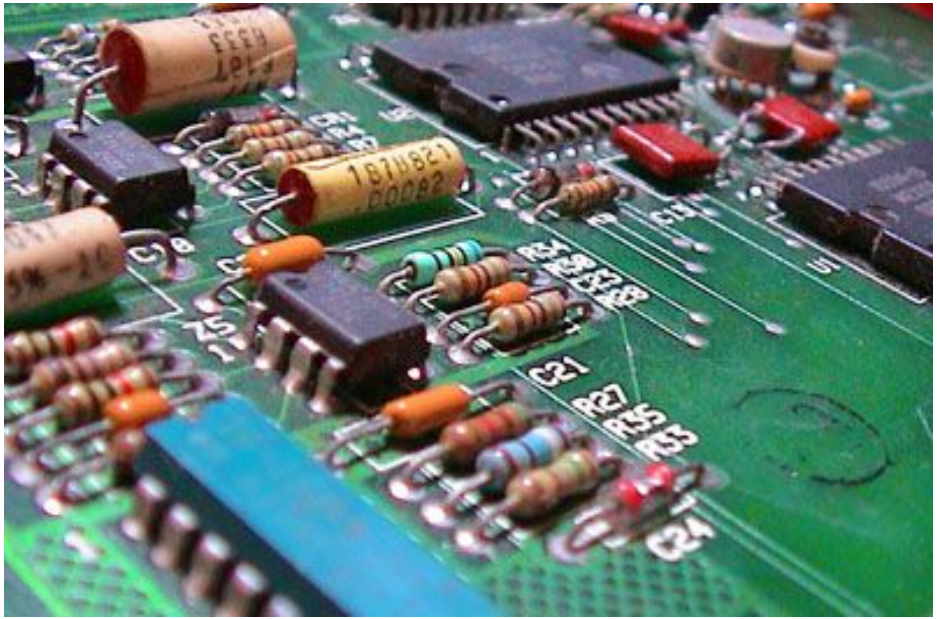

Electronics and Schematics

John R. Leeman

8/2/21

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Image: WikiPedia

A Few Safety Notes

- Never work on high voltage DC or any AC systems unless qualified
- This class doesn't qualify you
- Don't work on live systems if possible
- Don't work alone
- Unsure? Stop
- Did I mention this course doesn't make you an electrician?

Image: FieldVibe

“Anything can be a fuse” - A Mechanical Engineer

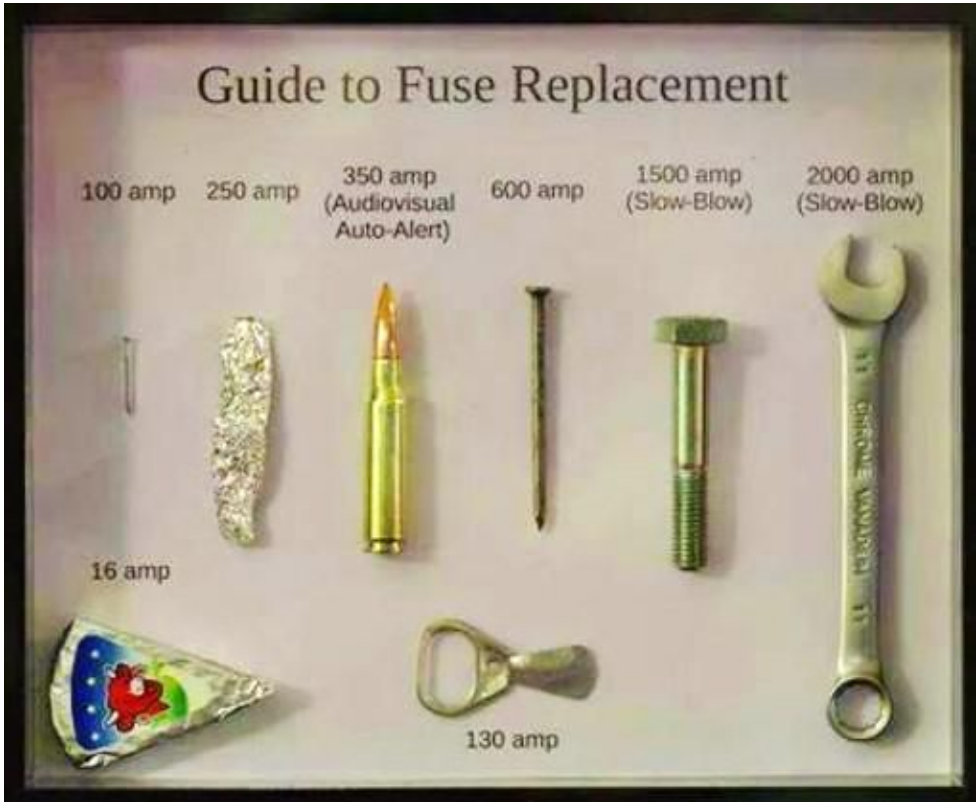

Image: Twitter

Electric circuits are closed loops that electrons flow through. Electrical energy is stored electrical potential difference.

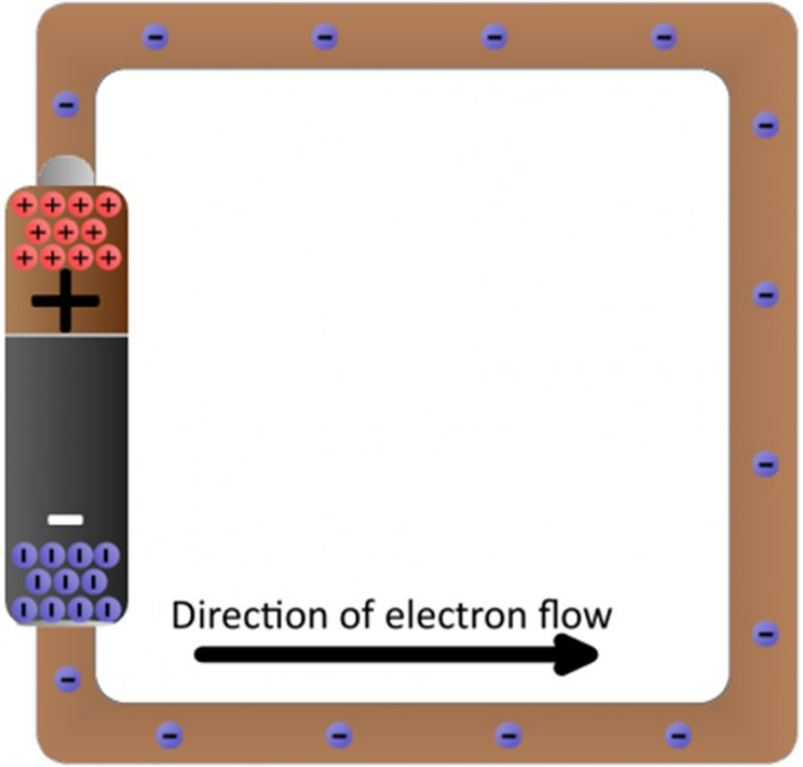

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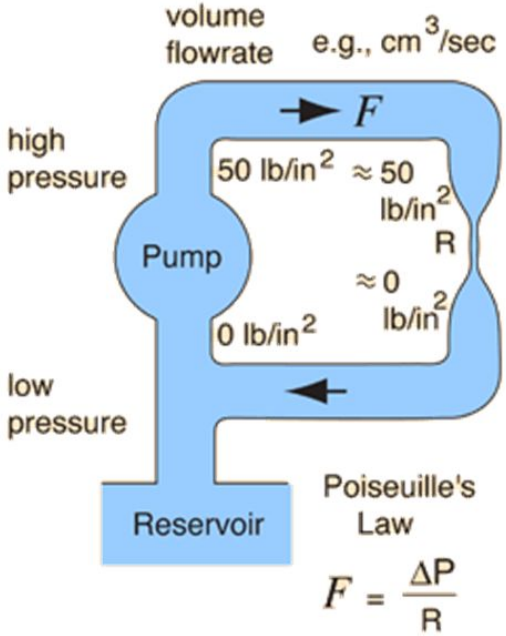
Image: Sparkfun

We generally think in conventional current flow, not electron flow

Image: XKCD

In electronics we generally only have to consider a few fundamental quantities

- Voltage
- Current
- Resistance
- Capacitance
- Inductance
- Reactance



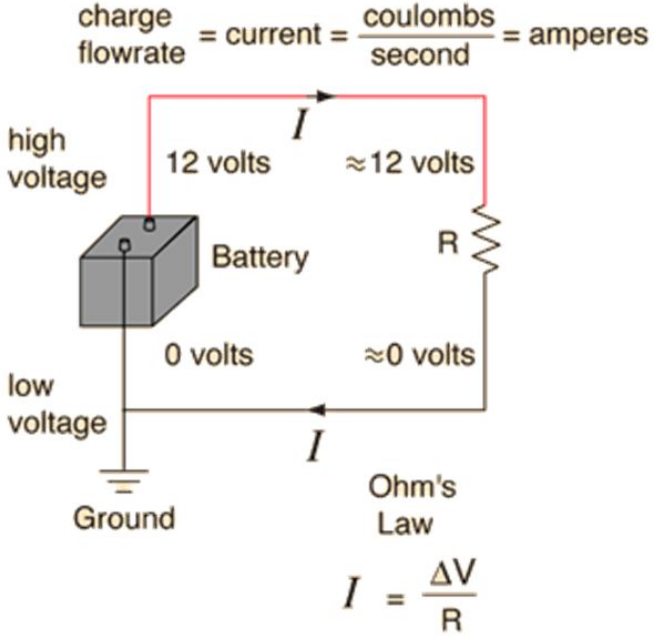


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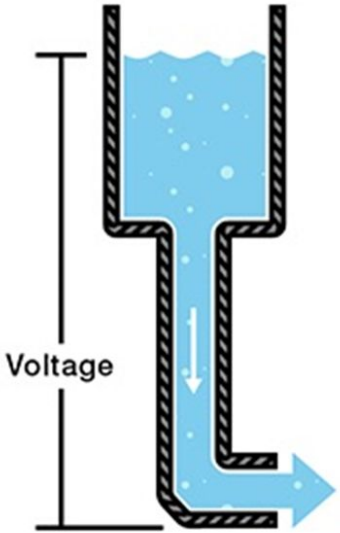
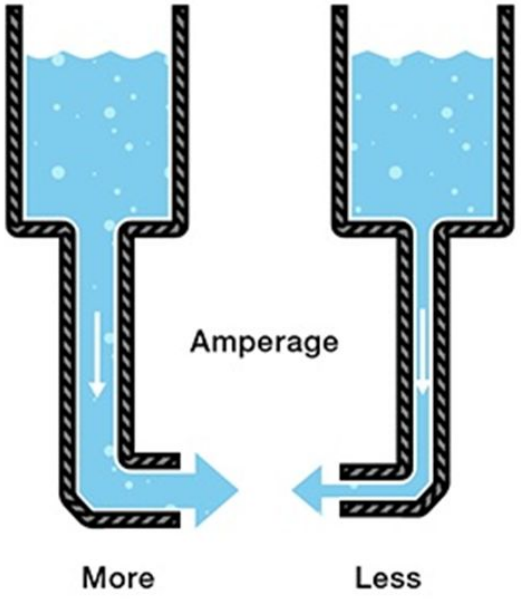
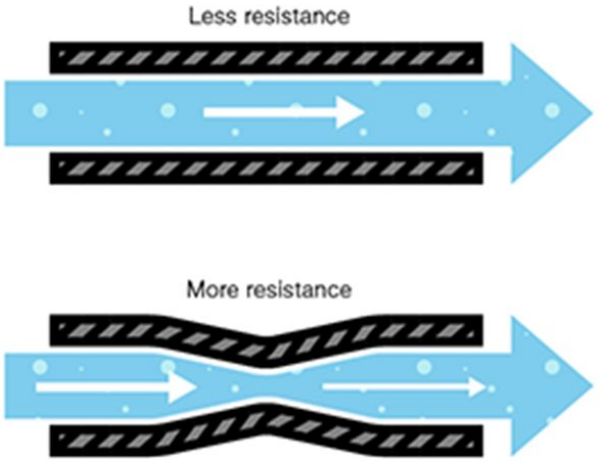
Image: Hyperphysics

We can use the water analogy for a bit longer







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Images: Sparkfun

Ohm’s Law relates all of these quantities

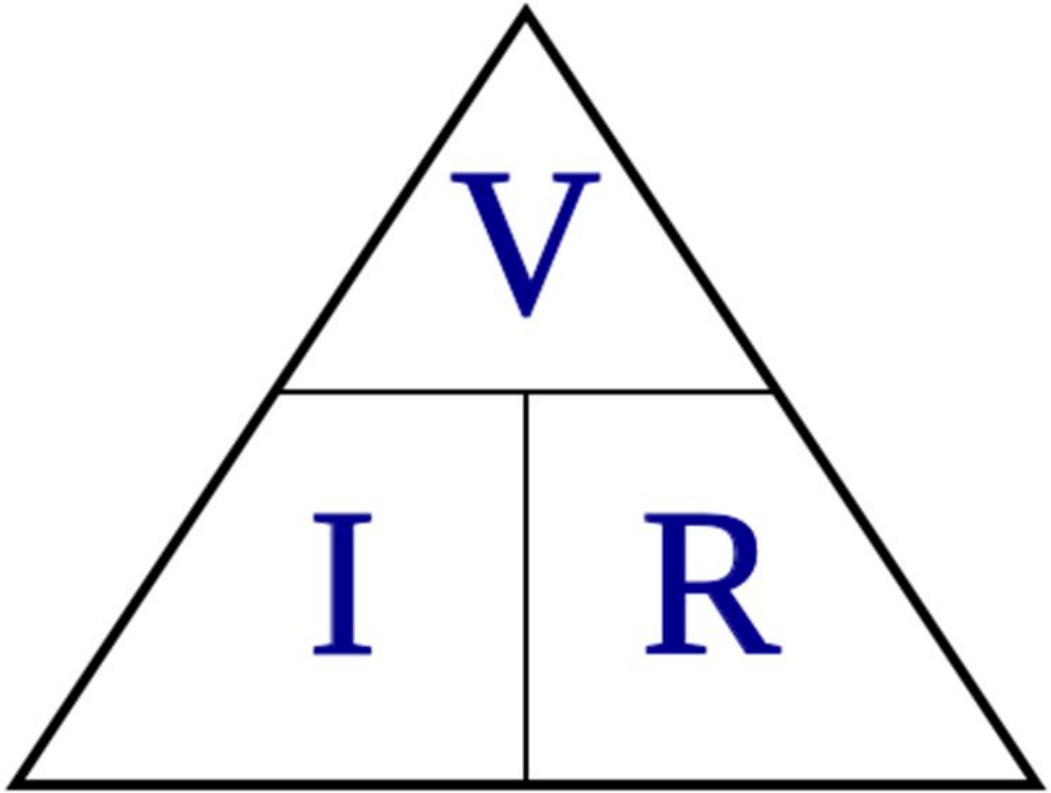

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Image: Wikipedia

Ohm's Law relates all of these quantities

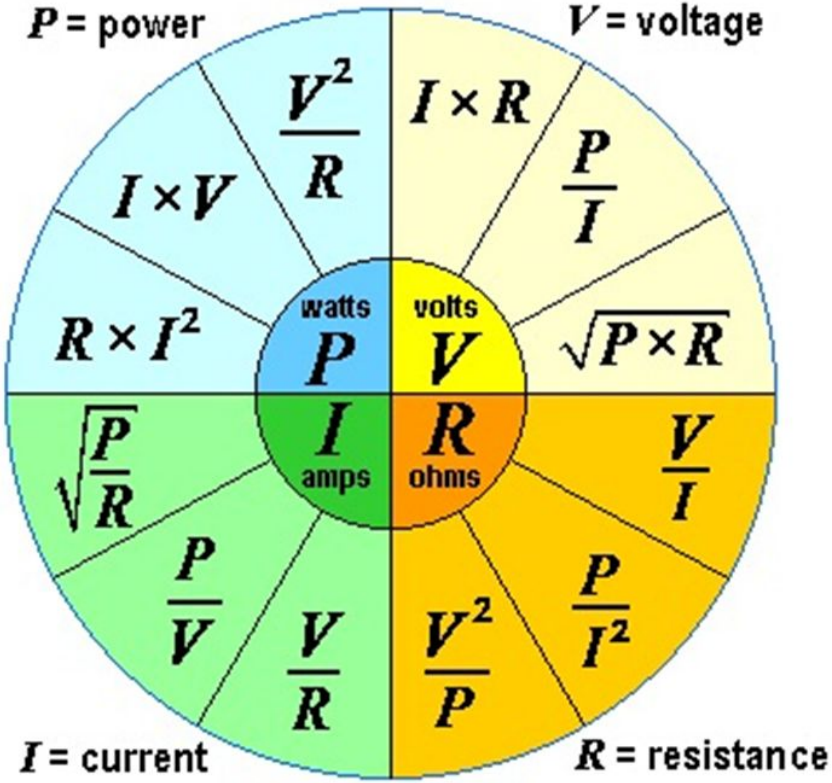

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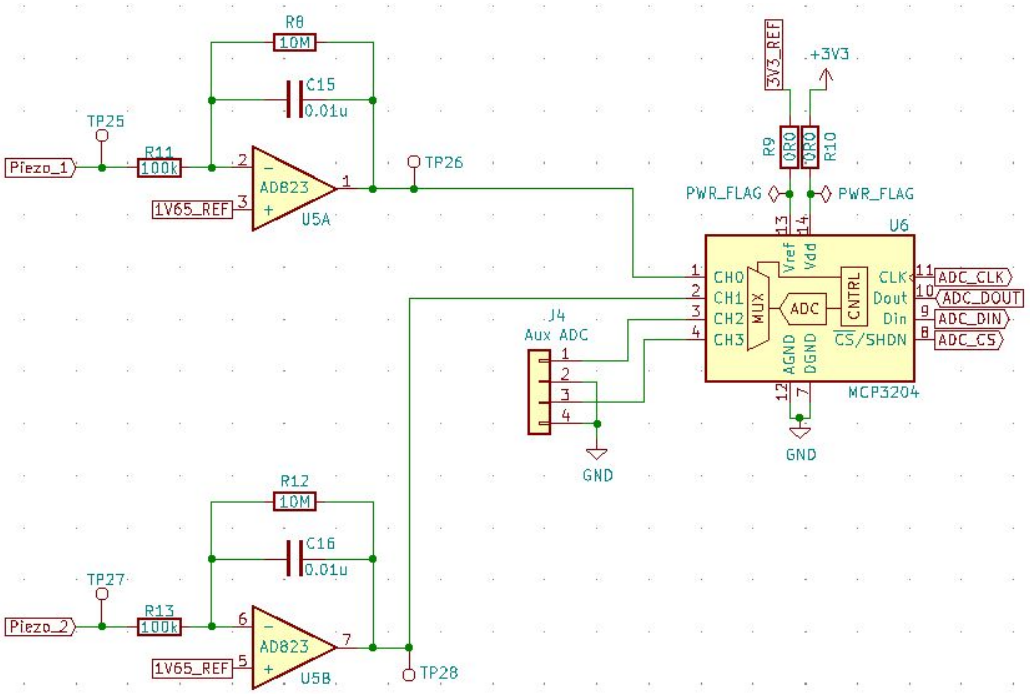
Image: sengpielaudio.com

We draw circuits in schematic diagrams with symbols to represent parts and connections



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The symbols are “standard” for many components

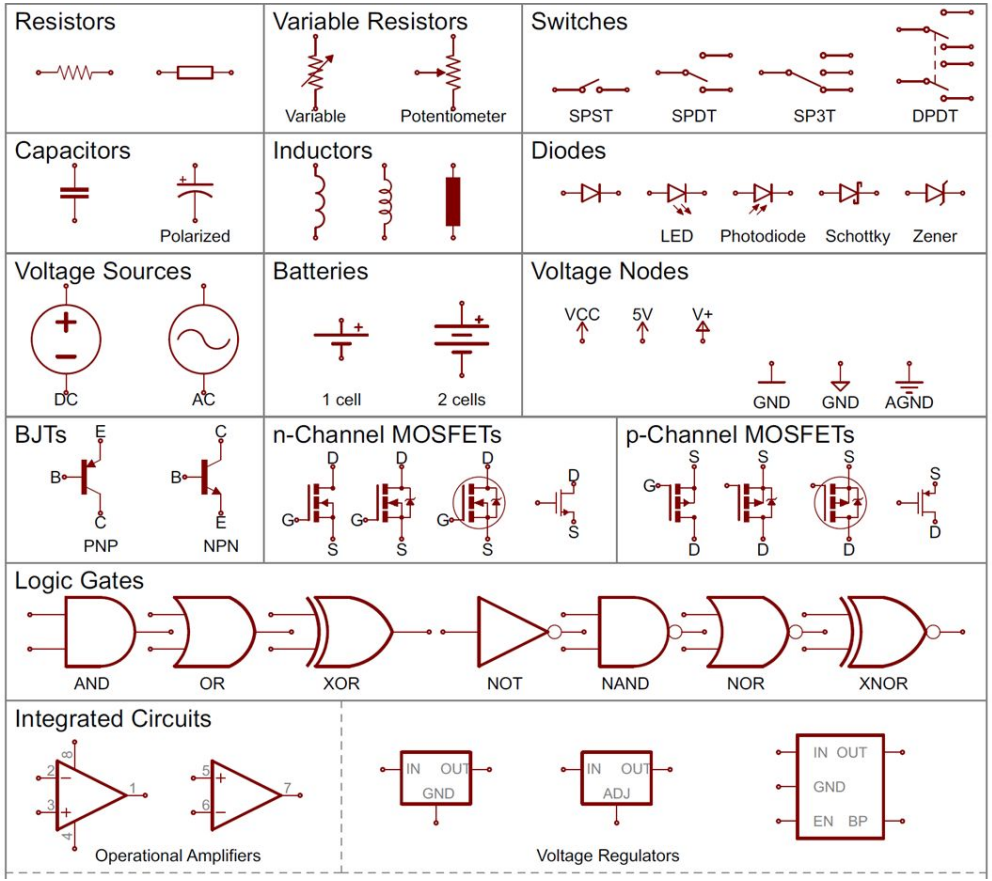


Image: Sparkfun

Junctions mark there connections are made

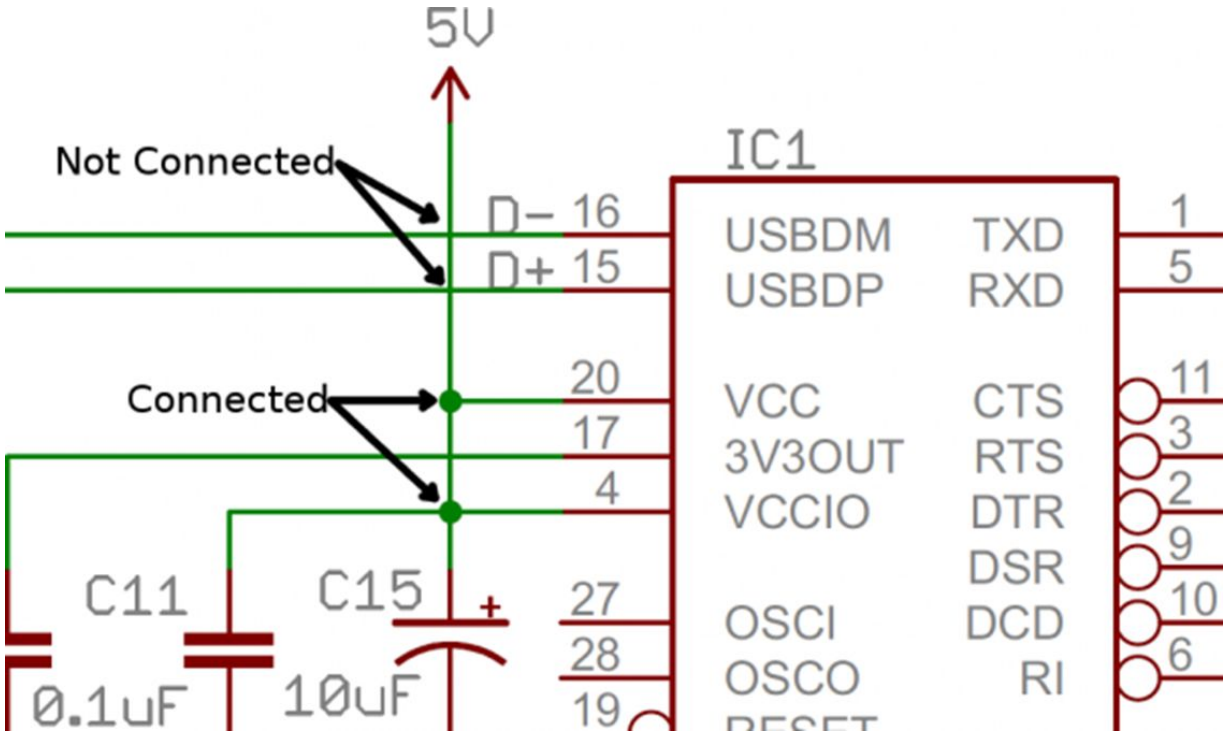


Image: Sparkfun

We also use net name labels to reduce schematic clutter

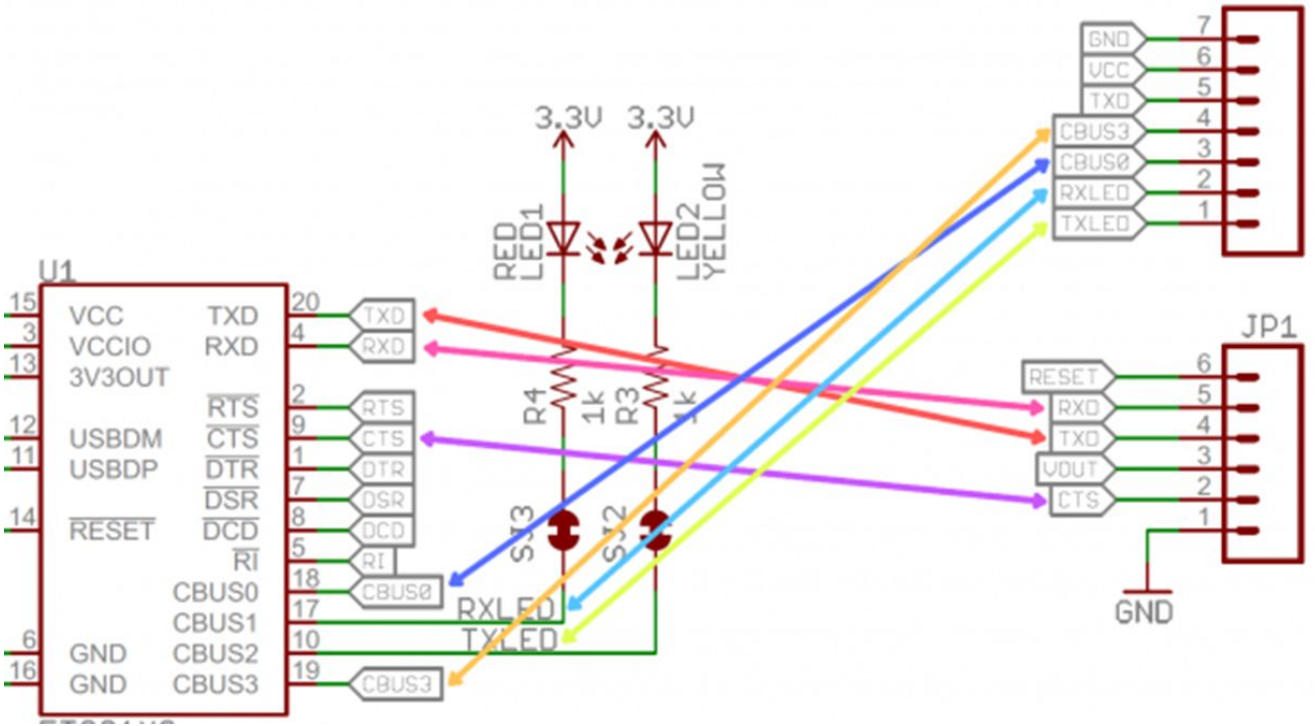
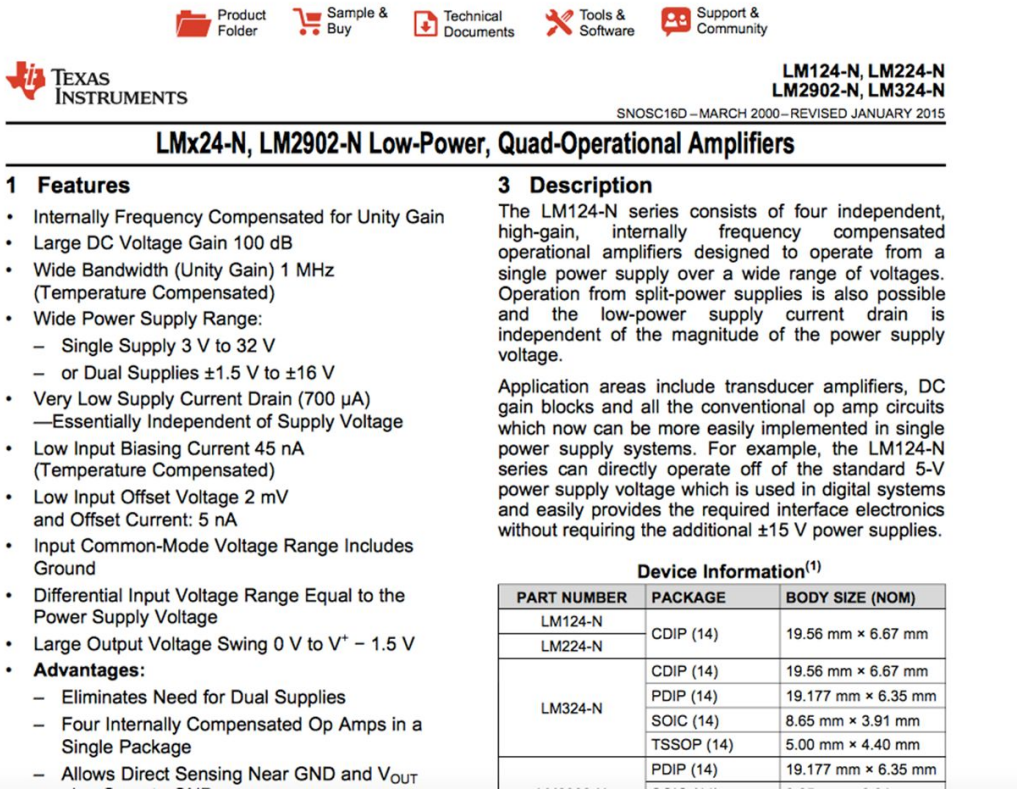


Image: Sparkfun

Golden rule - read the datasheet, completely, always, and ignore the “banner specifications” on page 1



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TEXAS INSTRUMENTS

LM124-N, LM224-N
LM2902-N, LM324-N

SNOSC16D – MARCH 2000 – REVISED JANUARY 2015

LMx24-N, LM2902-N Low-Power, Quad-Operational Amplifiers

1 Features

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain 100 dB
- Wide Bandwidth (Unity Gain) 1 MHz (Temperature Compensated)
- Wide Power Supply Range:
  - Single Supply 3 V to 32 V
  - or Dual Supplies ±1.5 V to ±16 V
- Very Low Supply Current Drain (700 µA) —Essentially Independent of Supply Voltage
- Low Input Biasing Current 45 nA (Temperature Compensated)
- Low Input Offset Voltage 2 mV and Offset Current: 5 nA
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Large Output Voltage Swing 0 V to V^+ − 1.5 V
- **Advantages:**
  - Eliminates Need for Dual Supplies
  - Four Internally Compensated Op Amps in a Single Package
  - Allows Direct Sensing Near GND and V_{OUT}

3 Description

The LM124-N series consists of four independent, high-gain, internally frequency compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124-N series can directly operate off of the standard 5-V power supply voltage which is used in digital systems and easily provides the required interface electronics without requiring the additional ±15 V power supplies.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM124-N	CDIP (14)	19.56 mm × 6.67 mm
LM224-N		
LM324-N	CDIP (14)	19.56 mm × 6.67 mm
	PDIP (14)	19.177 mm × 6.35 mm
	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	5.00 mm × 4.40 mm
	PDIP (14)	19.177 mm × 6.35 mm

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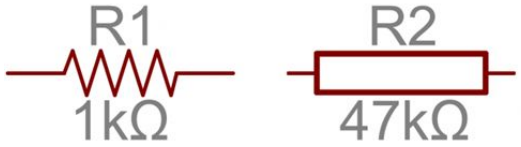
Resistors



Images: Sparkfun

There are common values, we recommend 1% or better

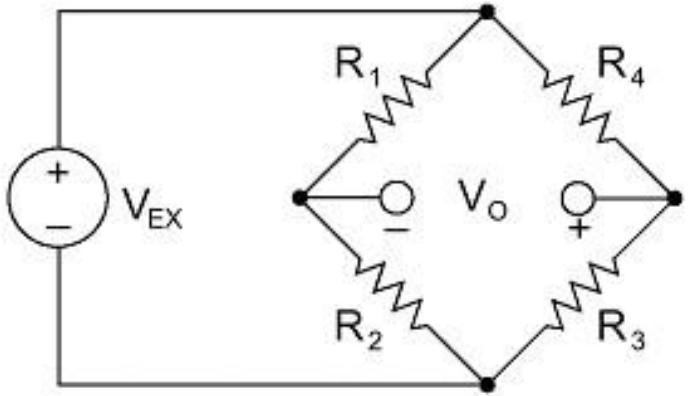
	Colour	Band 1 First digit	Band 2 Second digit	Band 3 Multiplier	Band 4 Tolerance
	Black	0	0	x 1 (x 1)	-
	Brown	1	1	x 10 (x 10)	1%
	Red	2	2	x 100 (x 100)	2%
	Orange	3	3	x 1 000 (x 1k)	not used
	Yellow	4	4	x 10 000 (x 10k)	not used
	Green	5	5	x 100 000 (x 100k)	not used
	Blue	6	6	x 1 000 000 (x 1M)	not used
	Violet	7	7	-	not used
	Grey	8	8	-	not used
	White	9	9	-	not used
	Gold	-	-	-	5%
	Silver	-	-	-	10%

Table J.1 Standard Resistance Values

	1% Resistor Values (kΩ)			
5% Resistor Values (kΩ)	100–174	178–309	316–549	562–976
10	100	178	316	562
11	102	182	324	576
12	105	187	332	590
13	107	191	340	604
15	110	196	348	619
16	113	200	357	634
18	115	205	365	649
20	118	210	374	665
22	121	215	383	681
24	124	221	392	698
27	127	226	402	715
30	130	232	412	732
33	133	237	422	750
36	137	243	432	768
39	140	249	442	787
43	143	255	453	806
47	147	261	464	825
51	150	267	475	845
56	154	274	487	866
62	158	280	499	887
68	162	287	511	909
75	165	294	523	931
82	169	301	536	953
91	174	309	549	976

Images: Open Univeristy, Chegg

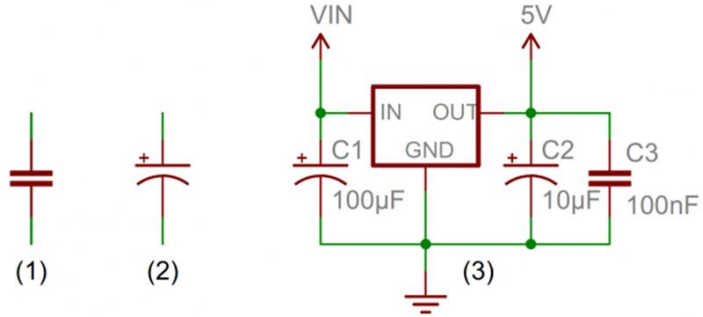
Bridge circuits are a common configuration



$$V_o = V_i \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right]$$

Images: National Instruments

Capacitors



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Images: Sparkfun

Inductors

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Image: embeddedmicro.com

Switches

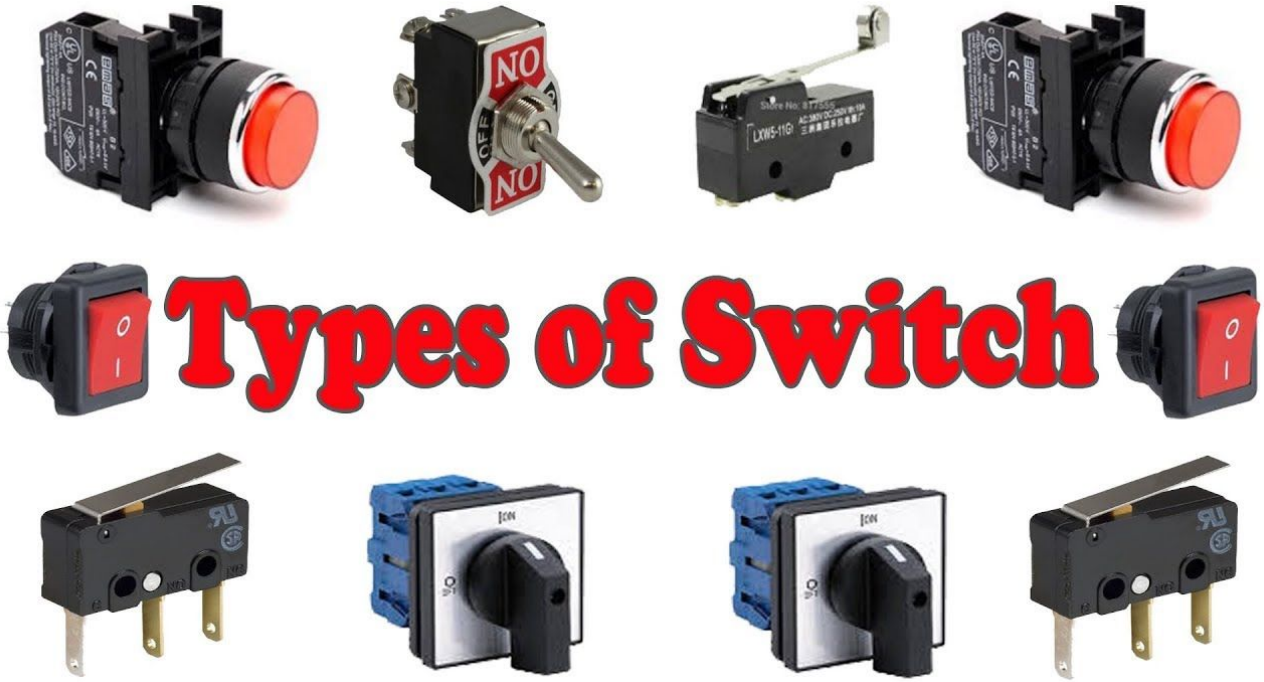

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Image: Learning Engineering

Common Equipment

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Images: Test Equipment Depot, tequipment.net, Tektronix

Diodes

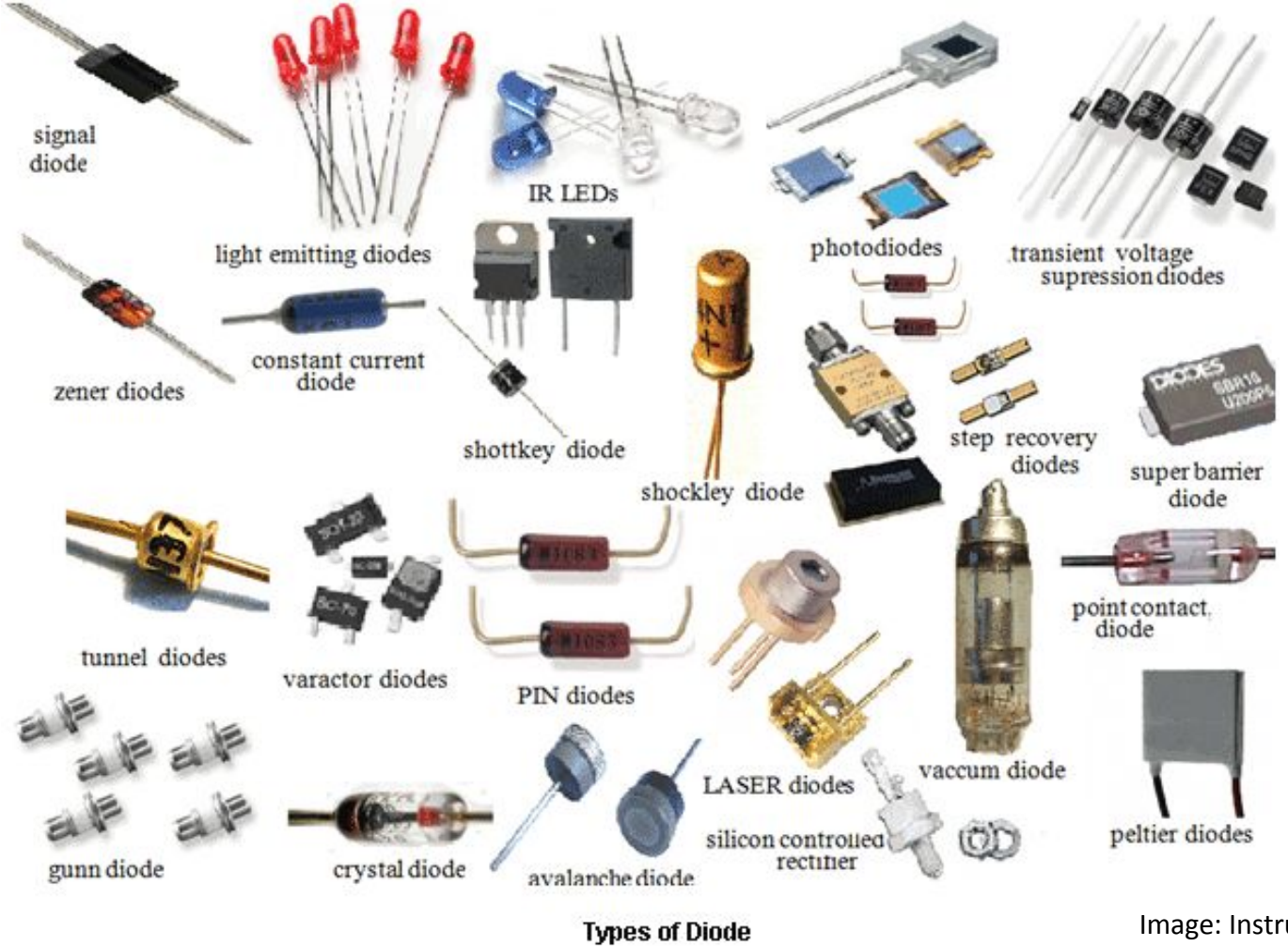
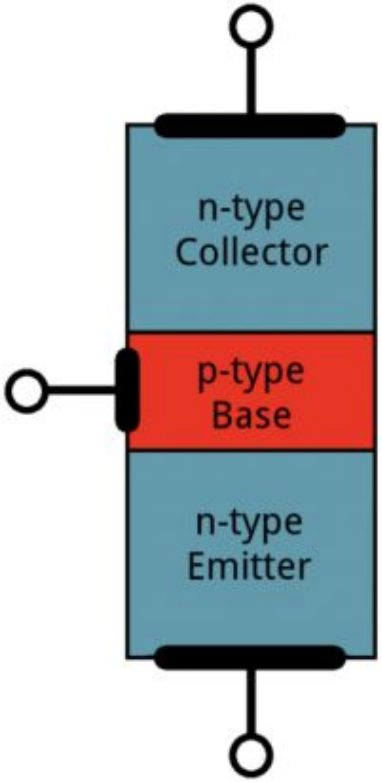
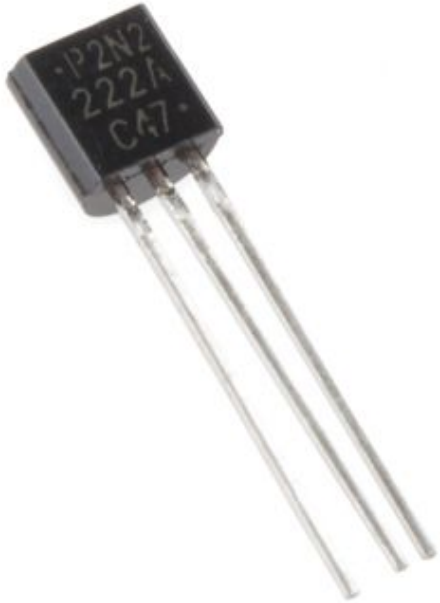


Image: Instructables

Transistors





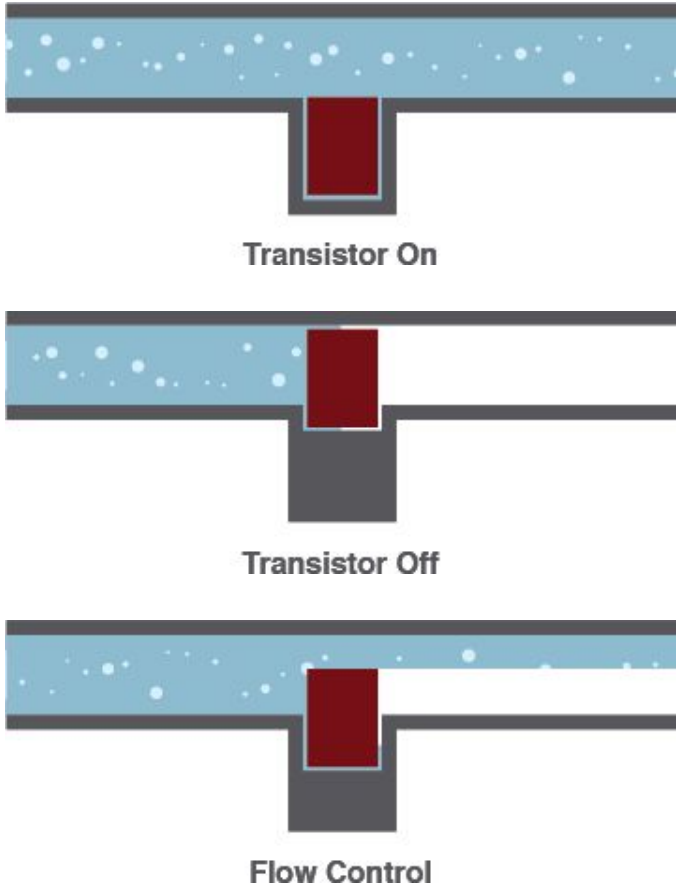


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Image: Sparkfun

Transistors can be operated in different modes

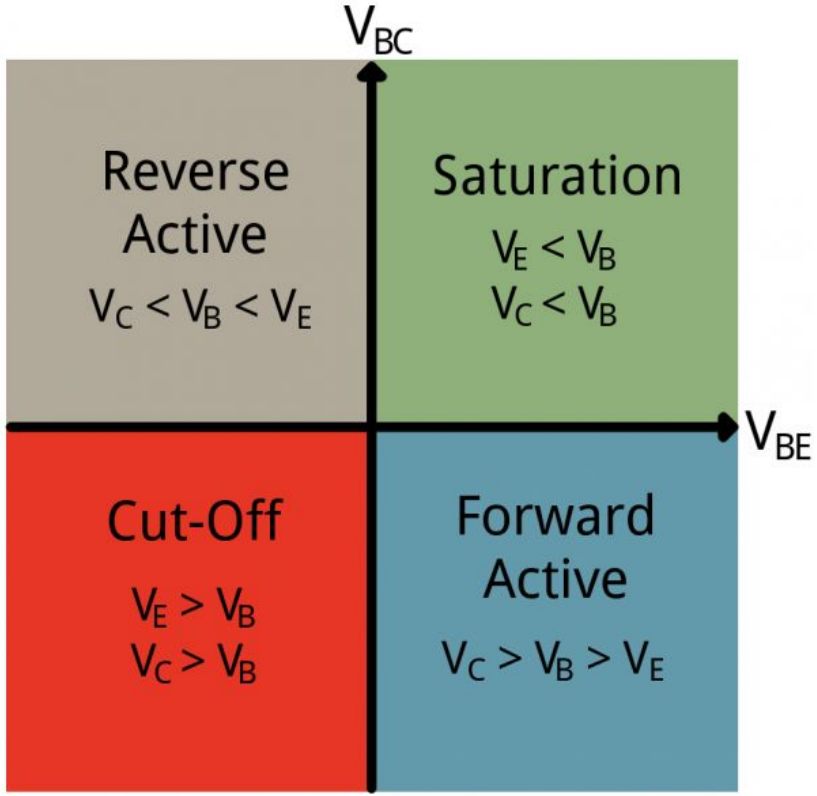

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Image: Sparkfun

Transistors as a switch

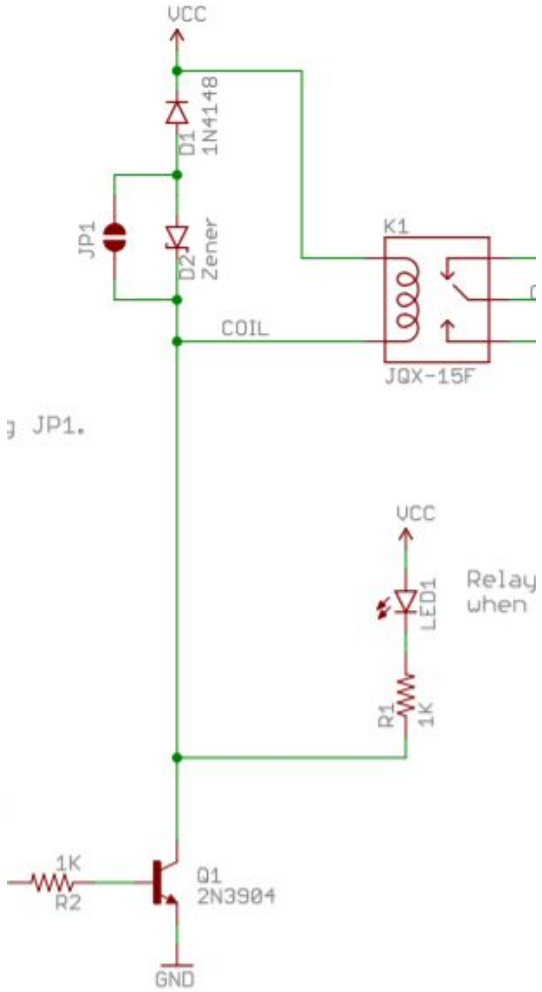

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Image: Sparkfun

FETs

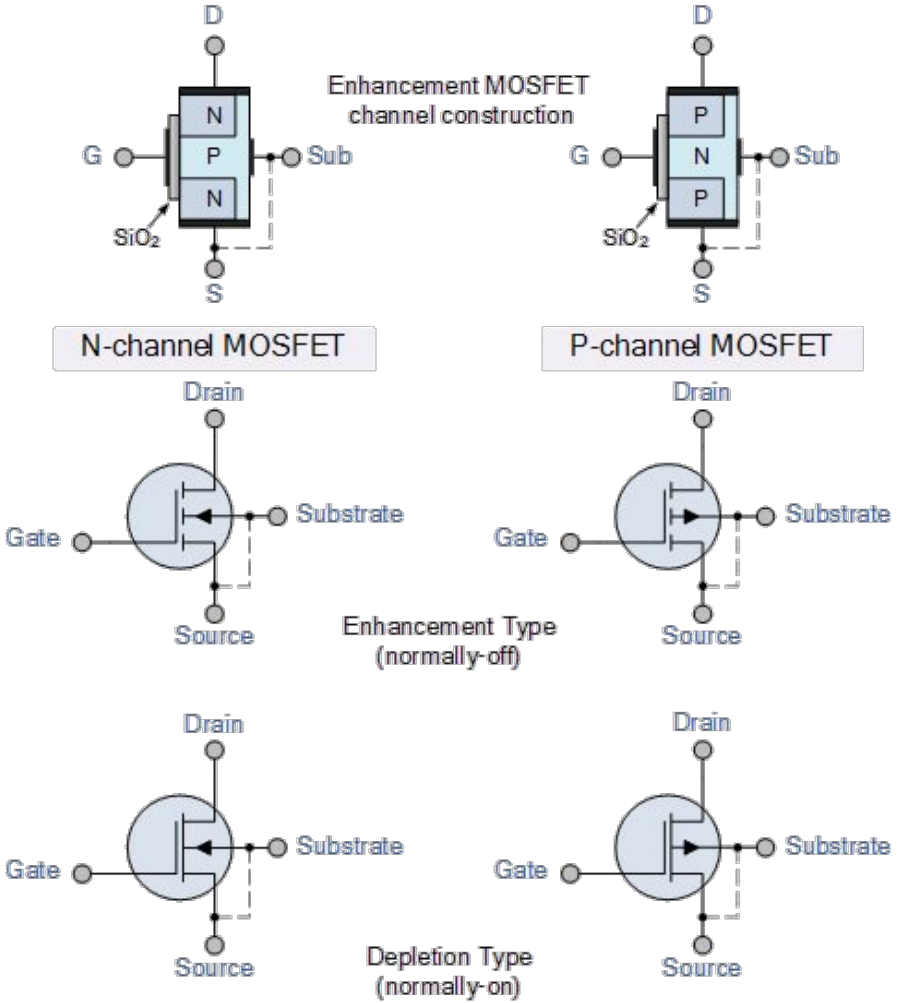

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Image: Electronics Tutorials

Voltage Regulation

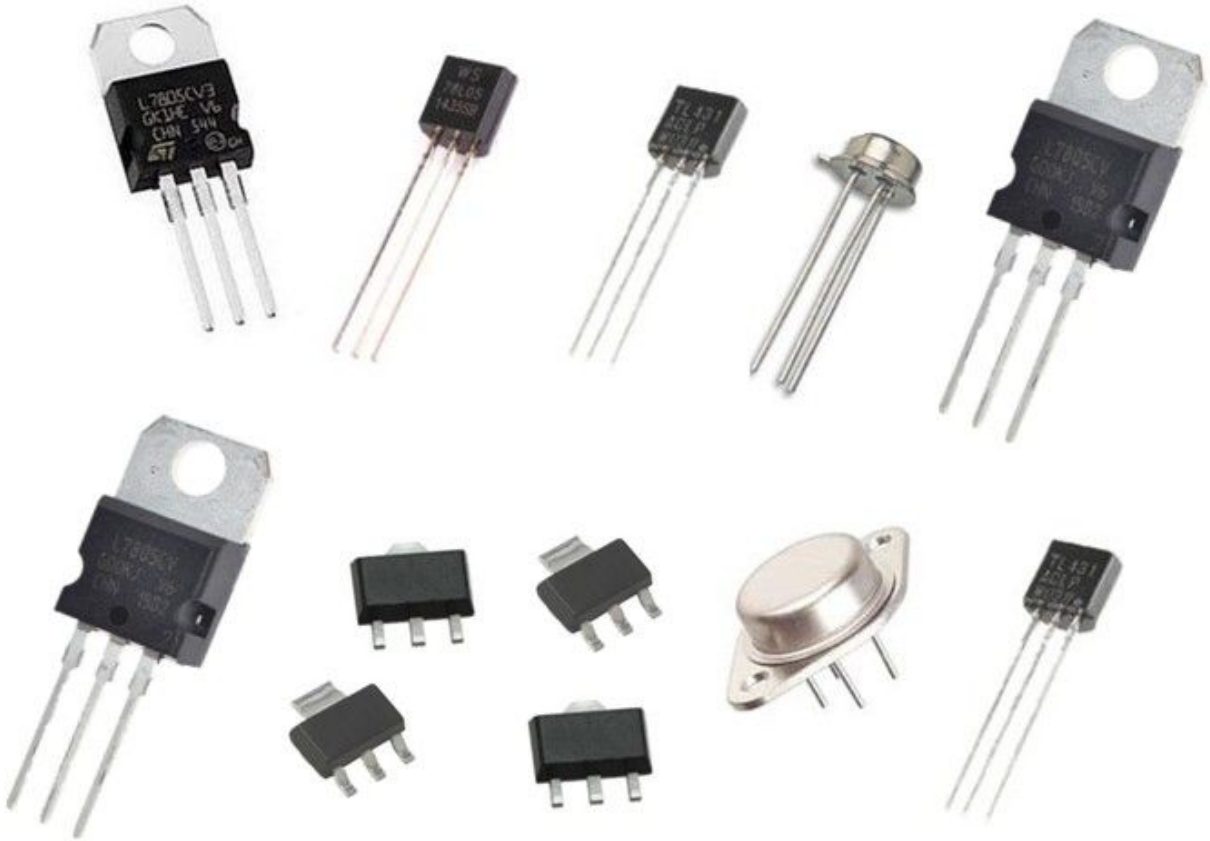

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Image: Components 101

Start/Stop Circuit

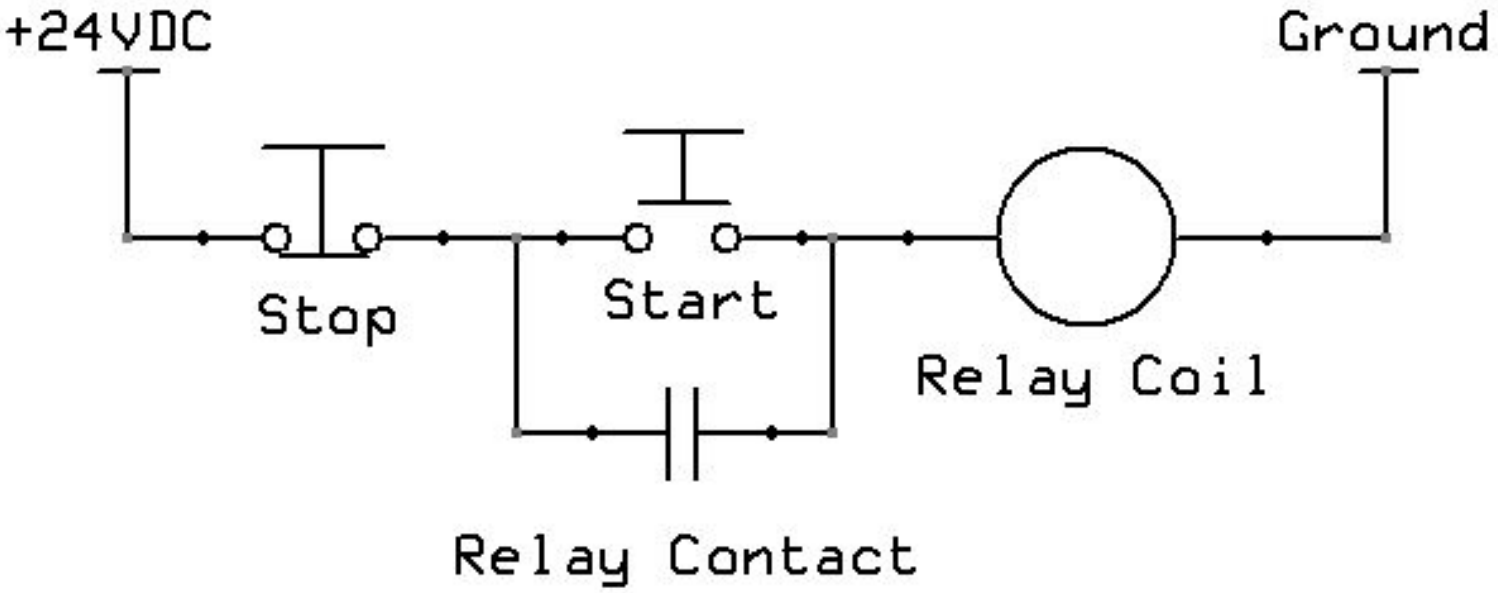

Image: drstienecker.com

Failsafe Circuit

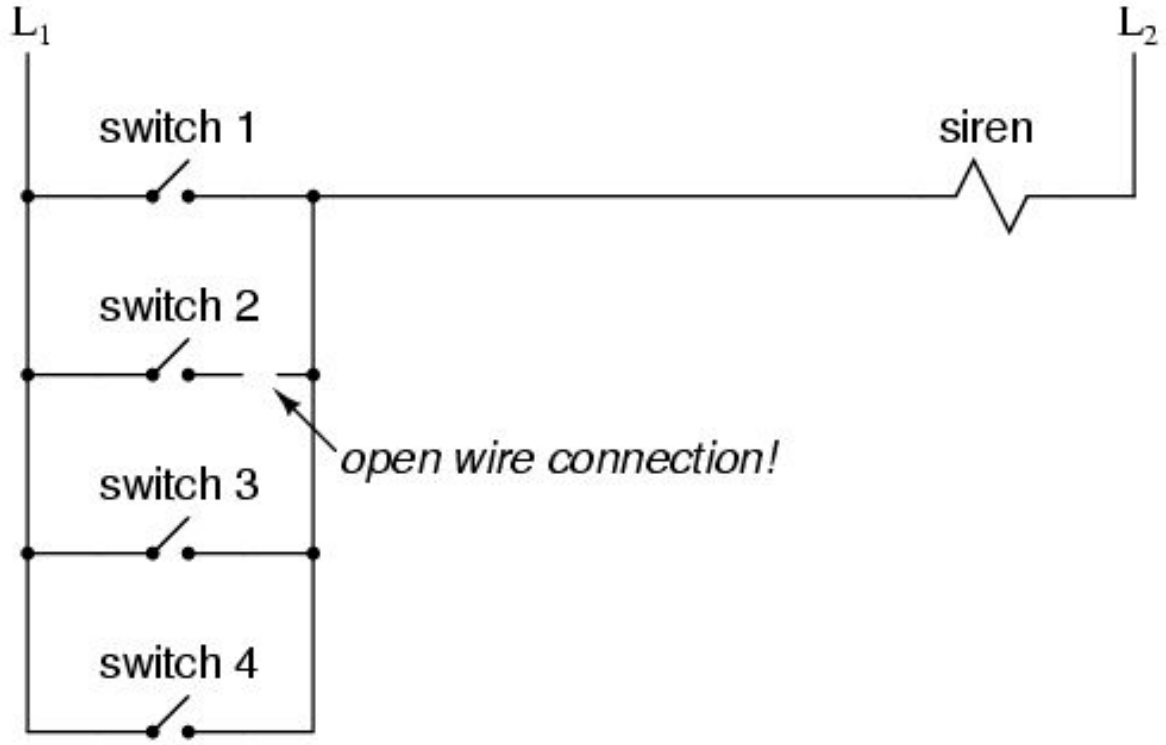

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Image: instrumentationtools.com

Failsafe Circuit

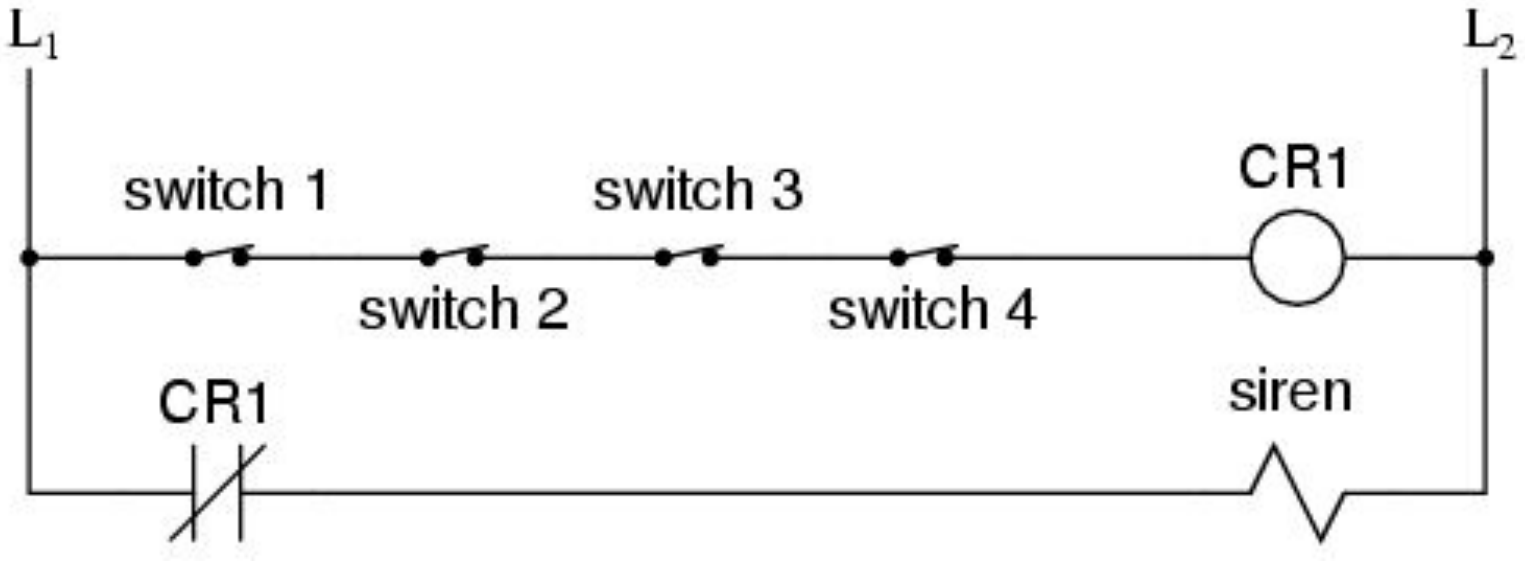

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Image: instrumentationtools.com

Motors

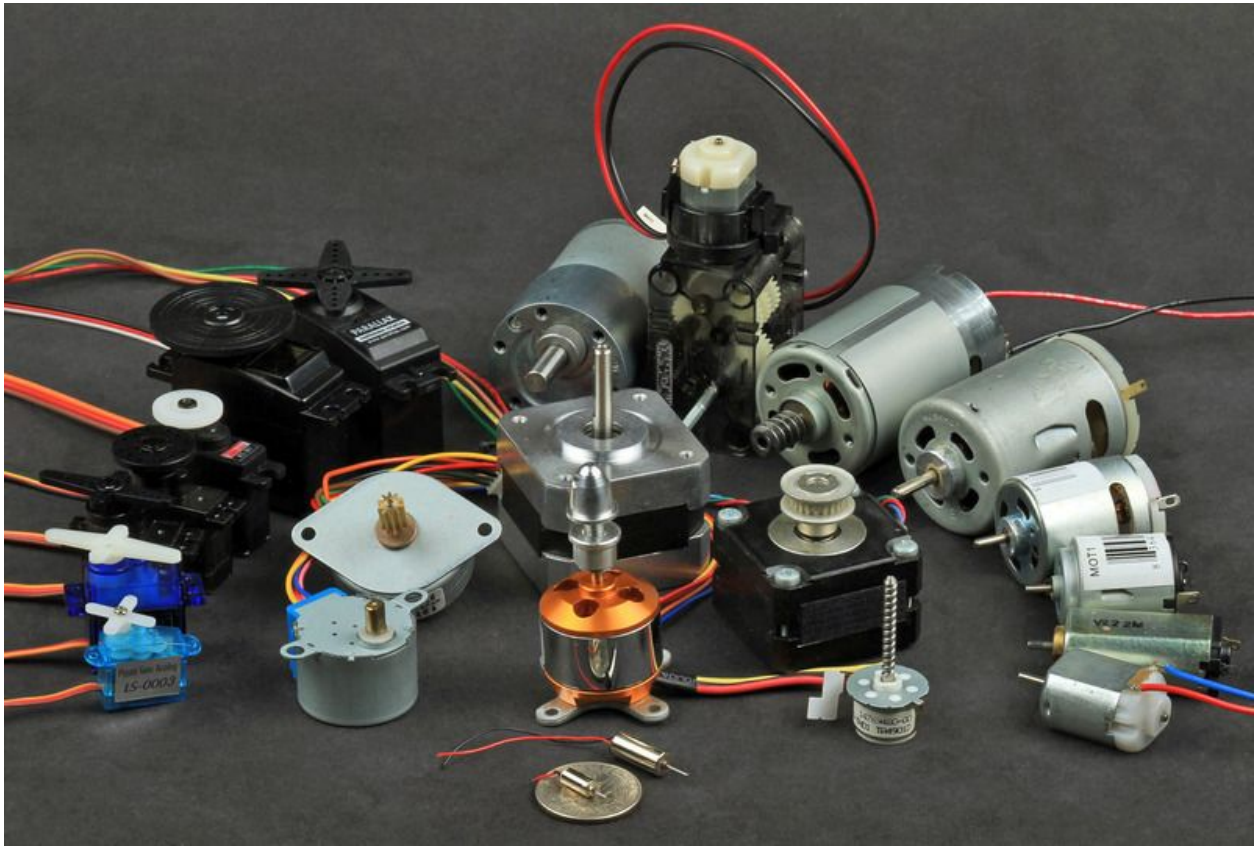

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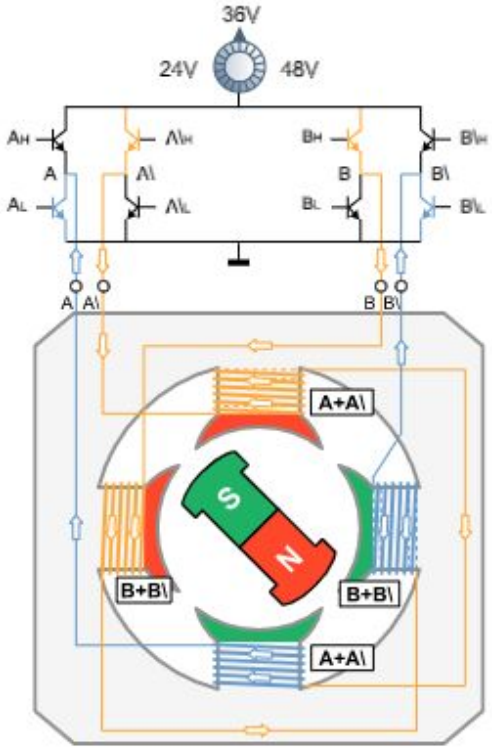
Image: Adafruit

Stepper motors work by moving a magnetic field electrically



4-lead bipolar control

4-lead motors are used in smaller motors to save space and in larger motors as the cost of wiring is lower. They cannot, therefore, be wired in serial, parallel or with one half of the winding according to the speed requirements as in the 6-lead and 8-lead versions.

Step operation								
F	0		1		2		3	
H	0	1	2	3	4	5	6	7
A_H $A\backslash_L$	1	0	0	0	0	0	1	1
B_H $B\backslash_L$	1	1	1	0	0	0	0	0
$A\backslash_H$ A_L	0	0	1	1	1	0	0	0
$B\backslash_H$ B_L	0	0	0	0	1	1	1	0
dez	12	4	6	2	3	1	9	8

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Image: https://us.nanotec.com/knowledge-base/stepper-motor-animation#

Wire

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Image: Simkan Cable

Connectors







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Image: Wikipedia, topflitecomponents, EBay, Amphenol, renhotecrf

Impedance is really “AC resistance”

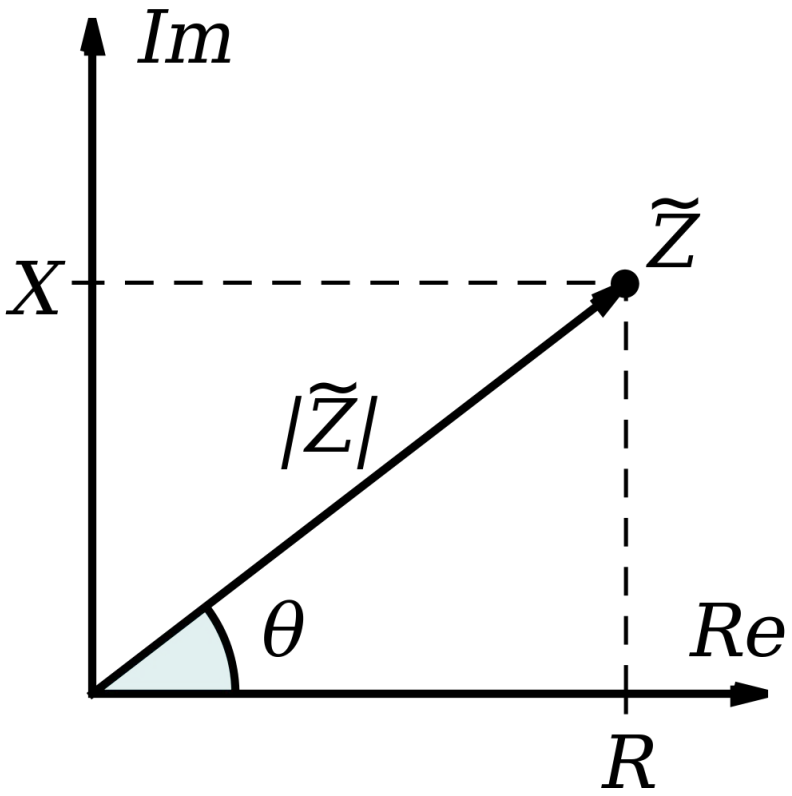

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Image: Wikipedia

Input impedance tells us how much load a system puts on the DUT

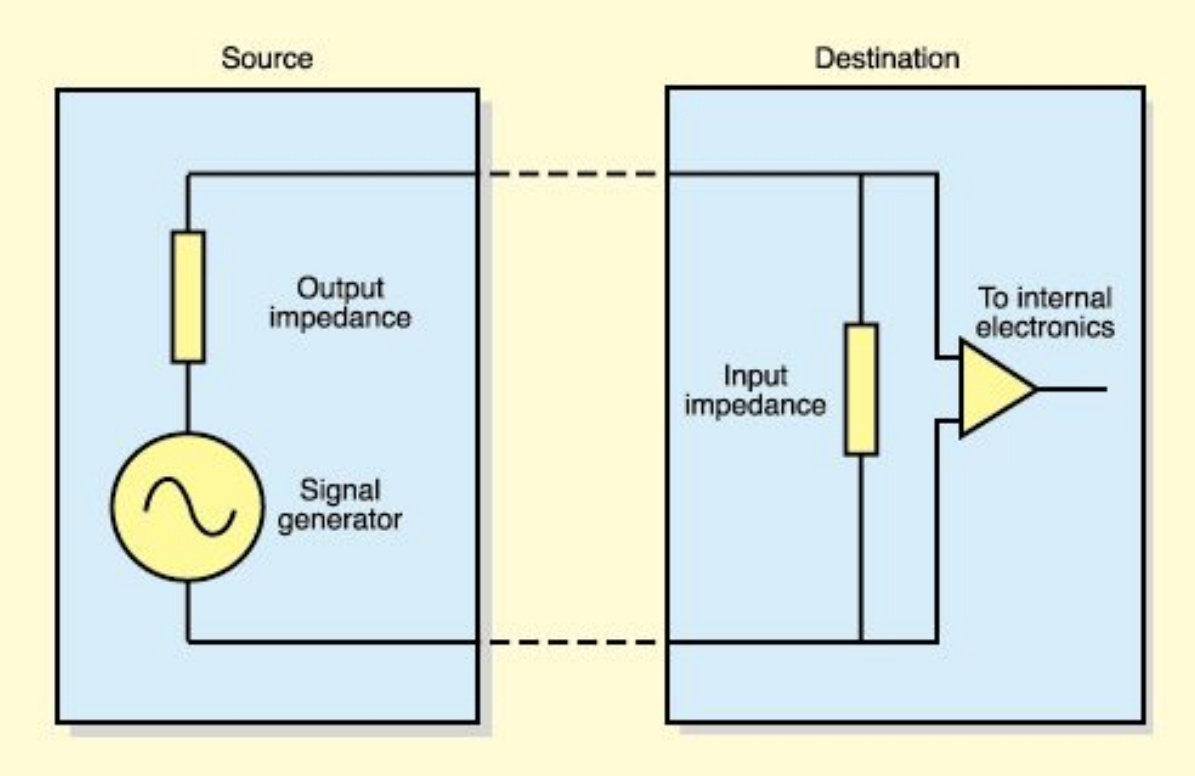

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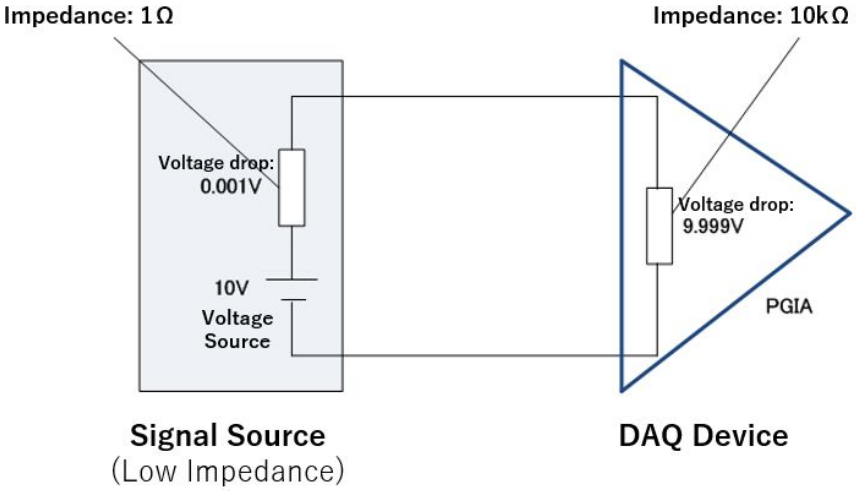
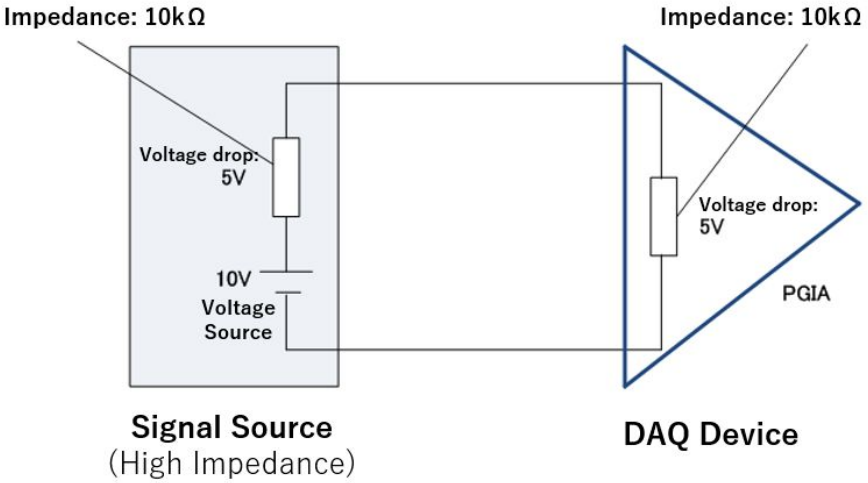
Image: Sound On Sound

Mismatched impedance can cause puzzling behavior





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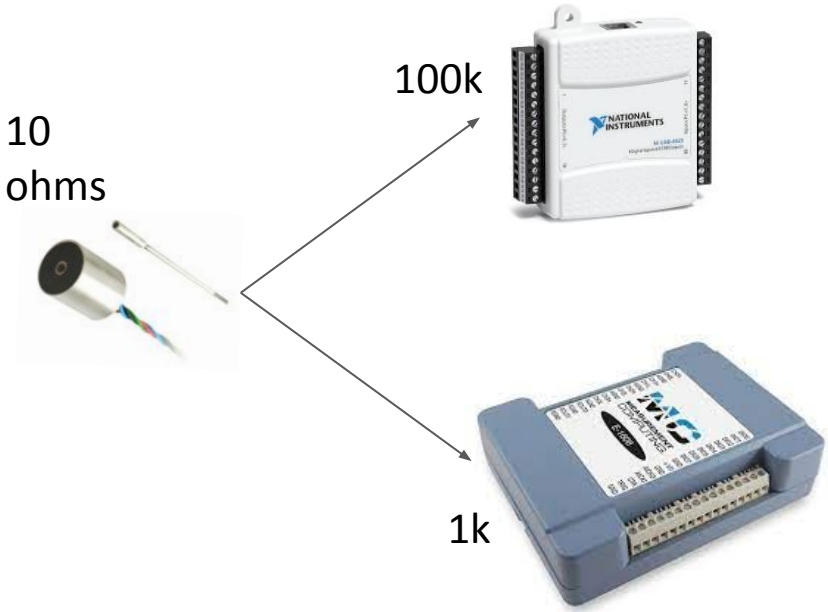
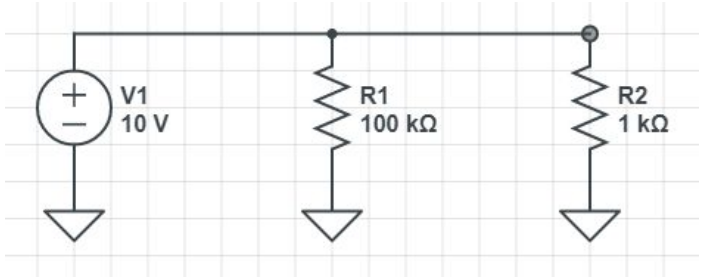
Images: National Instruments

This can also be a factor when connecting two DAQ systems





Rtotal = 990 ohms!

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Image: TransTek, National Instruments, MCCDAQ

Let’s analyze a real schematic and talk about how to analyze it