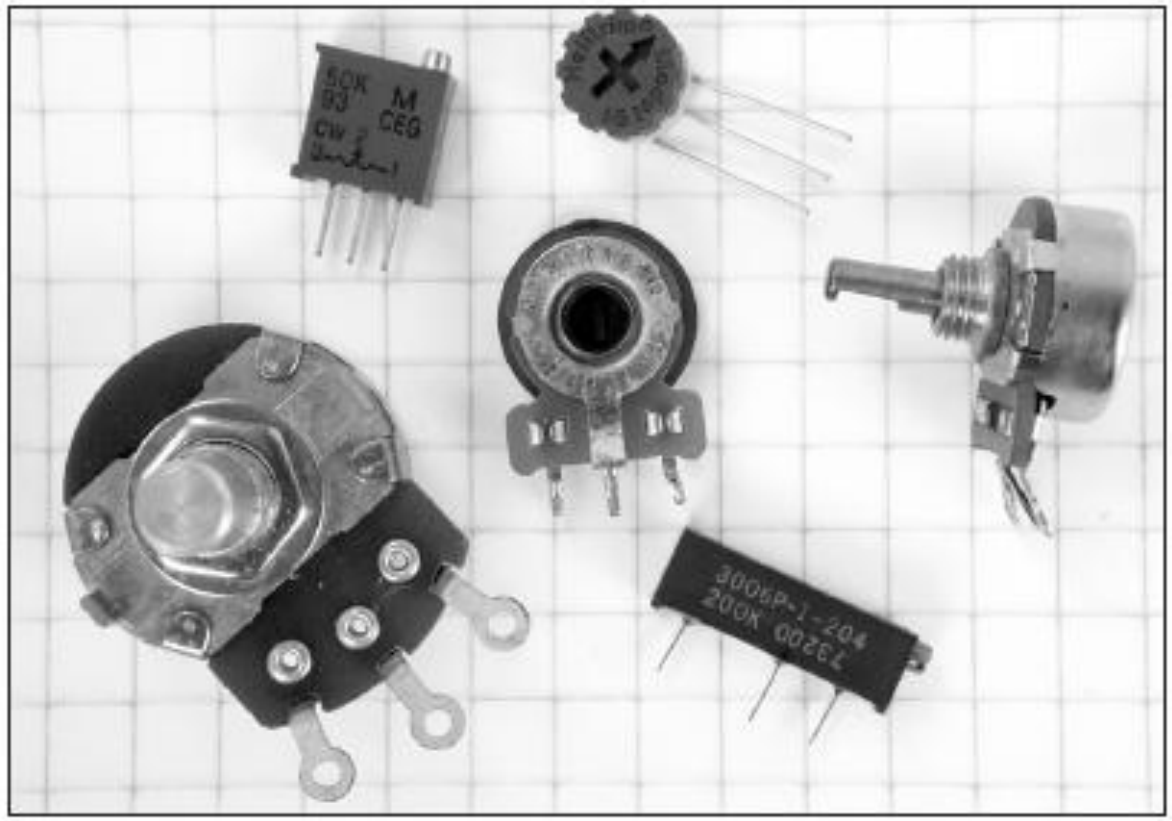
- Function: To store energy in the magnetic field created by current flowing in a wire
  - Called *inductance*, measured in *henrys* (H)
- Made from wire wound in a coil, sometimes around a core of magnetic material that concentrates the magnetic energy



Schematic

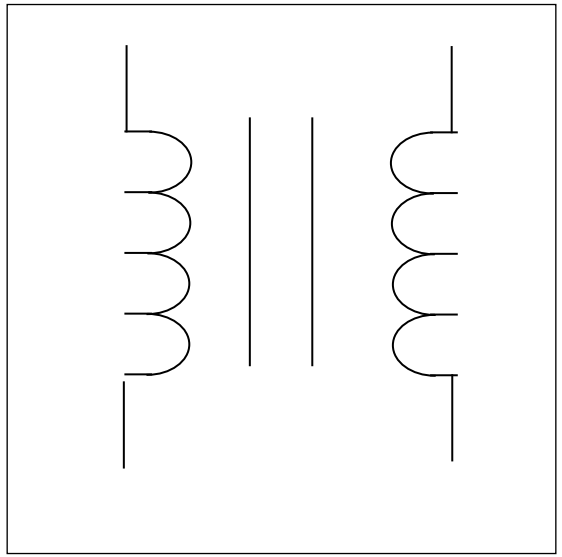
# Variable Components

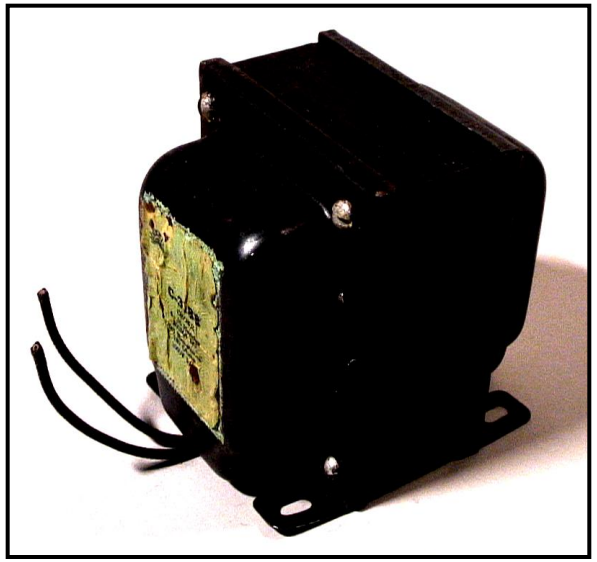
- All three types of basic components are also available as adjustable or variable models
- A variable resistor is also called a *potentiometer*, frequently used to adjust voltage or potential, such as for a volume control



# Transformers

- Made from two or more inductors that share their stored energy
  - Transfer energy from one inductor to another, but change voltage and current
- Example: laptop charging brick
  - Transfer energy from 120V AC to a lower voltage and current





# Reactance and Impedance

- In a resistor, AC voltages and currents are exactly in step, or *in phase*
- In capacitors and inductors, voltage and current have a *phase difference*
  - Capacitors and inductors store energy, resistors dissipate energy
- 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

# Reactance and Impedance (cont.)

- The combination of *resistance* (R) and *reactance* (X) is called *impedance*, represented by the symbol Z (units: ohms)
  - Impedance represents a circuit's *opposition* to ***both*** AC and DC currents

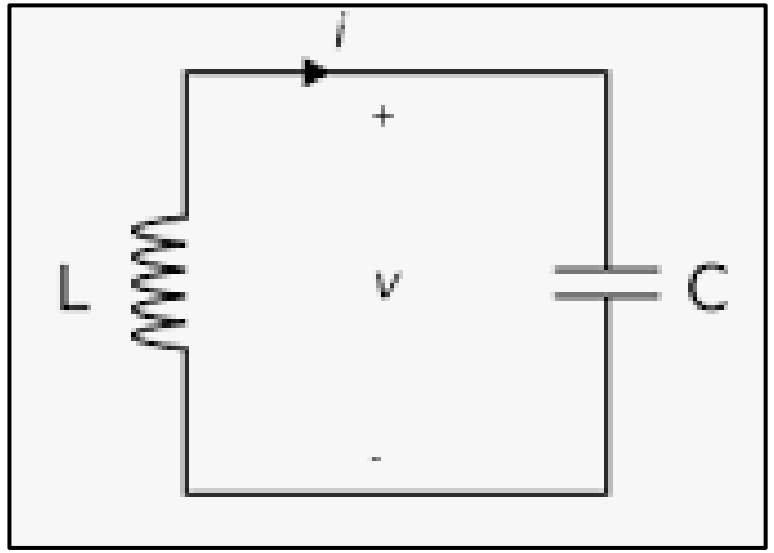
- Radio circuits almost always have both resistance and reactance, so impedance is often used as a general term to mean the circuit's opposition to AC current flow

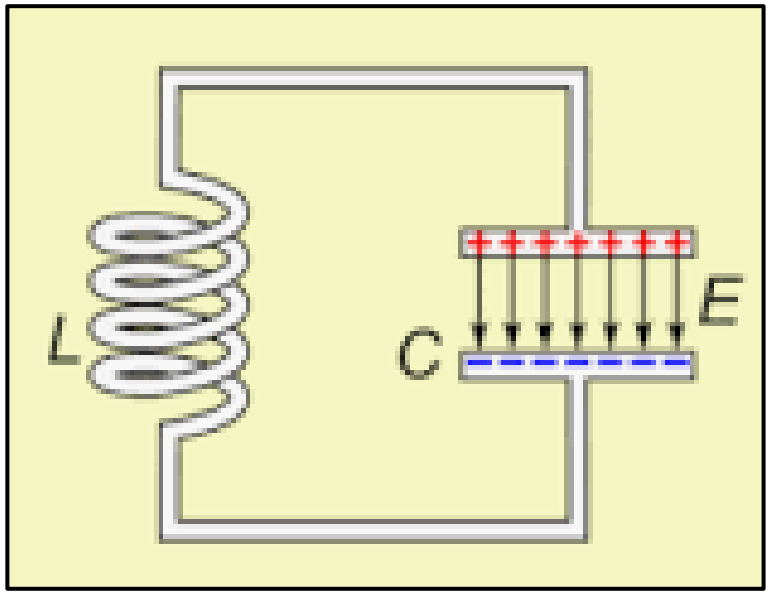
# Resonance

- Circuits that contain both a capacitor and an inductor are called *resonant* circuits or *tuned* circuits
- A component's reactance depends on frequency
  - Inductive reactance ($X_L$) increases with frequency, capacitive reactance ($X_C$) 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
- A tuned circuit acts as a *filter*
  - A filter passes or rejects signals at its resonant frequency
  - Useful for radios to filter out unwanted signals!

# 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*



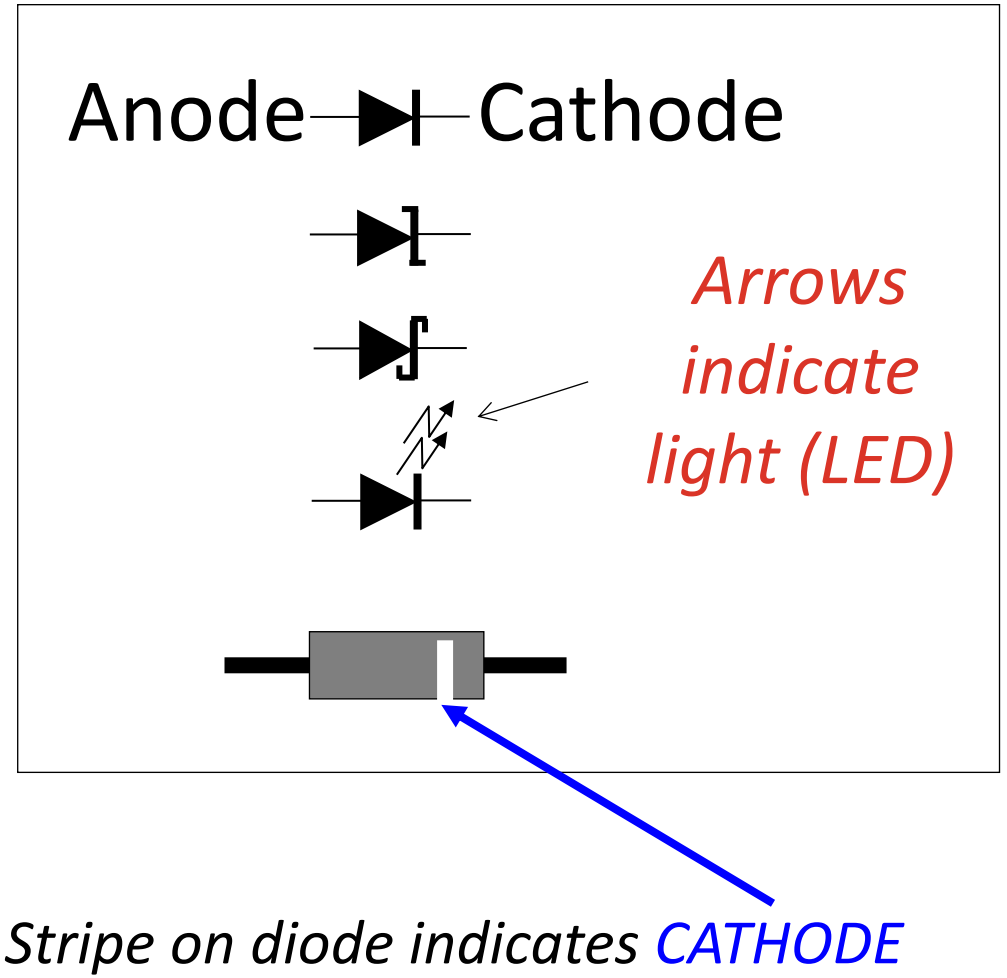



# Diodes, Transistors and Integrated Circuits
## *(Semiconductors)*

- Components made of “OK” conductors (not metals)
  - ***N-Type semiconductors:*** made from materials with more electrons
  - ***P-Type semiconductors***: made from materials with fewer electrons
- Structures of N and P material can control current flow
- When N- and P-type material are placed in contact with each other, the result is a *PN junction* that conducts better in one direction than the other

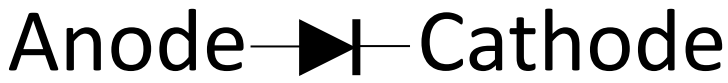
# Diodes


- One-way Current
  - Two electrodes (Anode, Cathode)
  - AC current is changed to varying pulses of DC (called *rectification*)
  - Diodes used to change AC power to DC power are called *rectifiers* (heavy-duty diodes)
- Designator (D or CR)
- If AC voltage is applied to a diode, the result is a pulsing DC current
  - Current is blocked when the voltage tries to push electrons in the wrong direction



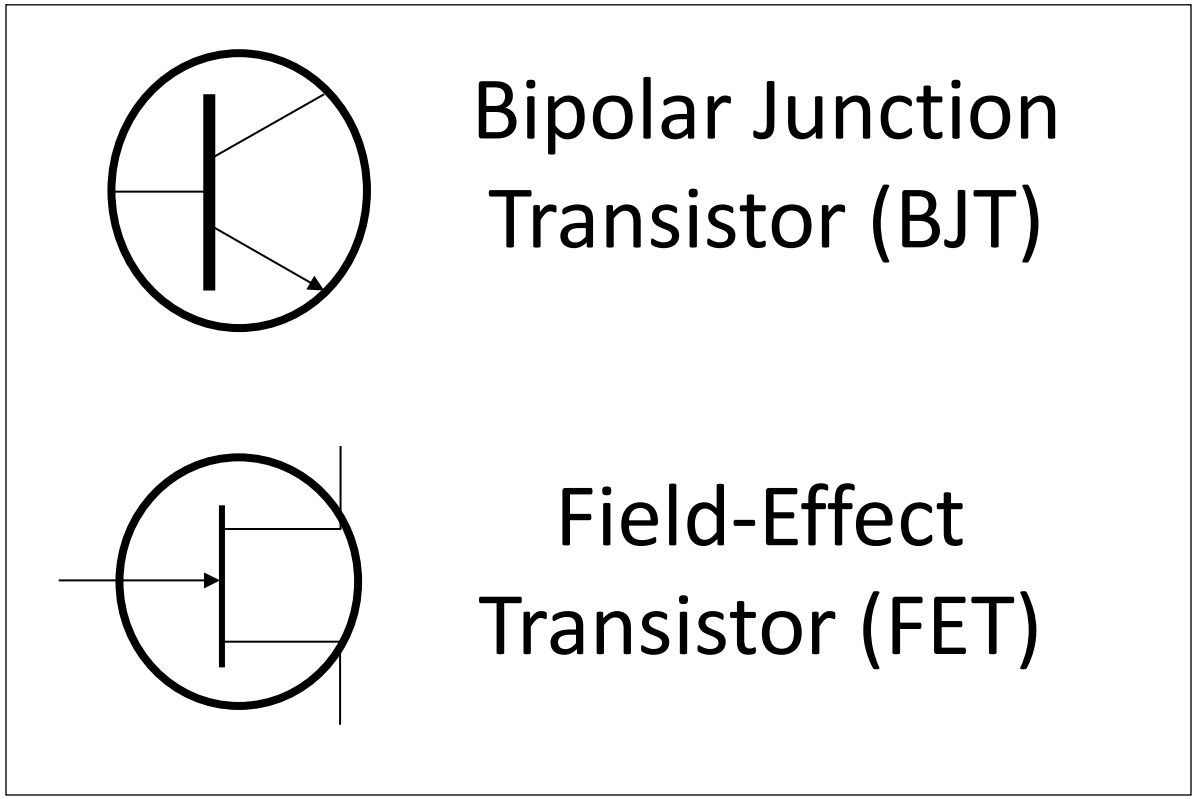
# Diodes (cont.)

- When current flows through a diode, a small positive voltage develops from the anode to the cathode
  - Called *forward voltage drop*, usually less than 1 V
  - Voltage depends on the type of diode and the materials it's made from
- Light-emitting diode or *LED* gives off light when current flows through it in the forward direction from anode to cathode
  - Used as visual indicators (use less power than incandescent bulbs/lamps)
  - Material from which the LED is made determines the color of light



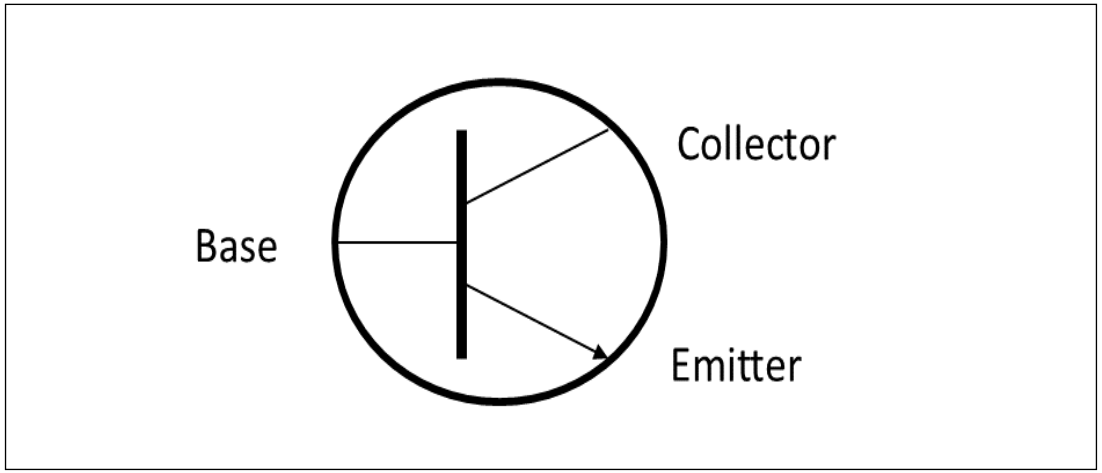
# Transistors

- 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*
- Designator (Q)



# Transistors (cont.)

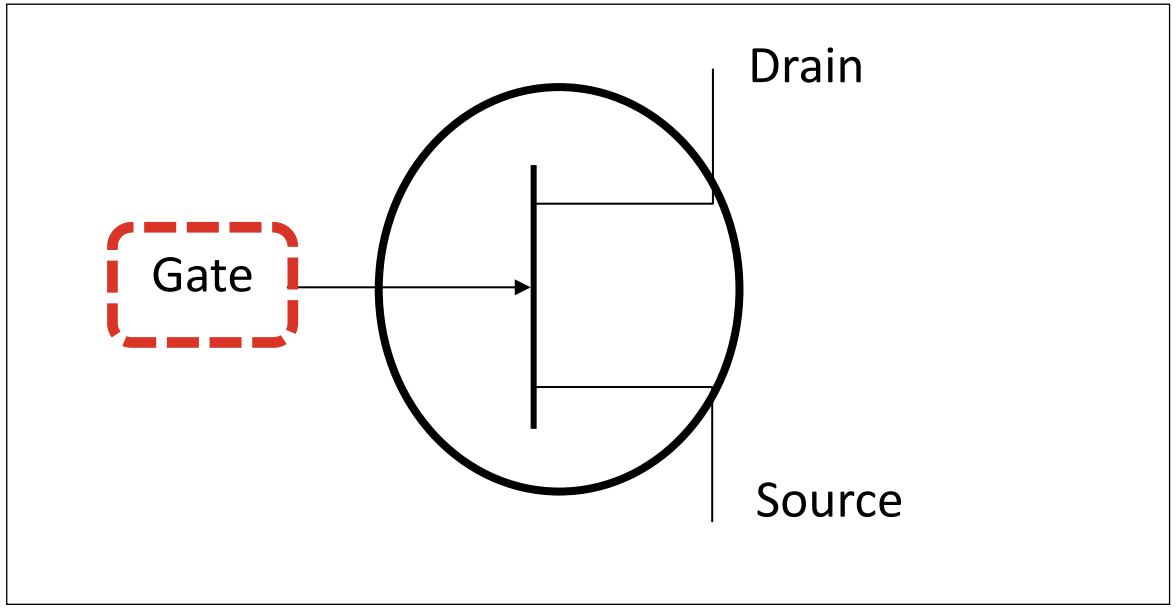
- Two common types of transistors: *bipolar junction transistors* (BJT) and *field effect transistors* (FET)
- The Bipolar Junction Transistor (BJT) has three layers of N or P material connected to electrodes
- Depending on the arrangement of layers, a BJT is either an NPN or PNP transistor
- The three electrodes of an FET are the *gate*, *drain*, and *source*
- RF power transistors are used as the primary gain-producing component in RF power amplifiers




*Bipolar Junction Transistor Schematic (showing the 3 electrodes)*

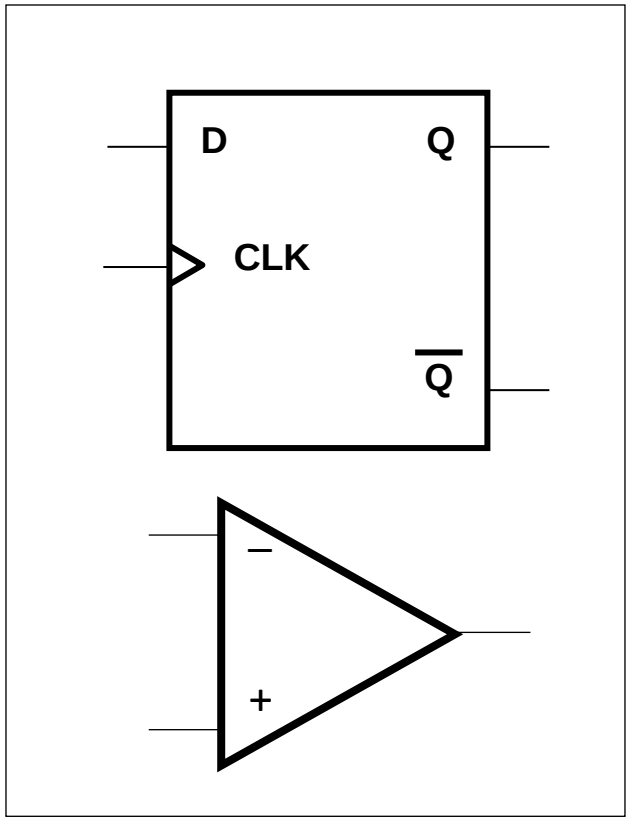
# Transistors (cont.)

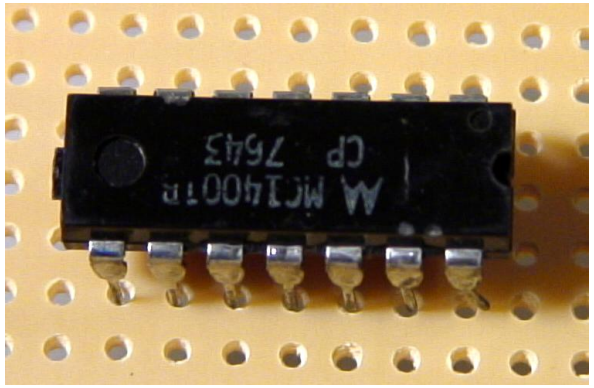
- The Field-Effect Transistor (FET) has a conducting path or channel of N and P material connected to the drain and source electrodes
- Voltage applied to the gate electrode controls current through the channel



# Integrated Circuits

- An integrated circuit (IC or chip) is made of many components connected together as a useful circuit and packaged as a single component
- Designator (IC or U)

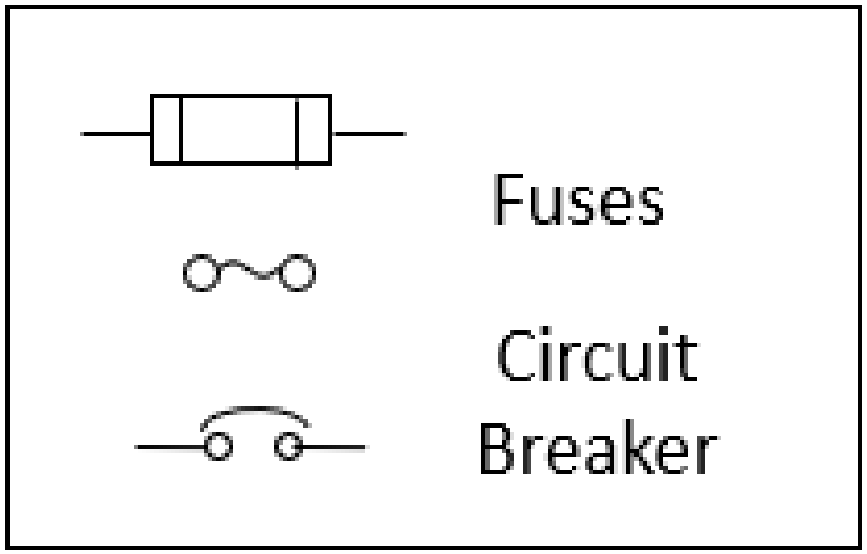


# Protective Components

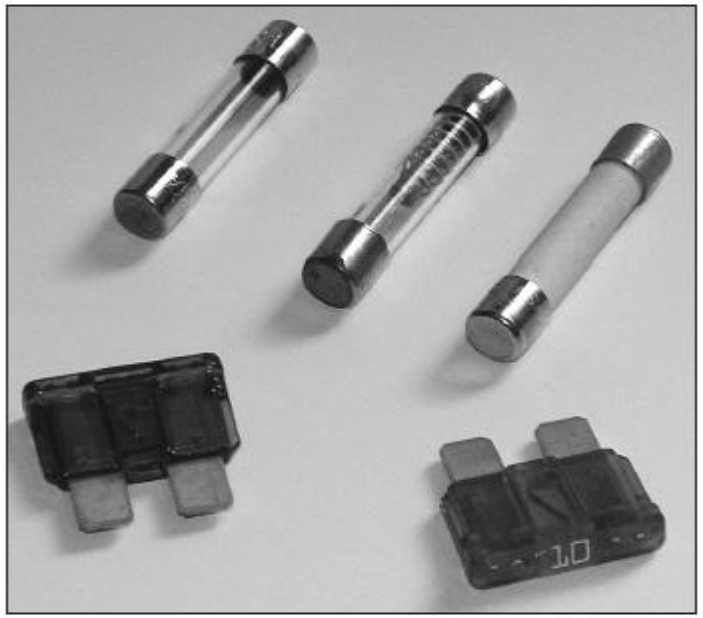
- Protective components (such as *fuses* and *circuit breakers*) are used to prevent equipment damage or safety hazards such as fire or electrical shock

- Designed to remove power in case of a circuit *overload*
  - Fuses blow – one time protection
    - Short length of metal is melted when circuit overloaded, which breaks the circuit
  - Circuit breakers trip – can be reset and reused
- Important: ***use the correct current rating!***
  - Replacing with a higher current rating could damage equipment or start a fire

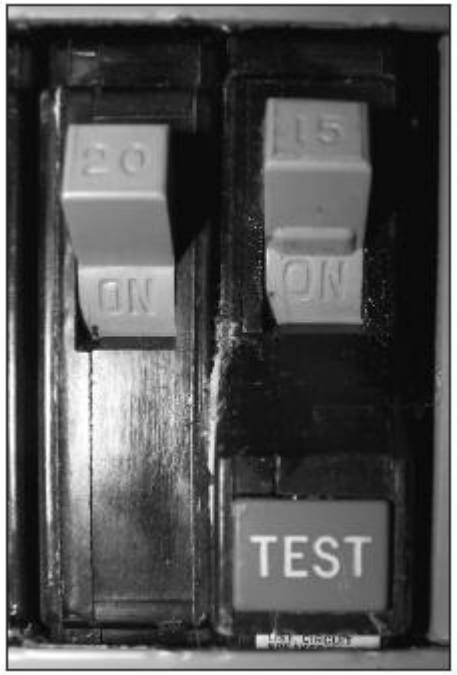



Schematics


Circuit Breaker



Fuses



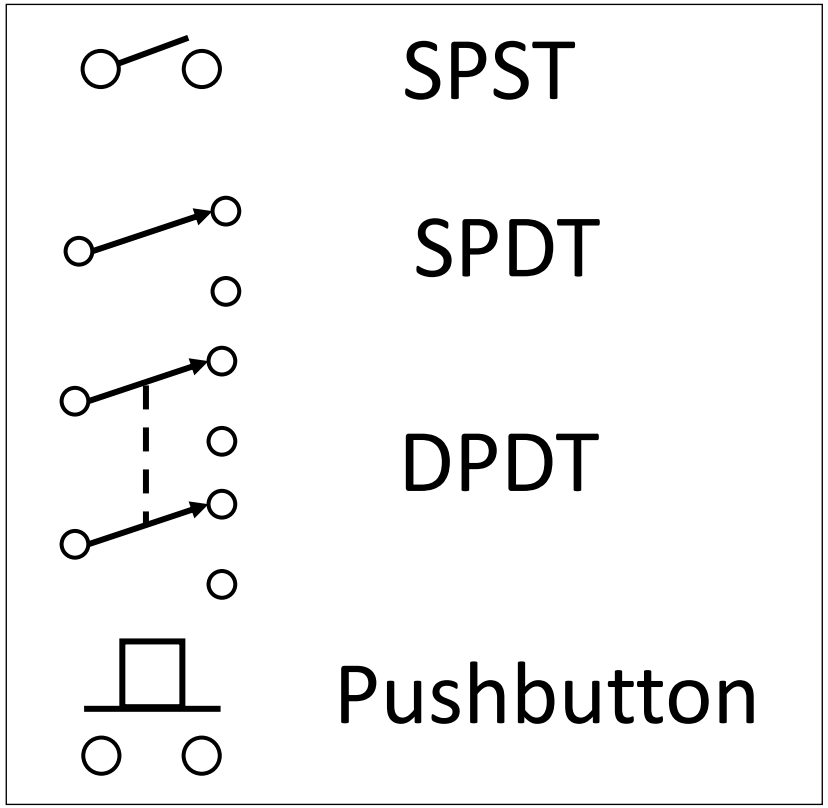

Ground Fault Circuit Interrupter (GFCI) circuit breaker

# Circuit Gatekeepers … Switches & Relays

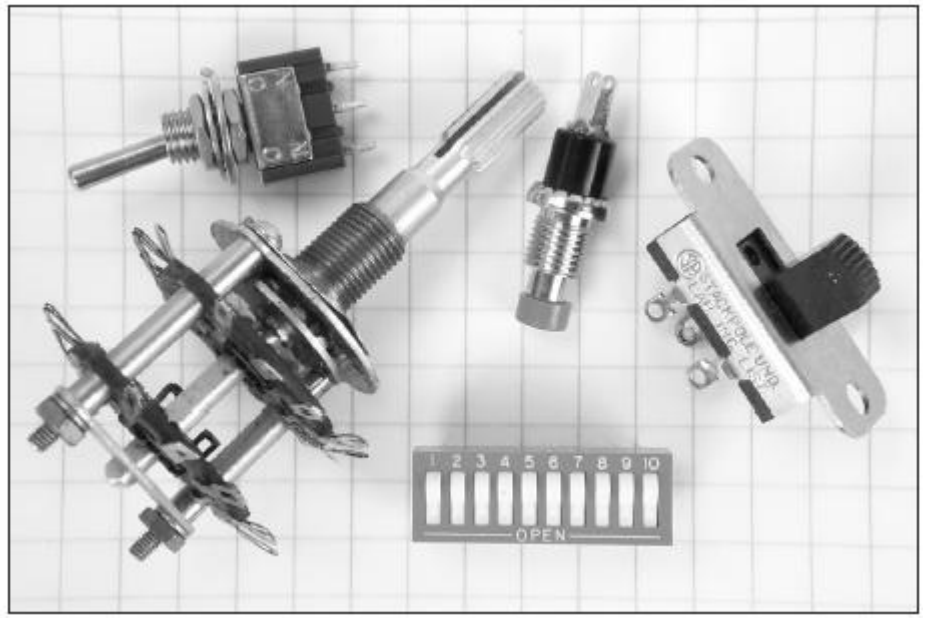
- *Switches* and *relays* control current through a circuit by connecting and disconnecting paths for current to follow
- Switches and relays are described by # poles, # throws
  - The combination of poles and throws describes the switch
  - Each circuit controlled by the switch is a *pole*
  - Each position is called a *throw*

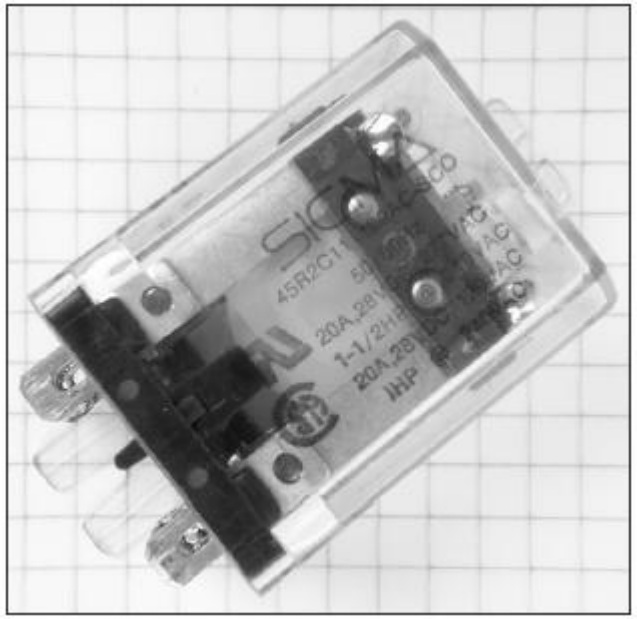
- Switches are operated manually
- Relays are controlled electronically by electromagnet

# Switch Configurations




Switches



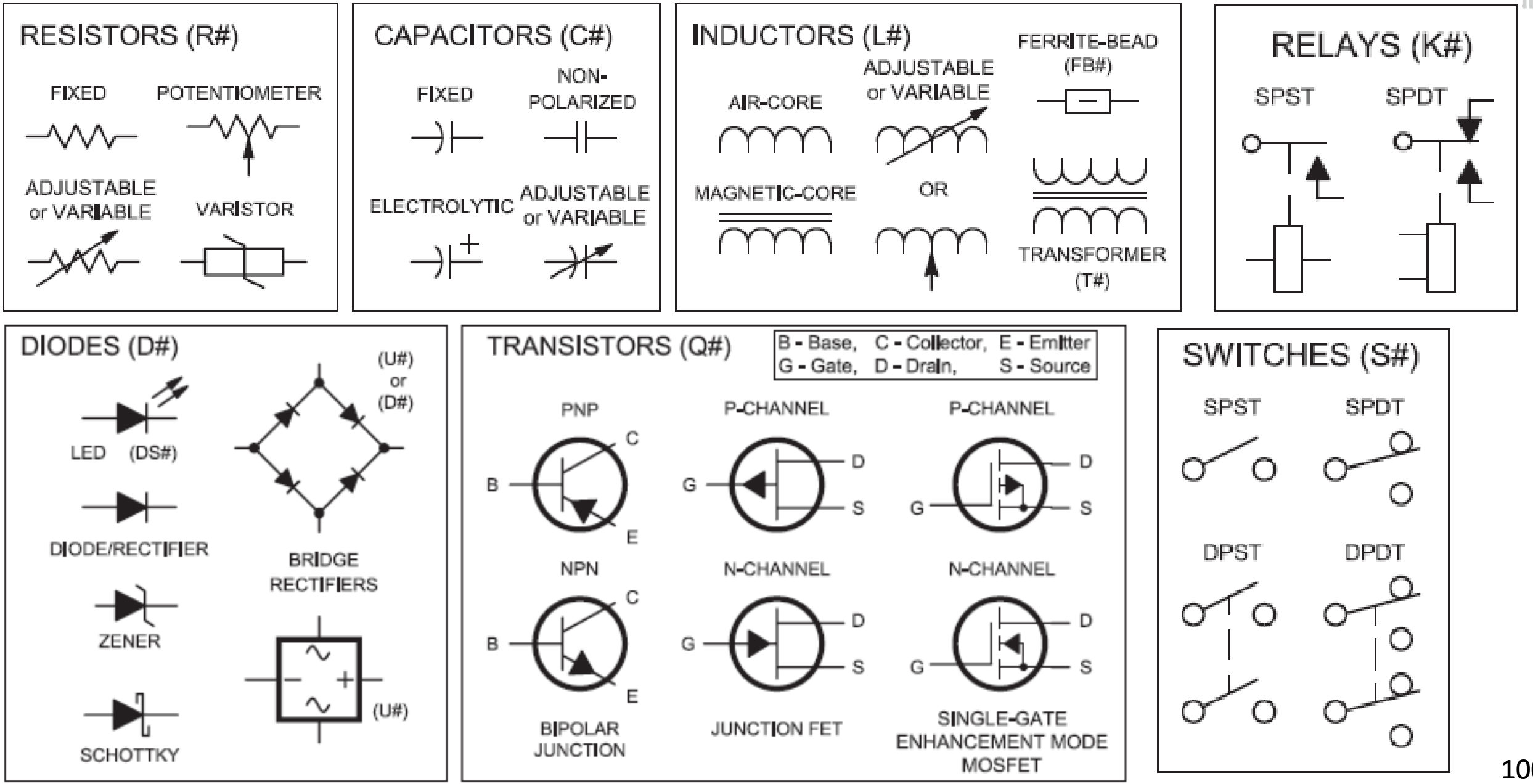



Relay

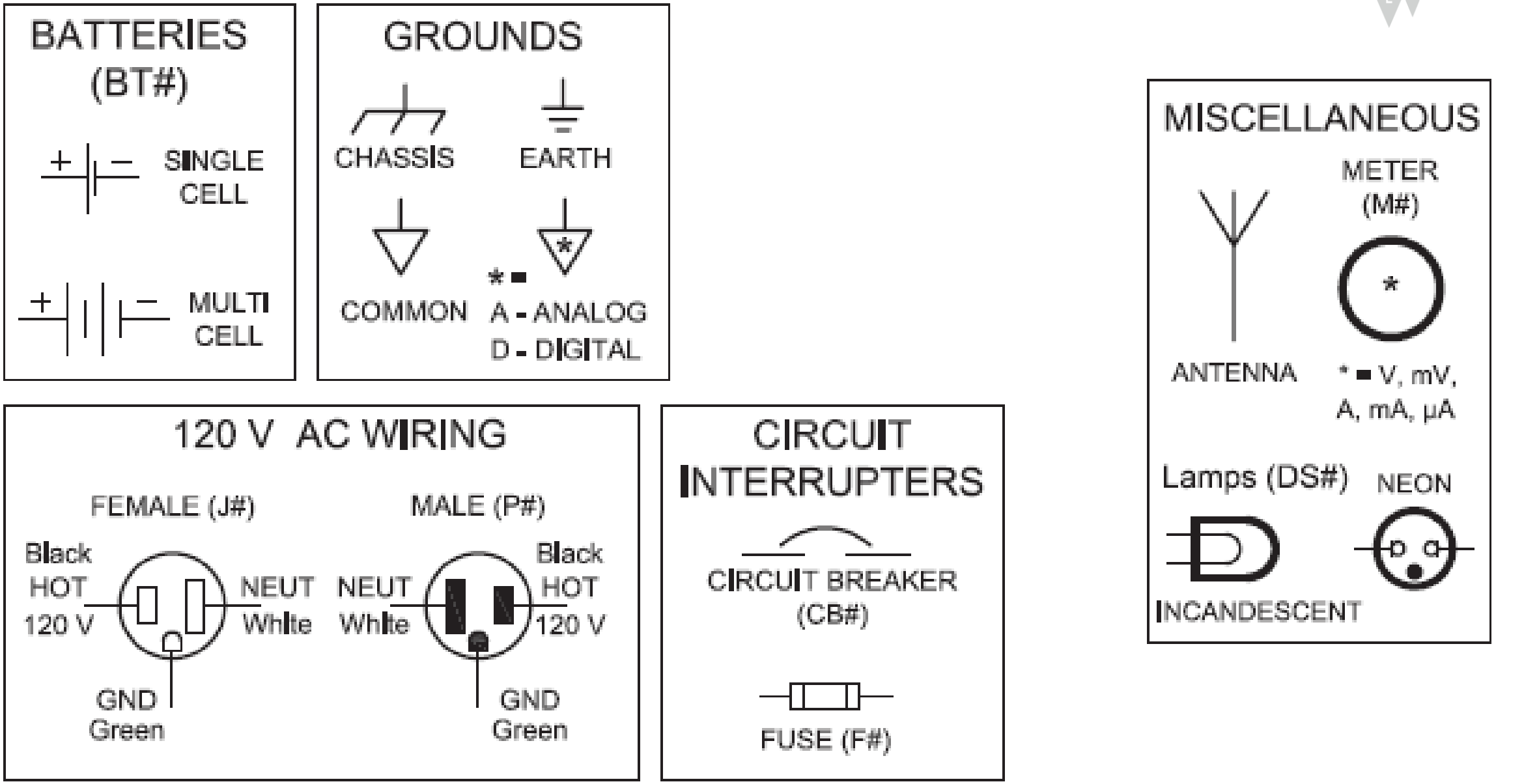
# Indicator, Meters and Displays

- Indicators and displays are important components for radio equipment
  - An *indicator* is either ON or OFF
- A *meter* provides information as a numeric value
- A *display* combines indicators, numbers, and labels
  - A *liquid crystal display* or **LCD** is used on the front panel of many radios and test instruments

# Fig 3.15 – Schematic Symbols (see text)



# Fig 3.15 – Schematic Symbols (cont., see text)



# Schematic Diagrams and Symbols

- *Symbols* are used when drawing a circuit because there are so many types of components
- *Schematic diagrams* are a visual description of a circuit and its components that uses standardized drawings called *circuit symbols*
  - Shows how the components are connected electrically

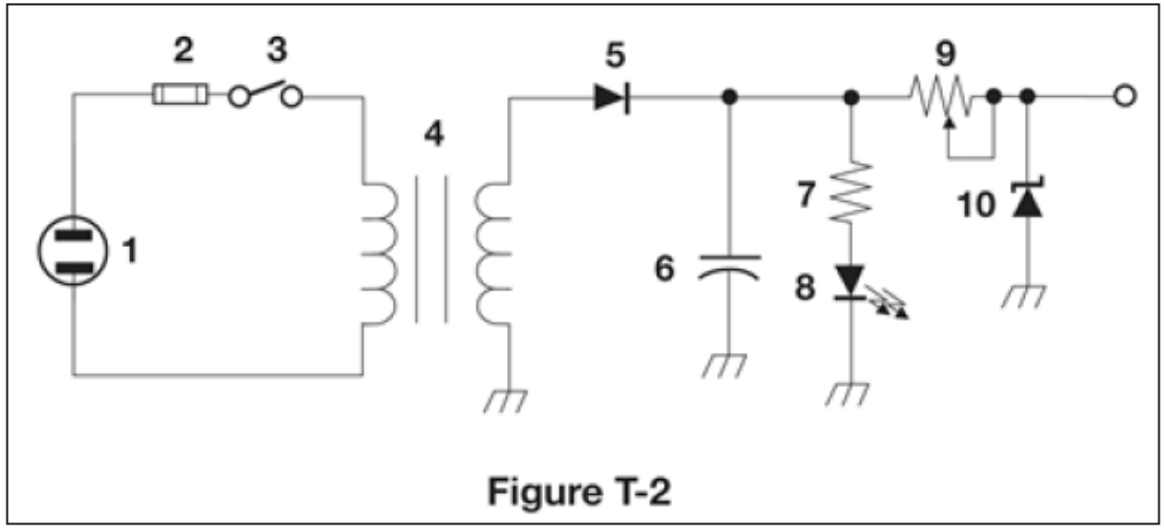



Figure T-2

# Next Week

- Please read chapters in the ARRL Book
  - **Ch 4**: Propagation, Antennas and Feed Lines (**Ch 4** in https://hambook.org)
  - **Ch 5**: Amateur Radio Equipment (**Ch 6** in https://hambook.org)

- Also start reviewing question pool, either on paper or https://hamstudy.org
  - Subelements from today:
    - **T5 –** Electrical Principles
    - **T6 –** Electronic and Electrical Components
  - Question pool is in the back of the book, and on ARRL website
    - https://arrl.org/question-pools (look for the Technician Class Question Pool)

- Slides: https://tinyurl.com/mcarc-intro-to-ham
- Radio office hours: Thursdays 7pm-8pm, PMC Condor Room
- Email: kk6dzw@arrl.net