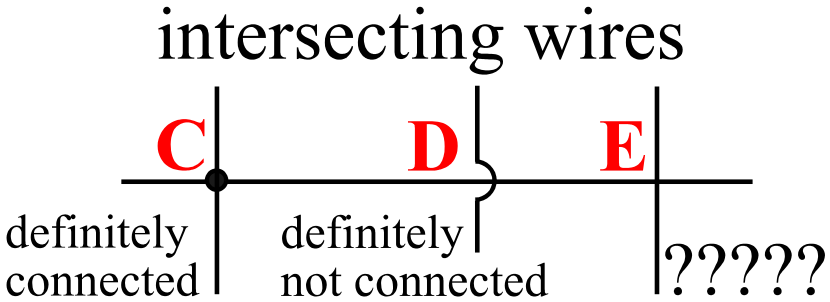
Lecture L02.02
Electronic Components and Schematics

Common Electrical Components, Basic Applications, and Schematic Symbols

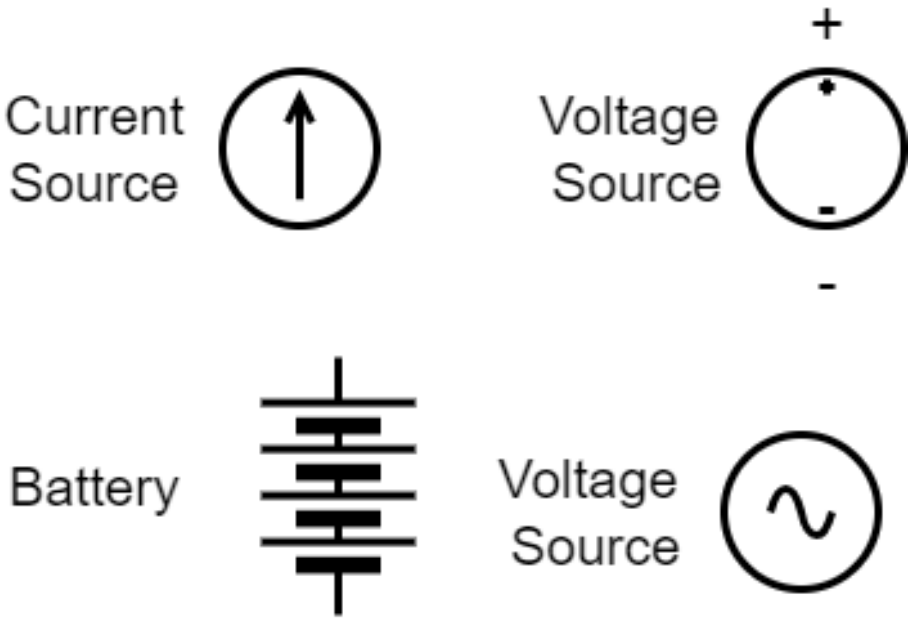
Nets and Nodes

- A line connecting one or more components is called a net or wire
- It represents that the components are electrically connected
  - Could be a physical wire, component leads, breadboard, or PCB connections
- Where wires cross, the connection can be ambiguous
  - A can be assumed to be connected
  - Styles C and D to the right are preferred since they are clear
  - Intersection E is ambiguous



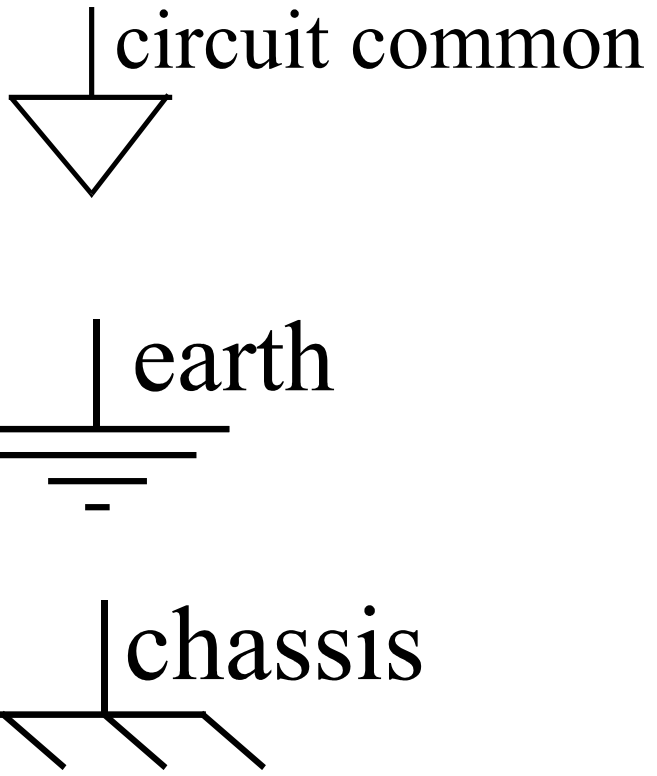
Power Sources

- Voltage and Current Sources apply a fixed voltage or current where drawn
- The could be batteries or power supplies or other sources
- Batteries sometimes used the special symbol shown to the right
  - The longer horizontal line represents the positive terminal



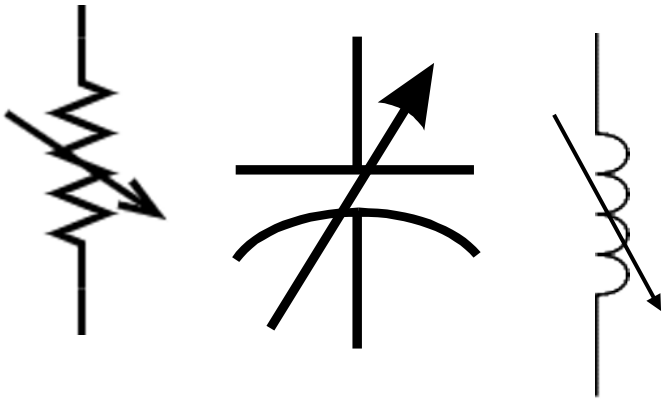
Symbols for Ground

- The two triangular symbols are often used to indicate a common 0V for the circuit, which will call ground
- When labeled “Earth” it indicates an actual connection to a conductor driven into the soil.
- “Chassis” means an electrical connection to the metallic case of chassis of a device



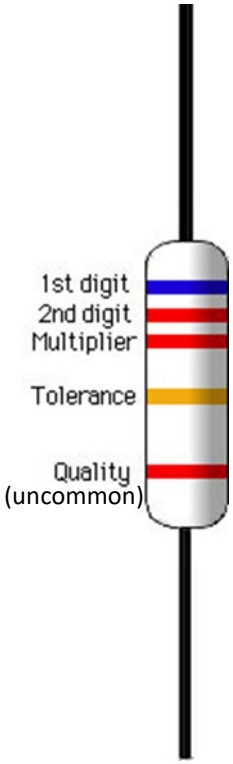
Adjustable and Variable components

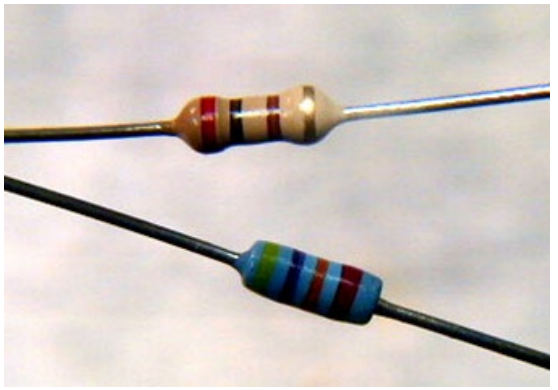
- Most common components have a variant that can change its value based on outside input
  - This could be a manual adjustment, like a set screw or a response to temperature or light
- This is usually indicated by an arrow drawn over the symbol
- Note these are intentional, engineered changes, most components also have a temperature dependence, which is not a desired effect

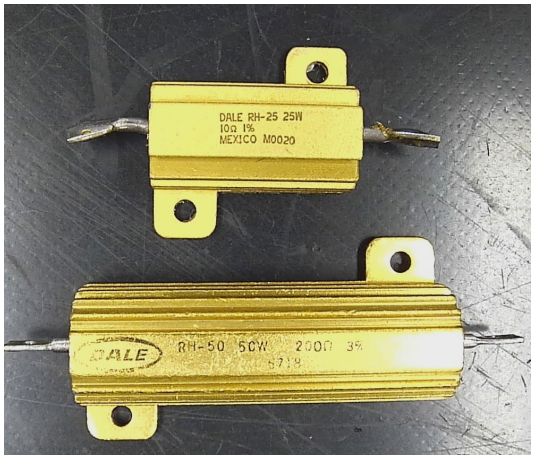


Resistors

- Designed to provide resistance in a circuit for a broad array of applications
- Because they dissipate power as heat high high-power rated resistors my have heat sinks
- Nonpolarized
- Commonly marked with value using a color code
  - For exam to the right the RED-BLACK-BROWN-Gold Resistor
  - Is 20×10^1 (200 Ohm) with a 5% tolerance







0 1 2 3 4 5 6 7 8 5% 10%

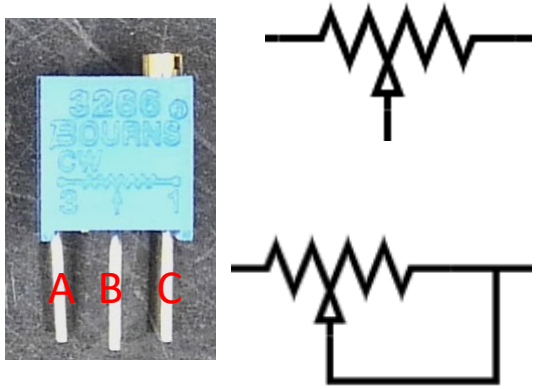
Big Bears Run Over Your Gladiola Bed Vexing Garden Worms

Resistor Schematic Symbols

- Variable adjustable resistors called potentiometers are a very common component
  - Have a knob or screw for adjusting the middle contact/lead
  - The middle lead taps off the resistor creating resistors that always add up to a fixed total value
    - For example in a 10KOhm “Pot” you could set A-B to be 3000 Ohm, B-C 7000 Ohm
    - By connecting the middle lead to one end we can bypass the second half of the resistor, creating a variable resistor you can change from ~0-Max Value

Resistor Symbol

Common Variant



Potentiometers

Capacitors and Inductors

Capacitors

- Consists of two plate-like electrodes separated by a nonconductive material called a dielectric
- When voltage is applied, charge slowly builds up creating an electric field to store energy
- Commonly used to smooth out voltage
- Units Farad (F) is Charge per Volt
- Some varieties are polarized (orientation matters)

$$i = C\frac{dV}{dt}$$

- In steady state (fully charged) acts like an open circuit (not connected)

Inductors

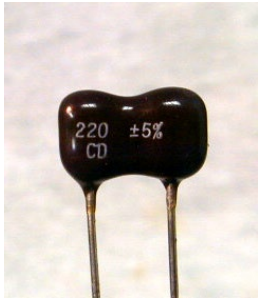
- Consists of a coil wrapped around a piece of magnetic material called a core
- As current flows through it builds and stores energy in a magnetic field
- Often used to create higher voltages
- Unit is the Henry
- Not polarized

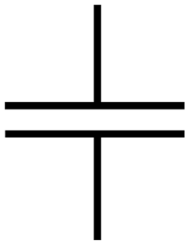
$$\mathrm{V} = L\frac{di}{dt}$$

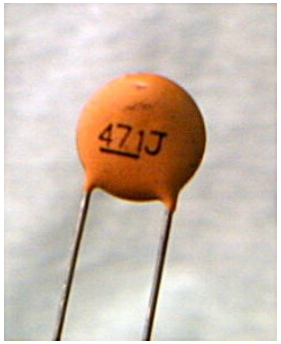
- In steady state(fully charged) acts a short circuit (just a regular wire)

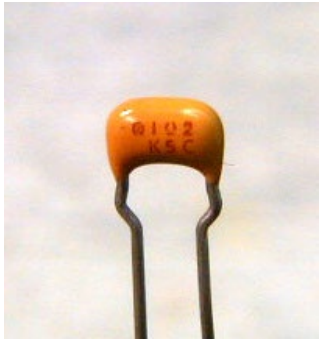
Capacitor Packages and Symbols

Nonpolarized Capacitors

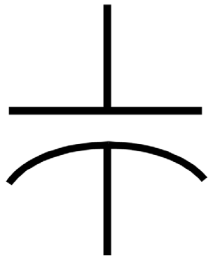


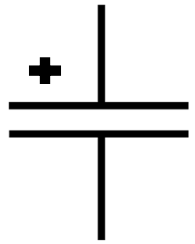


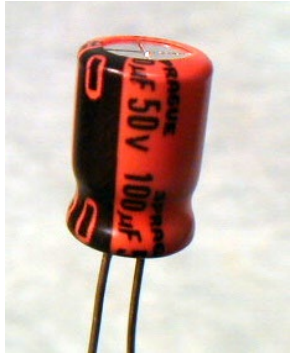




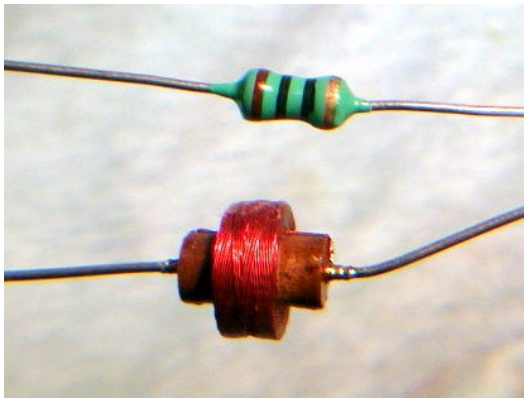
Polarized Capacitors

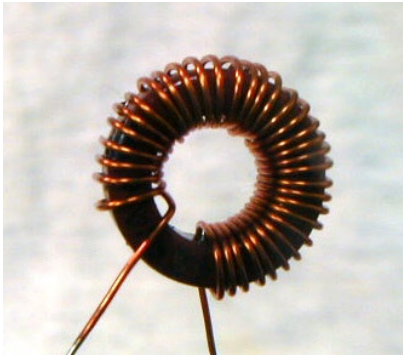




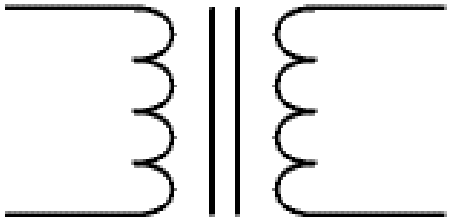


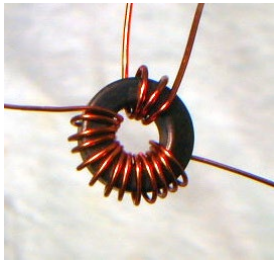
Inductor Packages and Symbols





- A related component is a transformer
- Two coils magnetically coupled by a common core
- Allowes



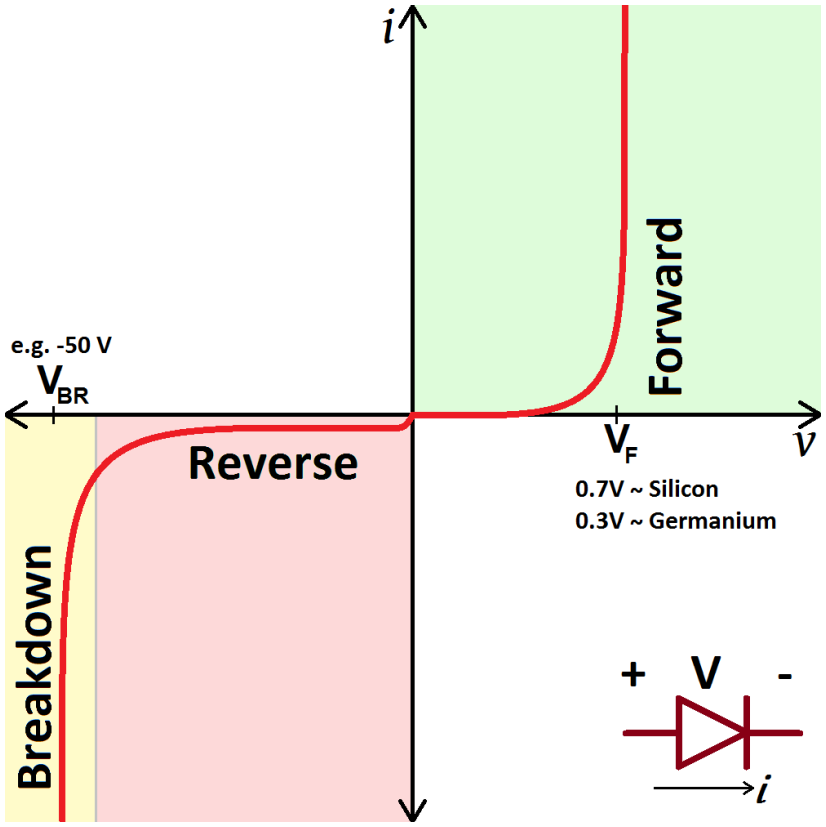


Semiconductor Components

- The previous components all worked are basic principles of electric and magnetic fields and linear relationships between current and voltage
- The remaining devices use semiconductor materials (silicon, germanium, gallium, …) to create very non-linear behavior
  - Older Vacuum tube-based versions are still used in some applications
- Semiconductor devices
  - Diodes
  - Transistors
  - Integrated Circuits

Diodes

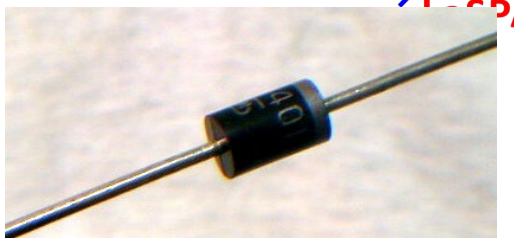
- Diodes create a small energy barrier to charge flow in the forward direction
- Once overcome by reaching V_f that voltage drop remains the same regardless current, leading to vertical V vs I region
- The diode blocks current in the reverse direction (except for a small trickle of current) until a higher breakdown voltage is reached V_{br}
- These characteristics allow the diode to regulate the direction of current flow or create

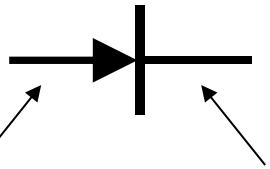


Typical Diode Voltage Vs Current

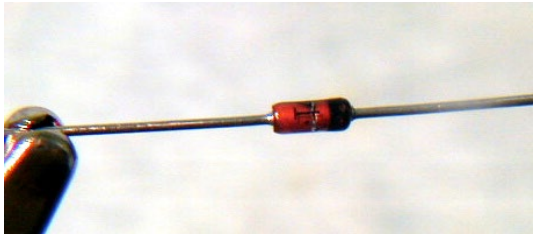
Diodes Appearance and Symbols

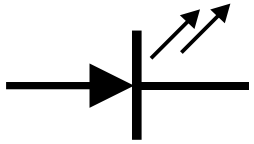
- Diodes inherently have a direction with the (+) side called the Anode and (-) cathode
- Physical Packages usually have a band or stripe for the cathode, matching the symbol
- A common usage is to convert the energy into light
  - Since V_f is fixed and the charge is fixed (electrons have –e), the wavelength of light emitted is fixed





Anode(+) Cathode(-)



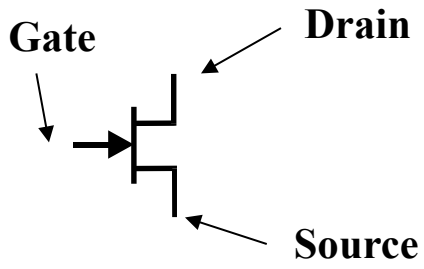


Light-emitting diode (LED)

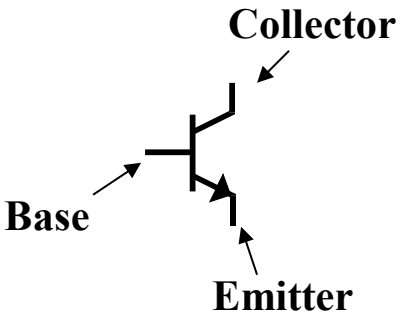
Transistors

- Three terminal devices
- The signal at the left terminal (Gate or Base) controls the flow of charge between the two other connections (Drain and Source or Collector and Emitter)
- Commonly used either as a switch or an amplifier (creates a large signal from a small signal)
- 2 Types that differ on the underlying technology, Field Effect Transistors (FETs) and Bipolar Junction Transistors (BJT)
- Each of those has 2 types that depend on the behavior of the Gate/Base to positive or negative signals
  - NPN and PNP for BJTs
  - N-Channel and P-Channel for FETs

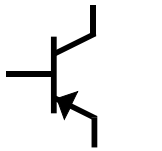
Field Effect Transistor



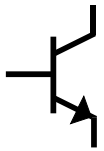
Bipolar Junction Transistor



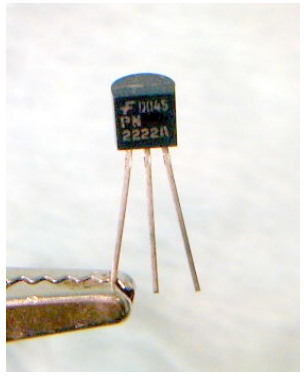
Terminal Designations and packaging styles



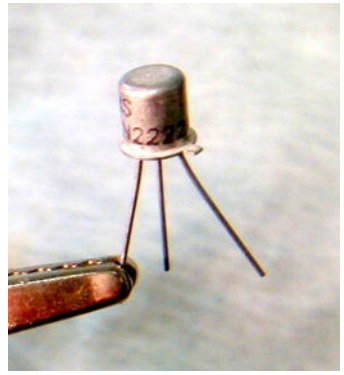
BJT PNP Transistor



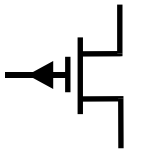
BJT NPN Transistor



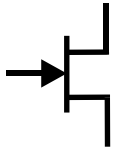
TO-92 package



TO-18 package

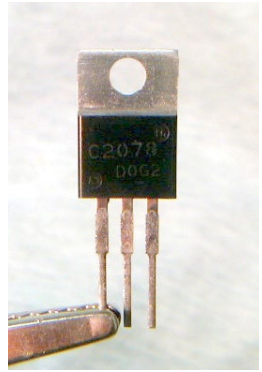


P-channel FET Transistor



N-channel FET Transistor

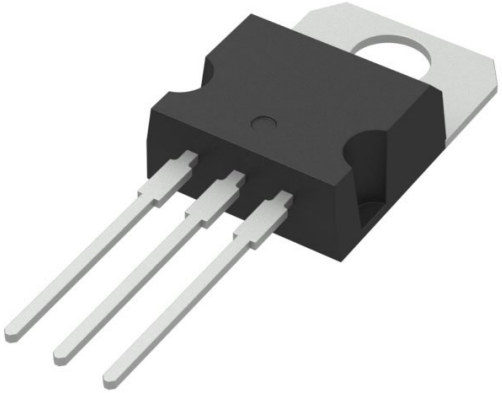
Physical form usually depends on the application rather than the type, so you usually cannot ID without looking up the part number

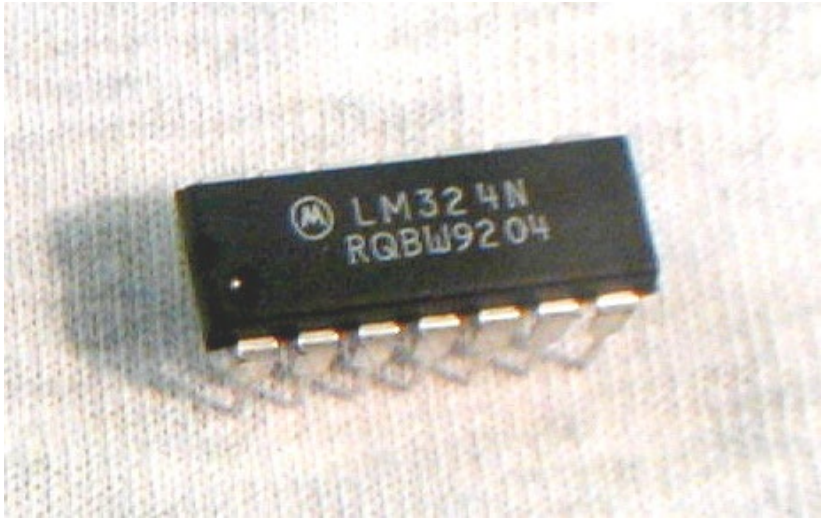


TO-220 package

Integrated Circuits

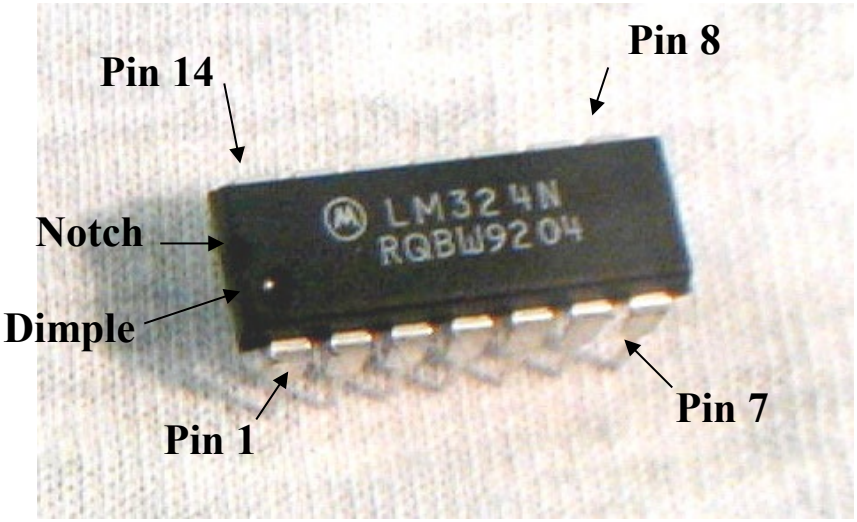
- Integrated circuits are purpose-designed devices that combine a specific circuit into a single discrete package
- They can be general use, like an amplifier, or very specific, like a clock
  - We will discuss one important type called and Op. Amp later
- Come in a wide variety of physical shapes and sizes, but are marked with a manufacturer (Motorola Logo to the right), part number (LM324N), and lot number (RQBW9204)





Pin identification and numbering convention

- Pin 1 is often identified with a dot or an indentation
- The pin 1 end of the chip is often identified with a notch, with pin 1 being on the left when the notch is up
- Pins are numbered sequentially in a counterclockwise direction
  - Notice how pin is directly across from pin 7, and pin 14 across from 1 in the example to the right
- Since the pins have different functions, you must pay attention to the numbering on schematics
- ICs can be susceptible to ESD (Static electricity) damage (many actually are), so rigorous precautions should be taken.
- Take care not to damage the pins when removing or installing the chip



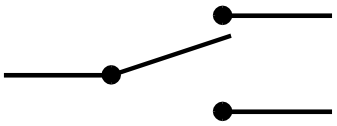
This is a common package called PDIP, where the pins come in 2 rows, designed to be soldered in through hole boards or installed in sockets

Switches

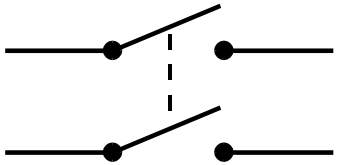
- Switches are mechanical devices that physically move or break electrical continuity in a circuit
- They are usually referred to by the number of moving switching elements (called poles) and the number of positions they can be in (called throws)
- A dashed lined

Single Pole Single Throw
SPST

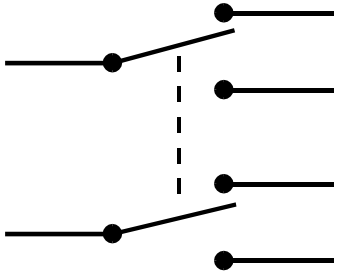
Single Pole Double Throw
SPDT



Double Pole Single Throw
DPST

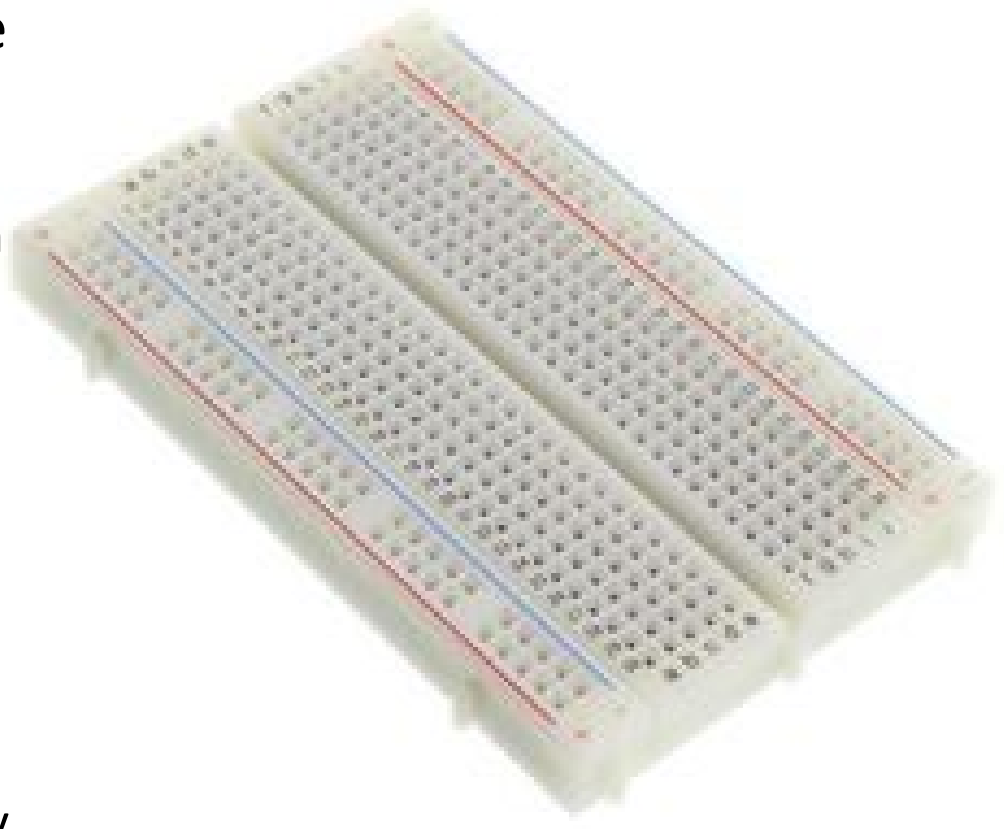


Double Pole Double Throw
DPDT



Solderless Breadboards

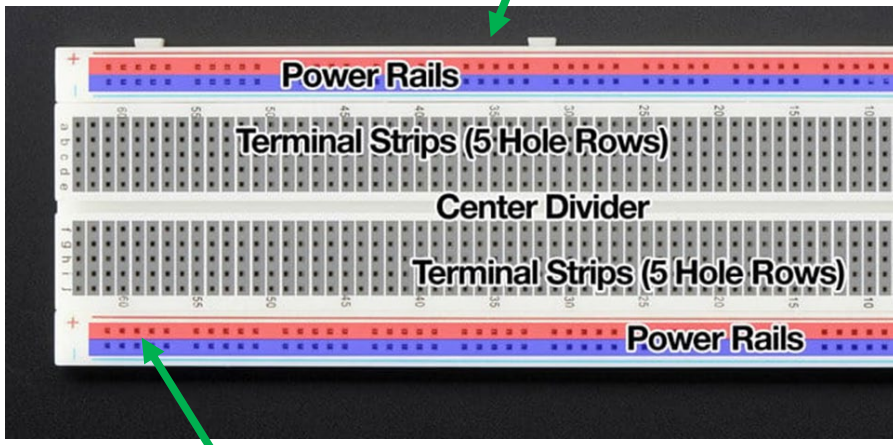
- Used to construct and prototype TEMPORARY circuits
  - After testing, you will want to transfer the circuit to a Printed Circuit Board (PCB) and solder it in place
- Electrical components can be connected by inserting their leads into the holes
  - Metal buses connect the holes along columns and rows in a specific pattern
  - Some parts may have leads that are too thin to make good contact or too thick to fit in the hole
  - Parts should slide in easily but stay secure
  - Use solid core wire when making connections, stranded wire will be too limp to insert



Breadboard Layout (Power Rails)

- The top two and bottom two rows are connected horizontally across the length of the board
  - Each row is separate and not connected to the others
- These are usually connected to power since many components will need to connect to power
- Even though the rows are marked with (+) and (-) feel free to ignore the markings
  - I recommend using the top row for (+) power, using the different rows for different voltages (+5V and 3.3V, for example)
  - Then use the bottom rows for negative/ground
  - Most chips + and – pins are on opposite sides
  - In this layout, power flows generally from top to bottom, which allows you to lay out your circuit cleanly

Connect the top rows to the (+) terminal of you power supply

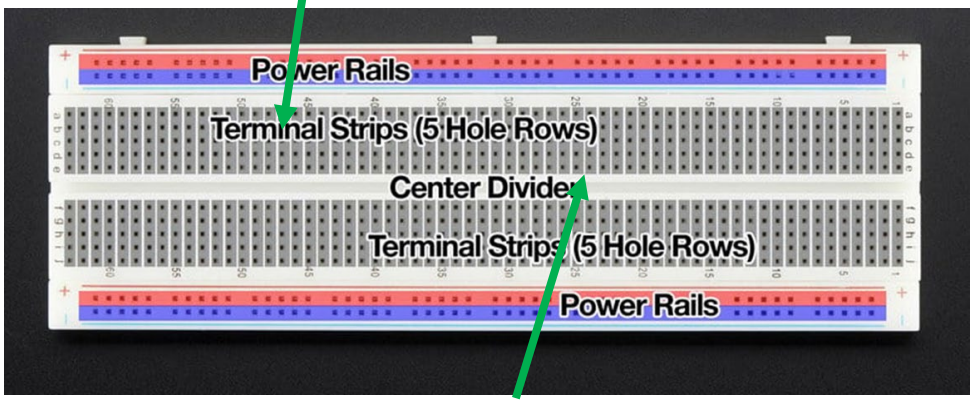


Use the bottom rows for negative

Terminal Strips Layout

- Terminal strips are connected in vertical columns
  - Since the columns are connected to each other will very rarely want a single component's leads connected to the same column
- A gap in the middle separates the top and bottom strips
  - Most components will be oriented horiztonally, unless they are long enough to jump across this gap

Terminal strips are connected in vertical columns



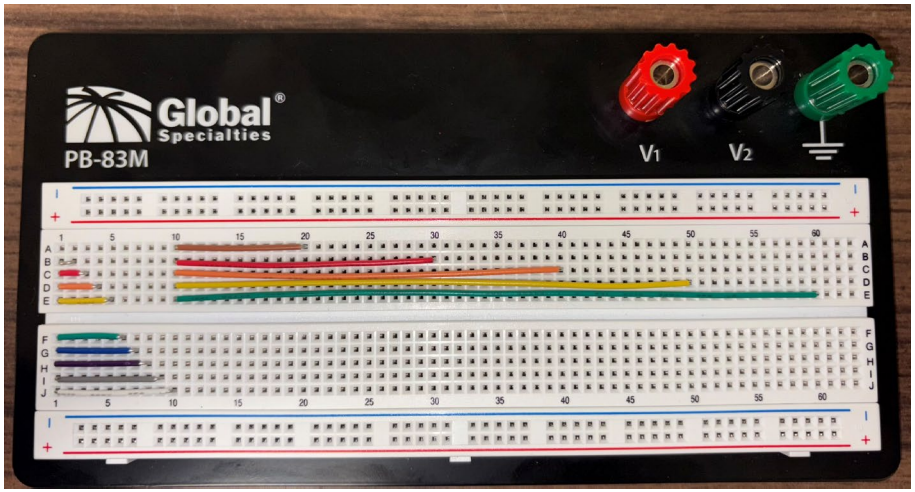
Center divider separates the top terminal strips from the bottom. The gap is sized to the common PDIP package. This allows installation of chip with each pin on a different terminal strip

Jumper Wires

- Pre-packes kits of wire can make the prototyping process
- Solid wire pre-bent at 90 degrees makes installing these wires easier
- They come in length matching the spacing of the breadboard holes

Jumper Length

- Set of jumper cables will follow the same color convention as resistors, with the number of vertical or horizontal spaces
- For example, an orange jumper will be able jump 3 spaces on the breadboard.
- You can also use the wires diagonally or with bends as needed but the length may be slight off



The longer leads come in lengths of 20, 30, 40, and 50. These long wires are often useful for connecting devices of the board or “jumping” over other components