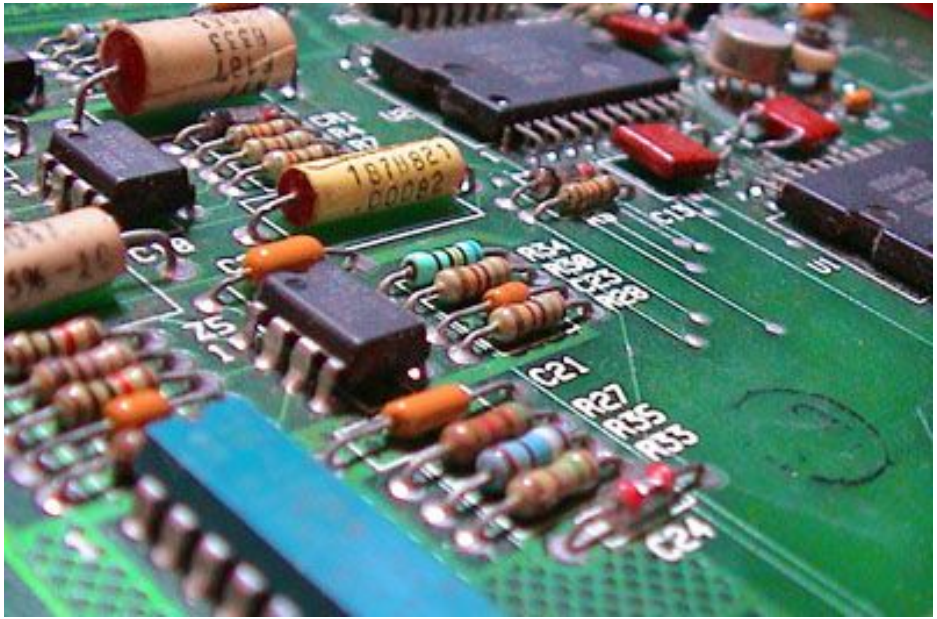

Test Equipment and Electricity Basics

John R. Leeman

GEARS 2022

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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

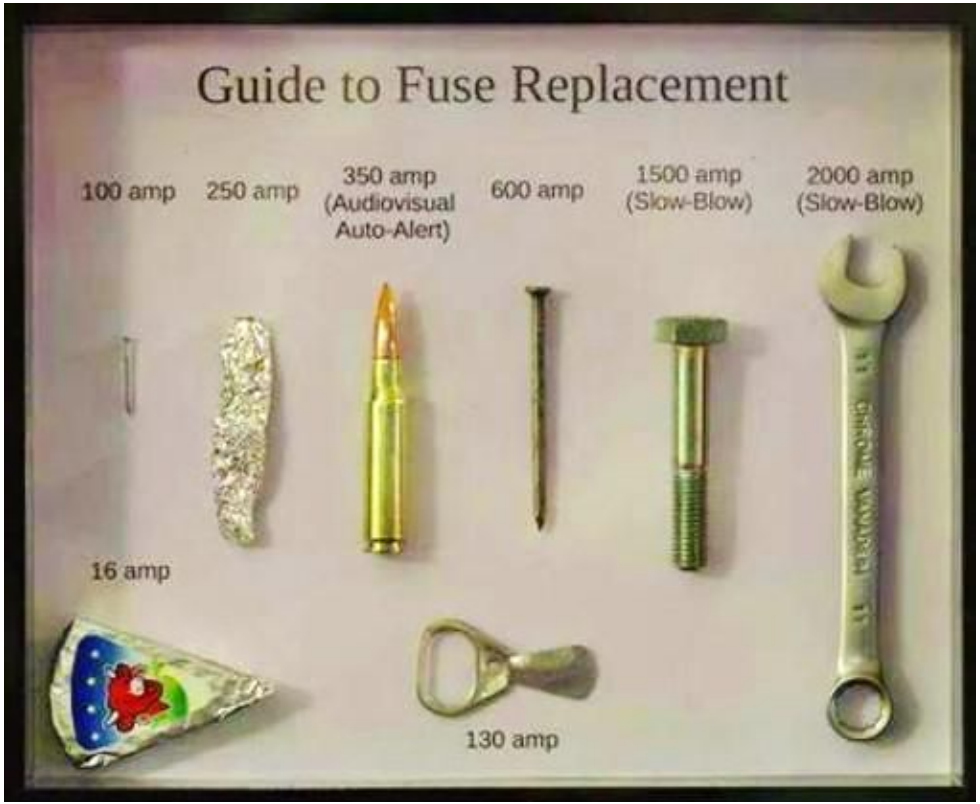

Image: Twitter

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

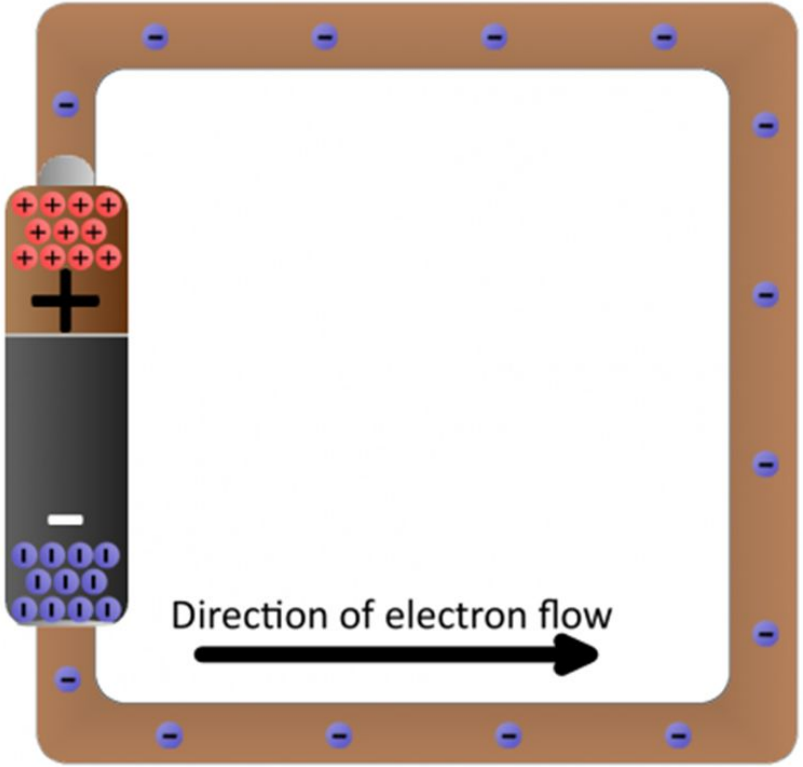

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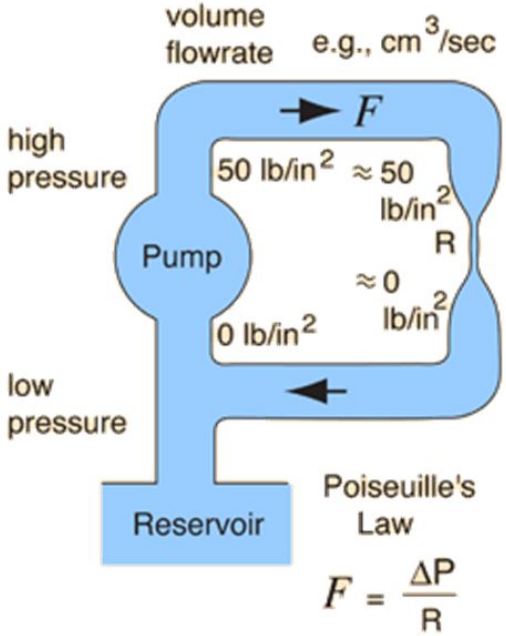
Image: Sparkfun

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



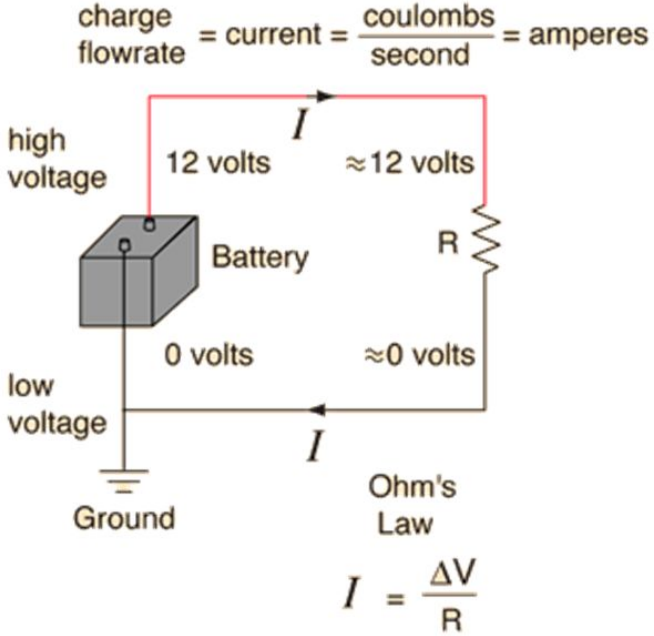


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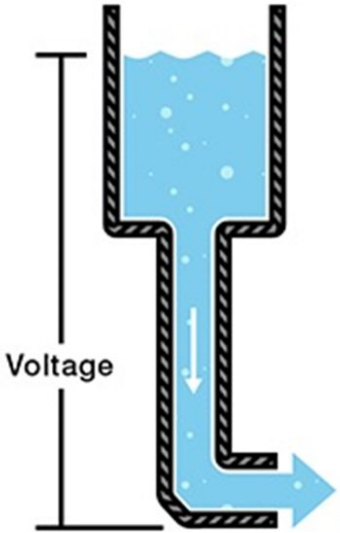
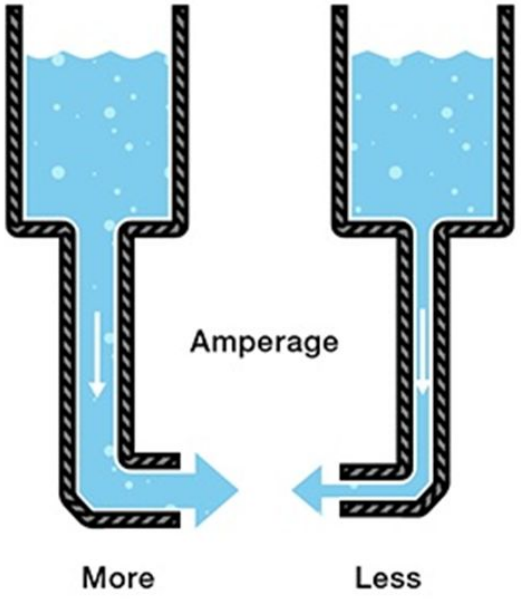
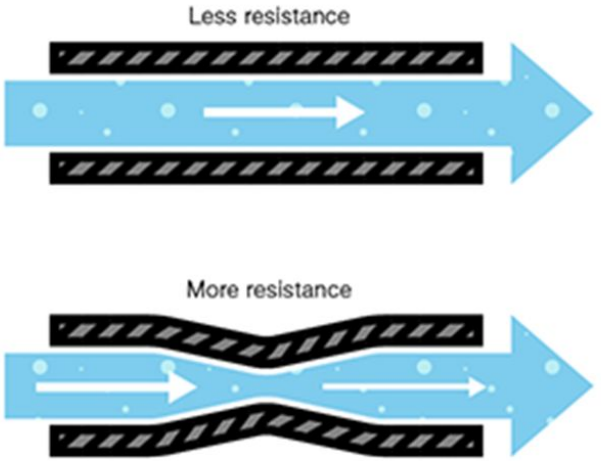
Image: Hyperphysics

We can use the water analogy for a bit longer







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Images: Sparkfun

Ohm’s Law relates all of these quantities

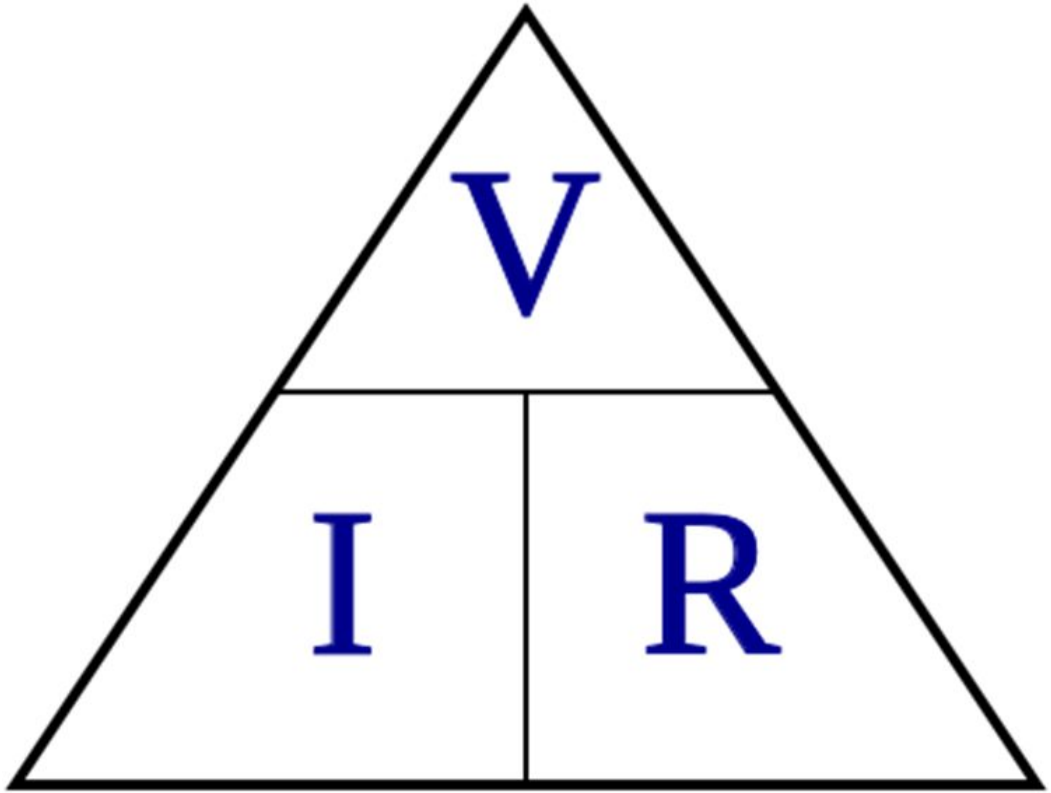

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Image: Wikipedia

Ohm's Law relates all of these quantities

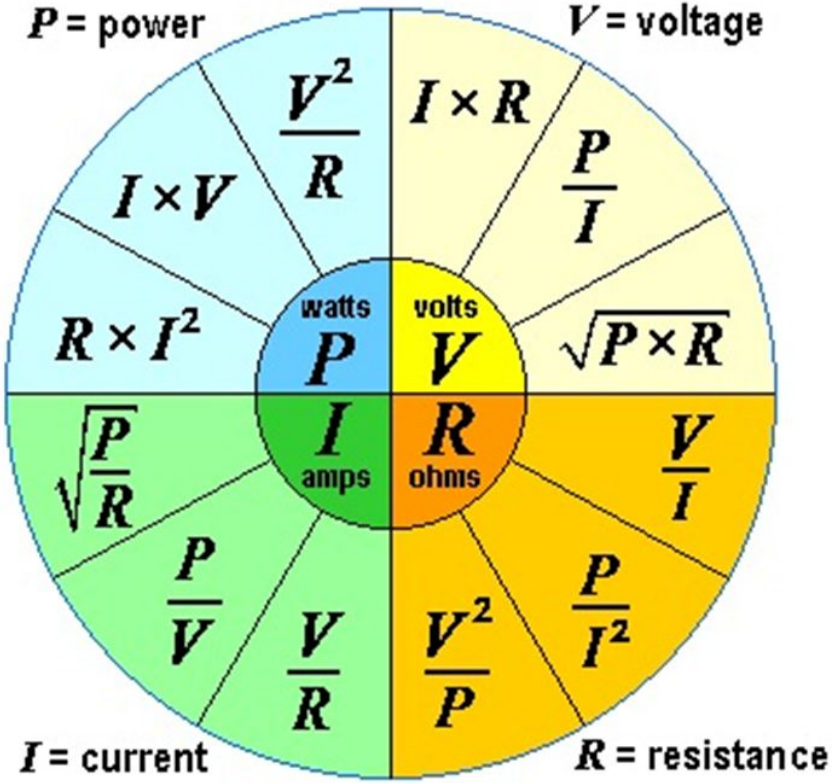

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Image: sengpielaudio.com

Let’s apply Ohm’s law to a few systems

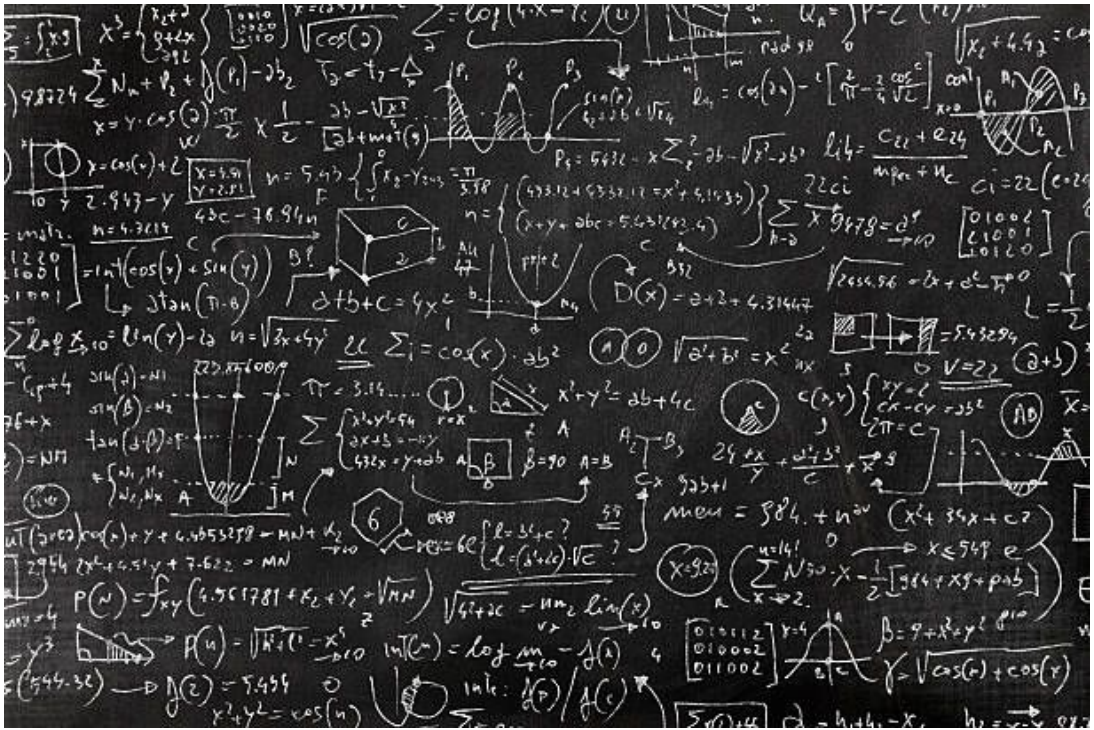

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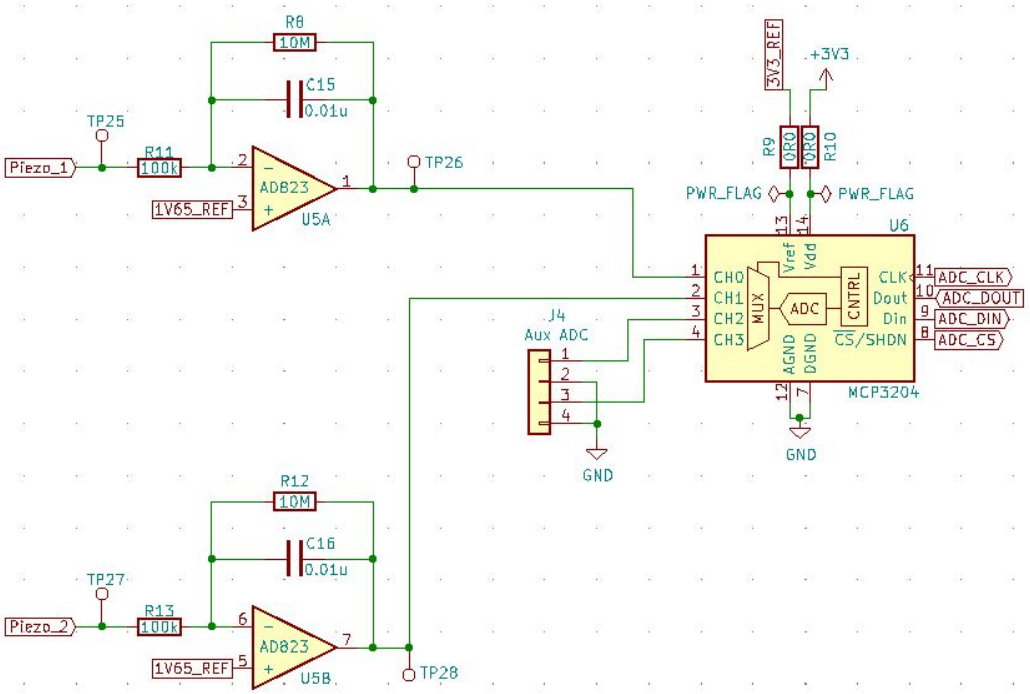
Image: iStock

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



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The symbols are “standard” for many components

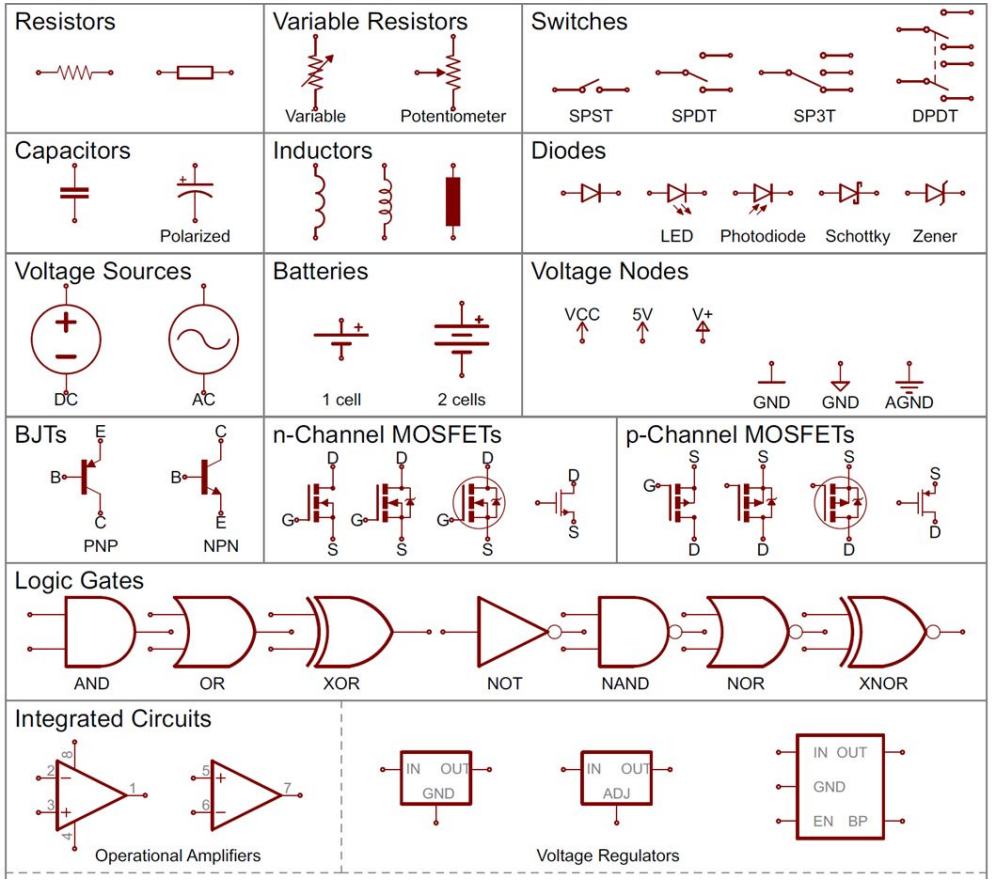


Image: Sparkfun

Junctions mark there connections are made

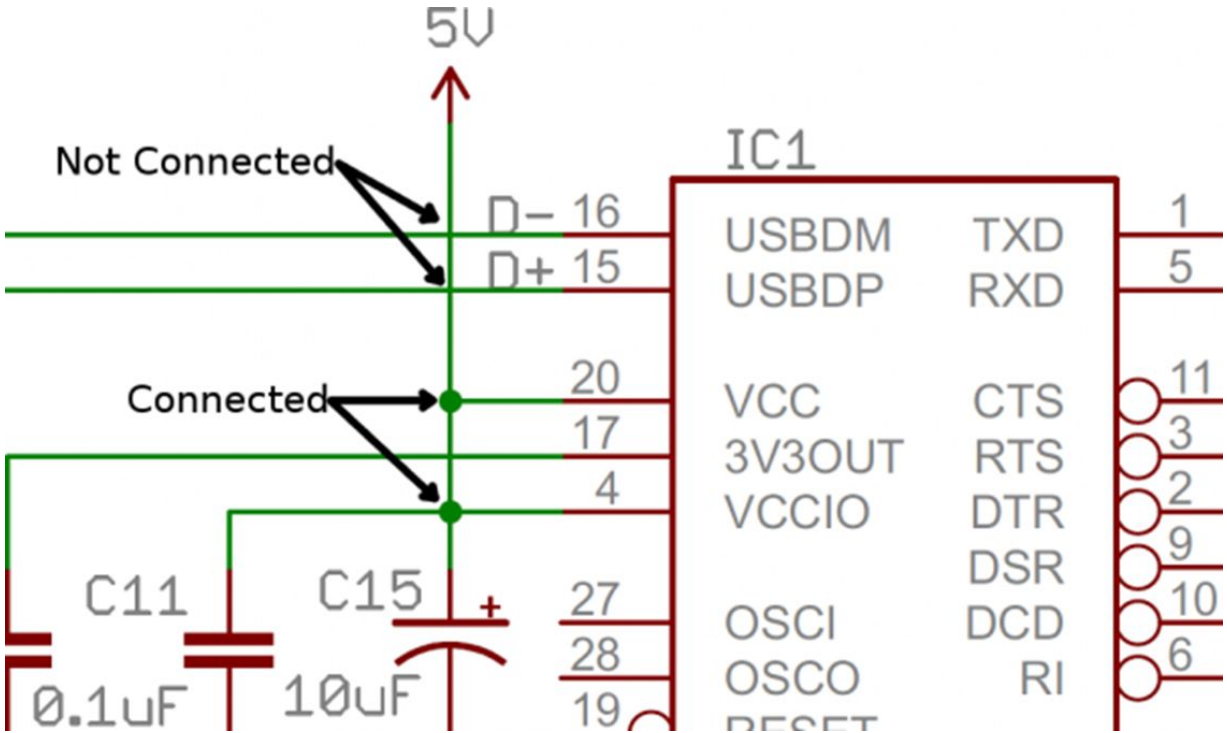


Image: Sparkfun

We also use net name labels to reduce schematic clutter

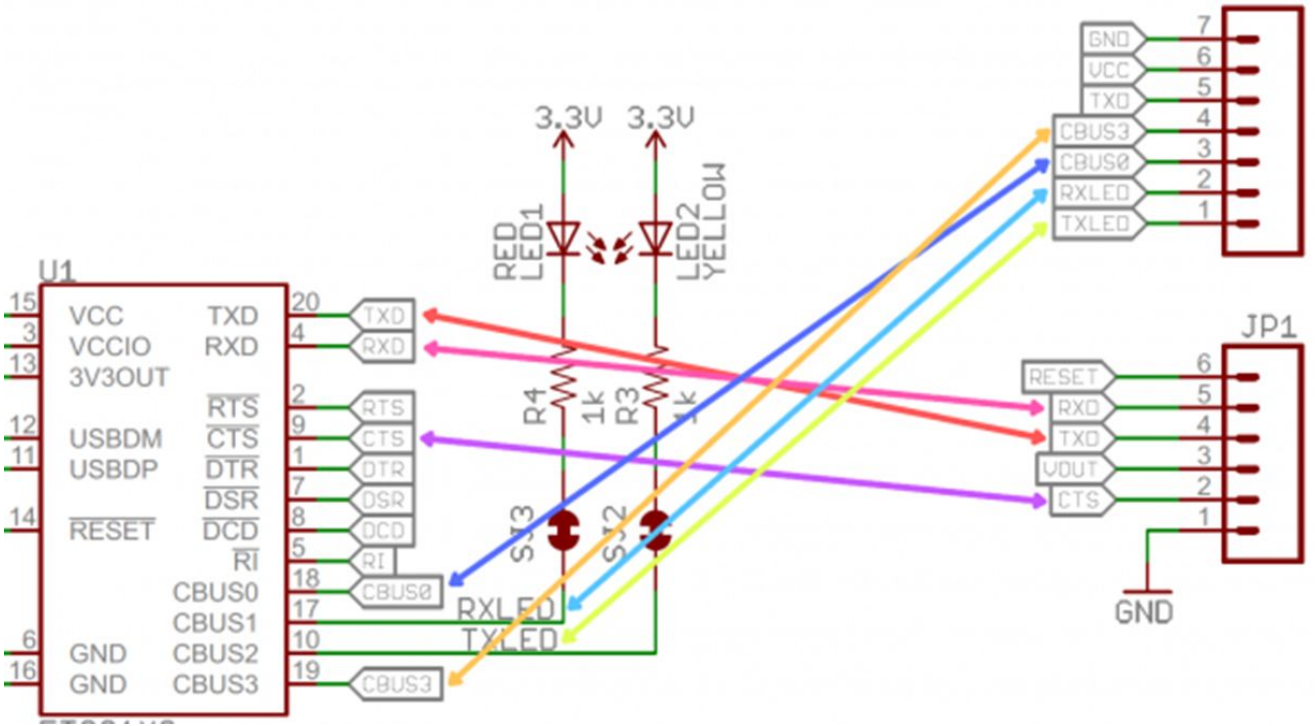
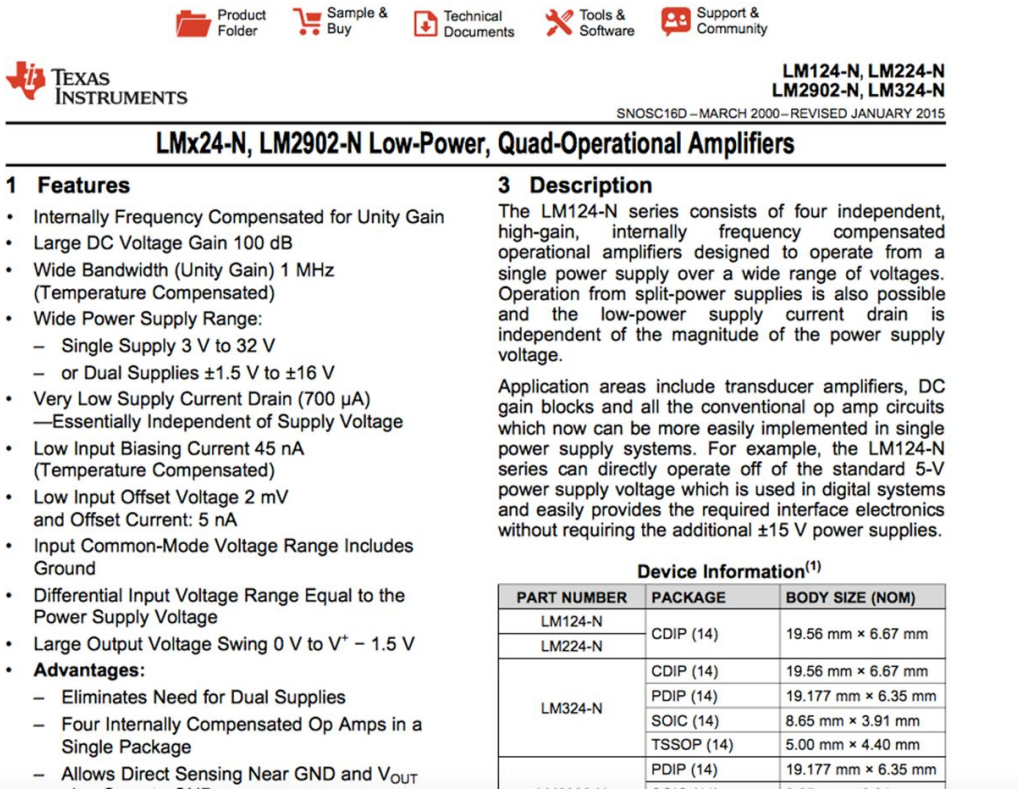


Image: Sparkfun

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



Product Folder | Sample & Buy | Technical Documents | Tools & Software | Support & Community

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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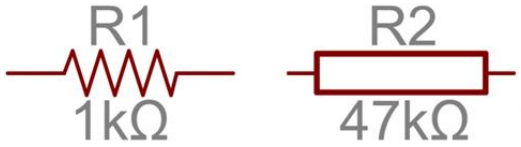
Resistors



Images: Sparkfun

There are common values, we recommend 1% or better

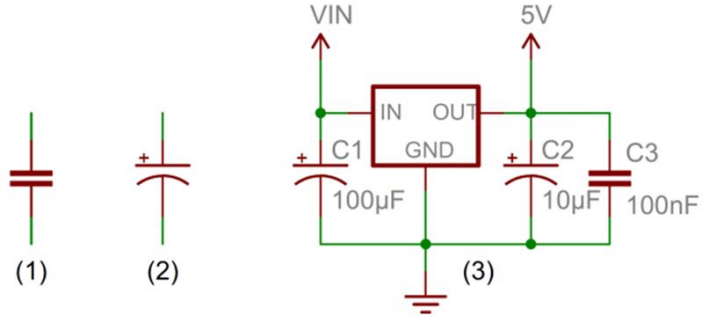
	Colour	Band 1 First digit	Band 2 Second digit	Band 3 Multiplier	Band 4 Tolerance
	Black	0	0	x 1 (x 1)	-
	Brown	1	1	x 10 (x 10)	1%
	Red	2	2	x 100 (x 100)	2%
	Orange	3	3	x 1 000 (x 1k)	not used
	Yellow	4	4	x 10 000 (x 10k)	not used
	Green	5	5	x 100 000 (x 100k)	not used
	Blue	6	6	x 1 000 000 (x 1M)	not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

Capacitors



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Images: Sparkfun

Inductors

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Image: embeddedmicro.com

Diodes

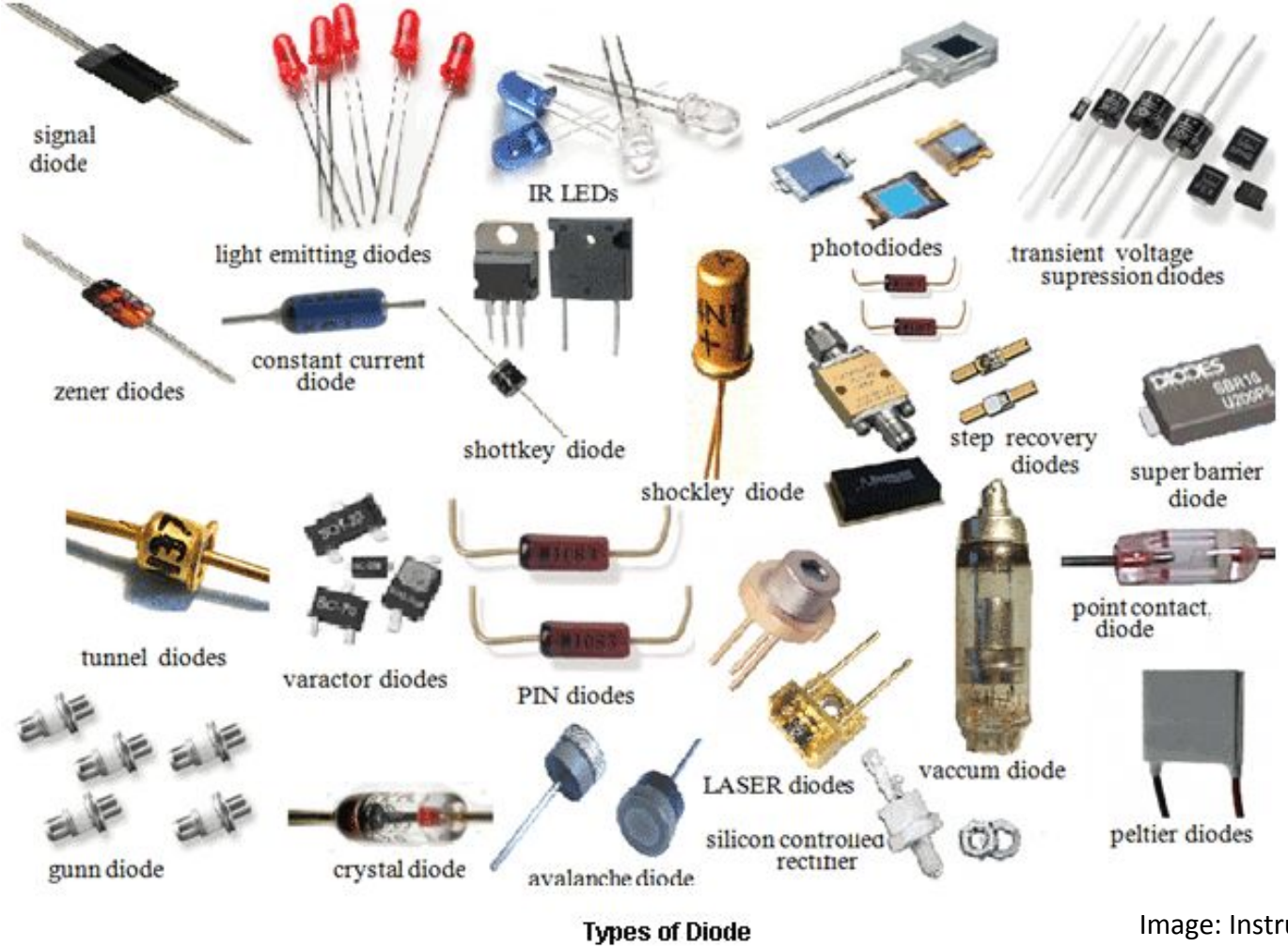

Image: Instructables

Switches

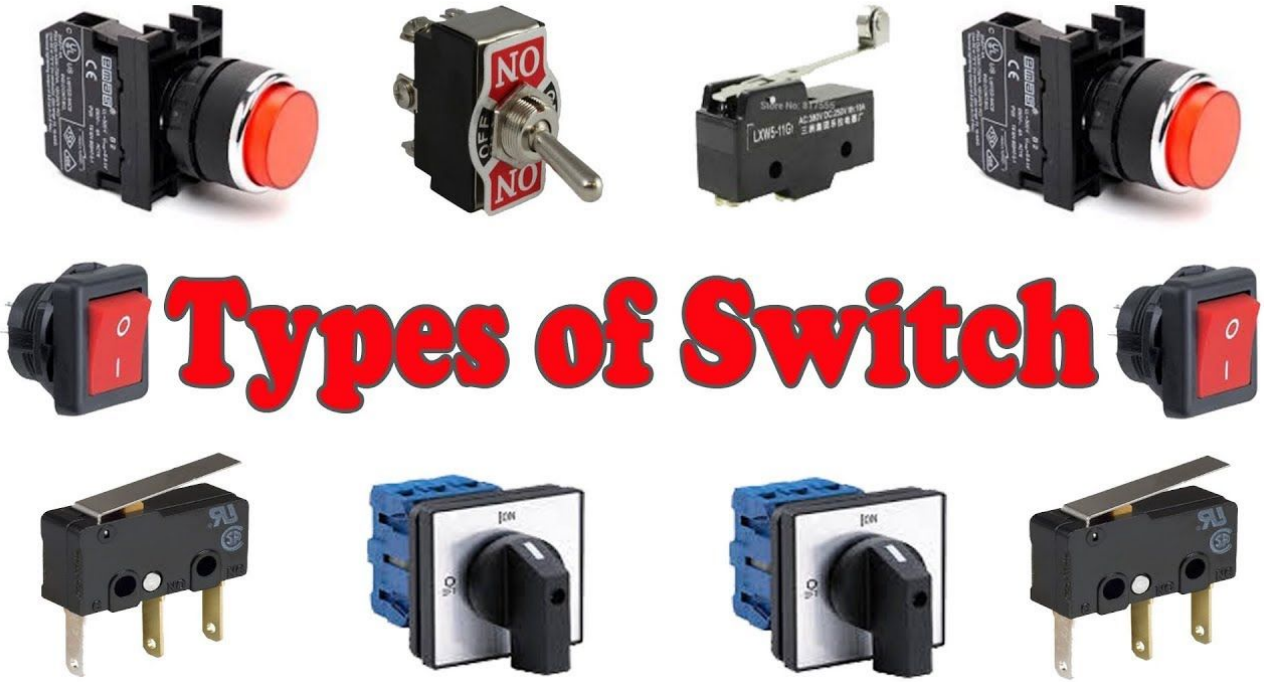

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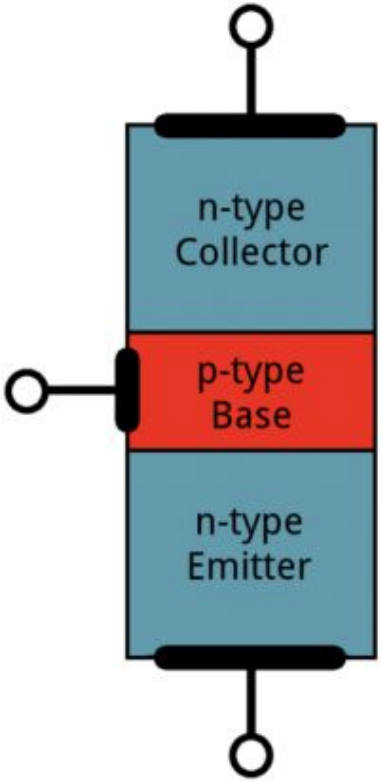
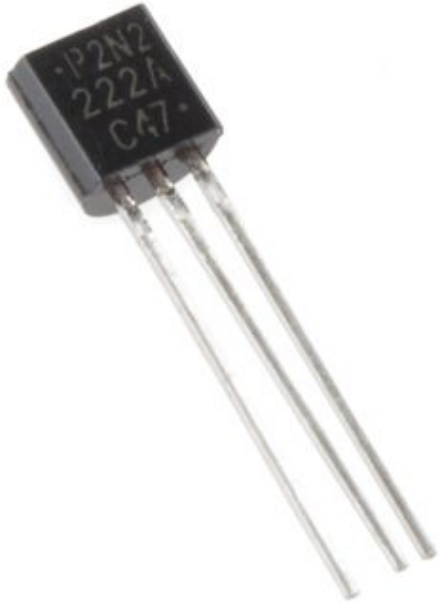
Image: Learning Engineering

Transistors





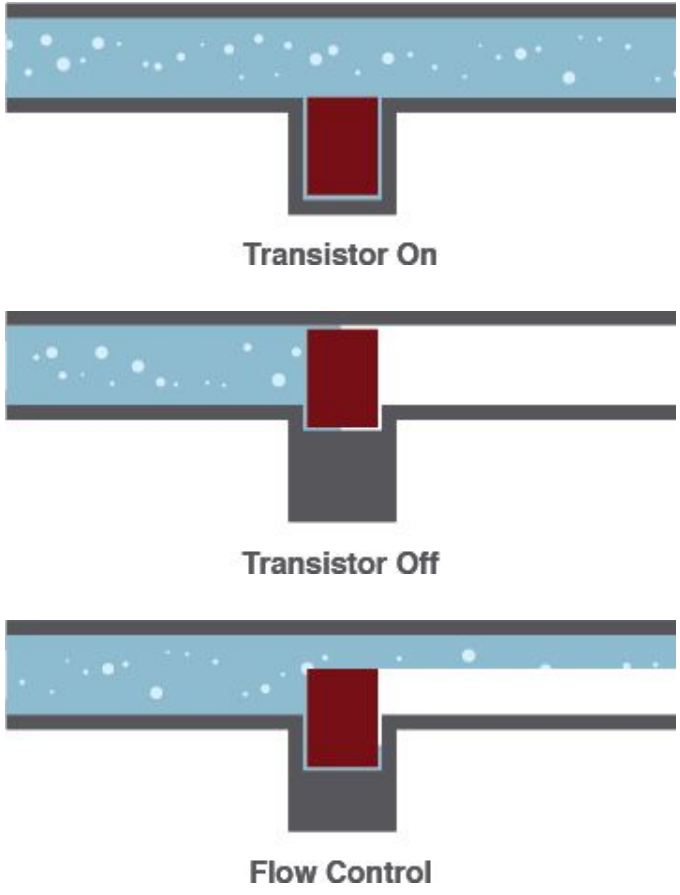


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Image: Sparkfun

Transistors can be operated in different modes

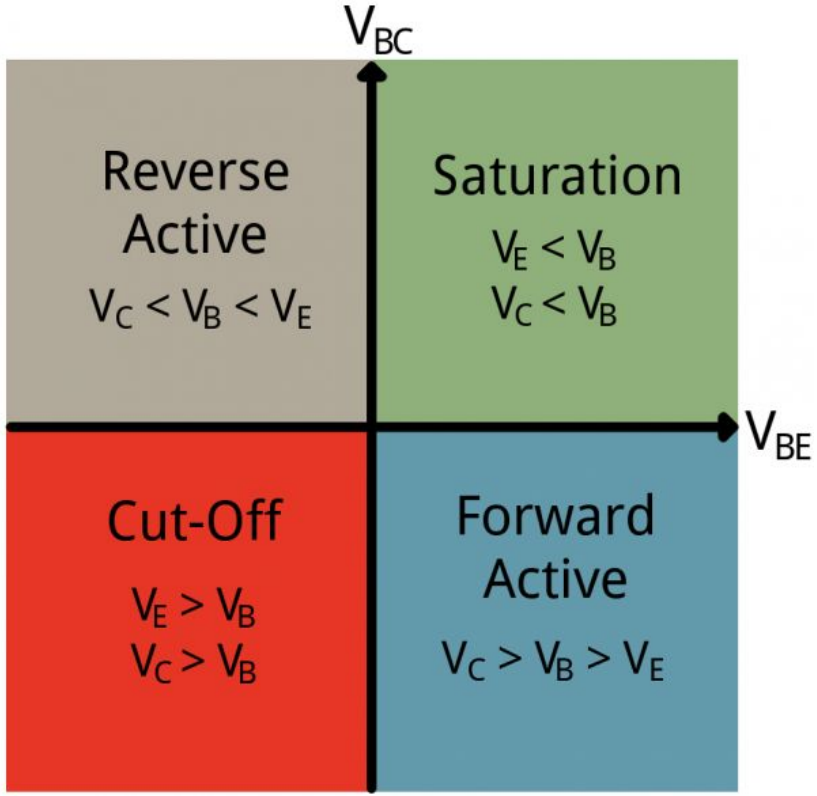

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Image: Sparkfun

Transistors as a switch

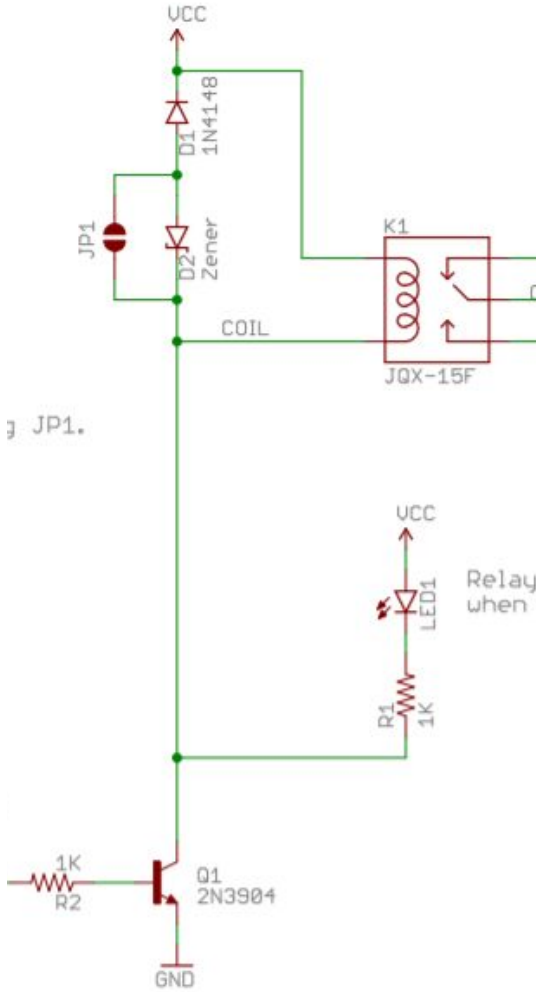

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Image: Sparkfun

FETs

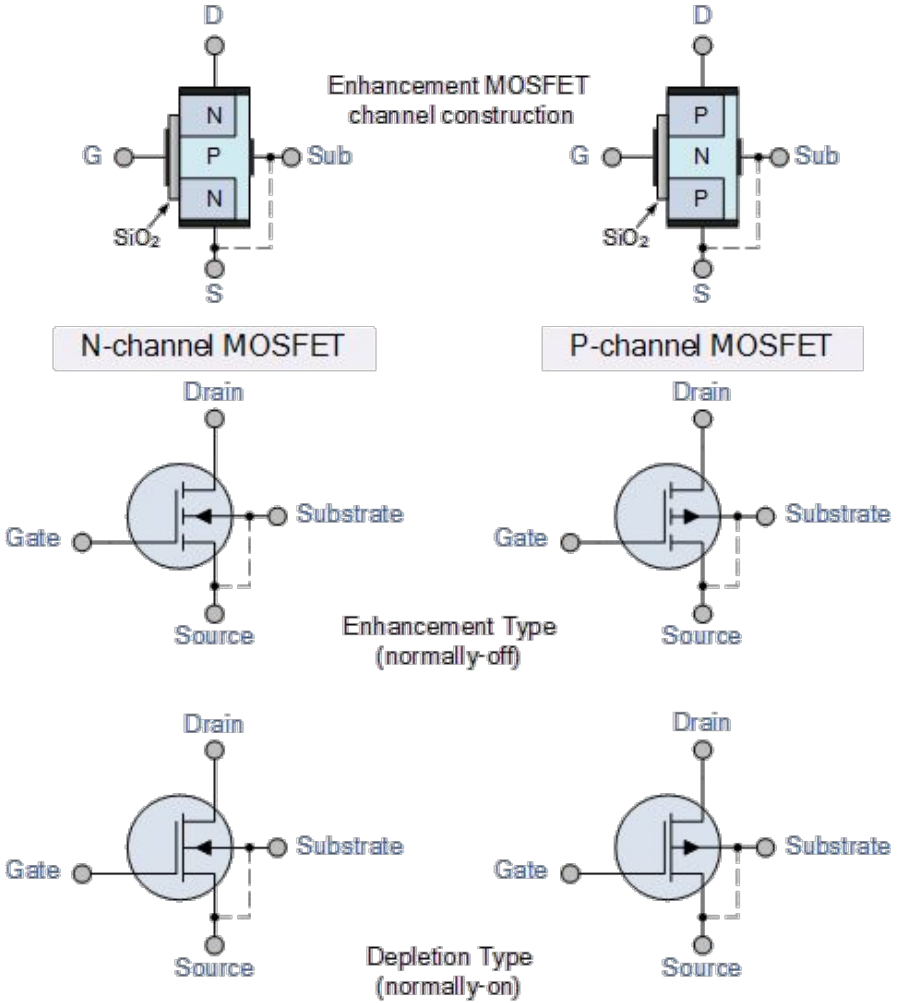

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Image: Electronics Tutorials

Voltage Regulation

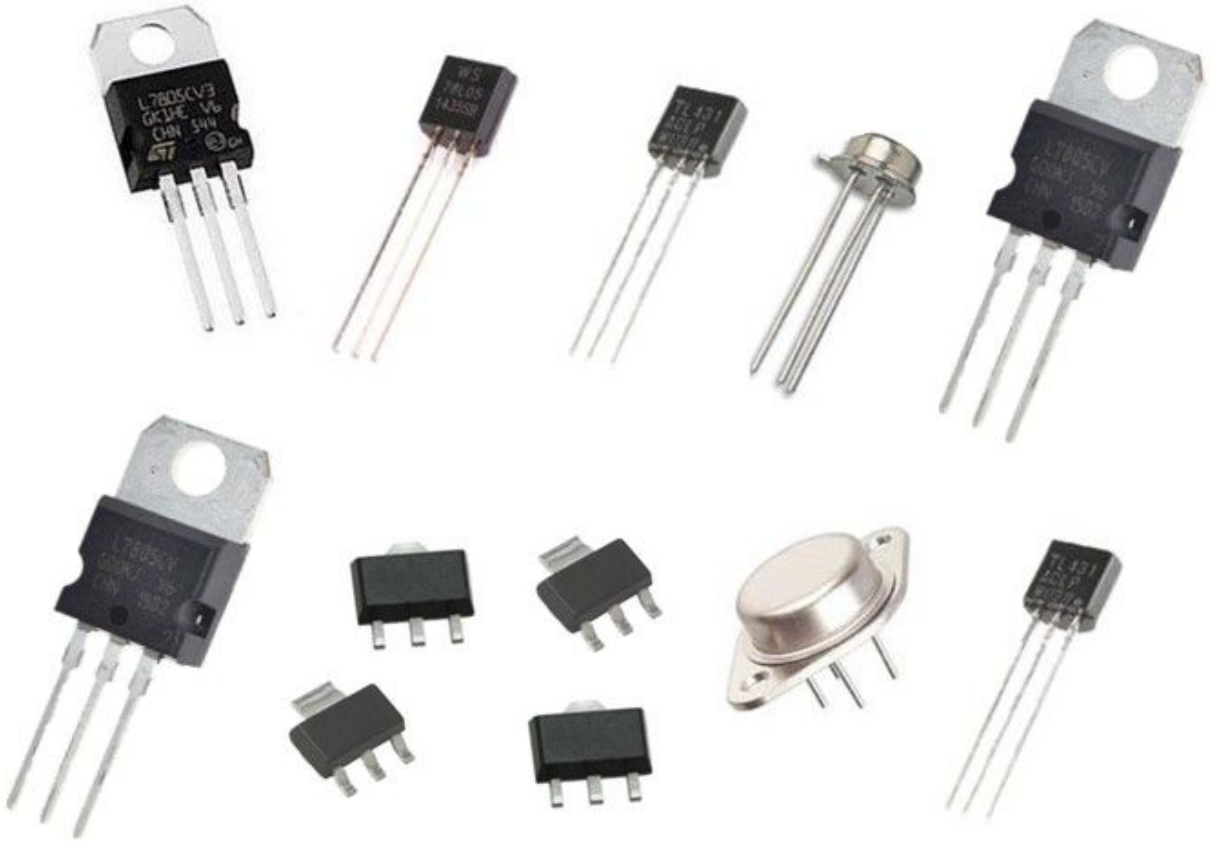

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Image: Components 101

Motors

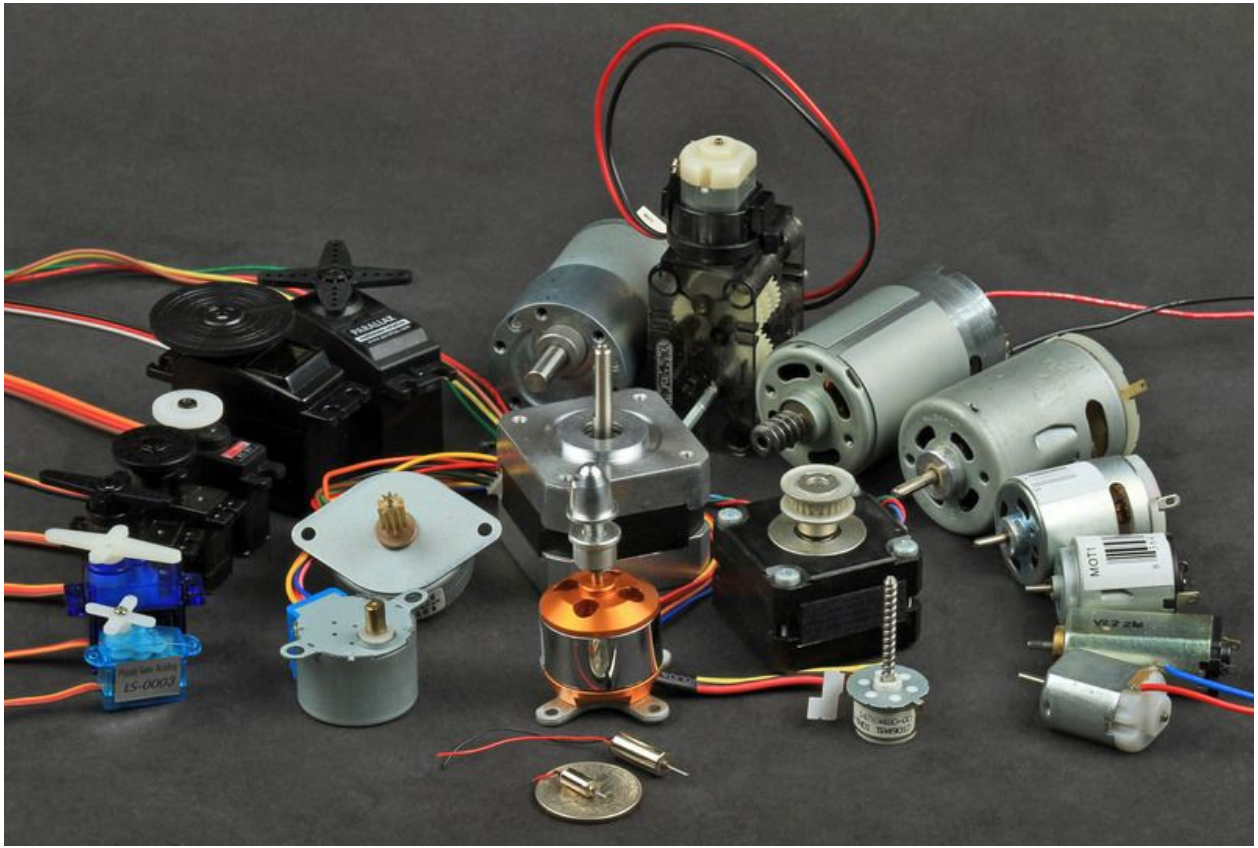

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Image: Adafruit

Wire

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Image: Simkan Cable

Connectors







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Image: Wikipedia, topflitecomponents, EBay, Amphenol, renhotecrf

Start/Stop Circuit

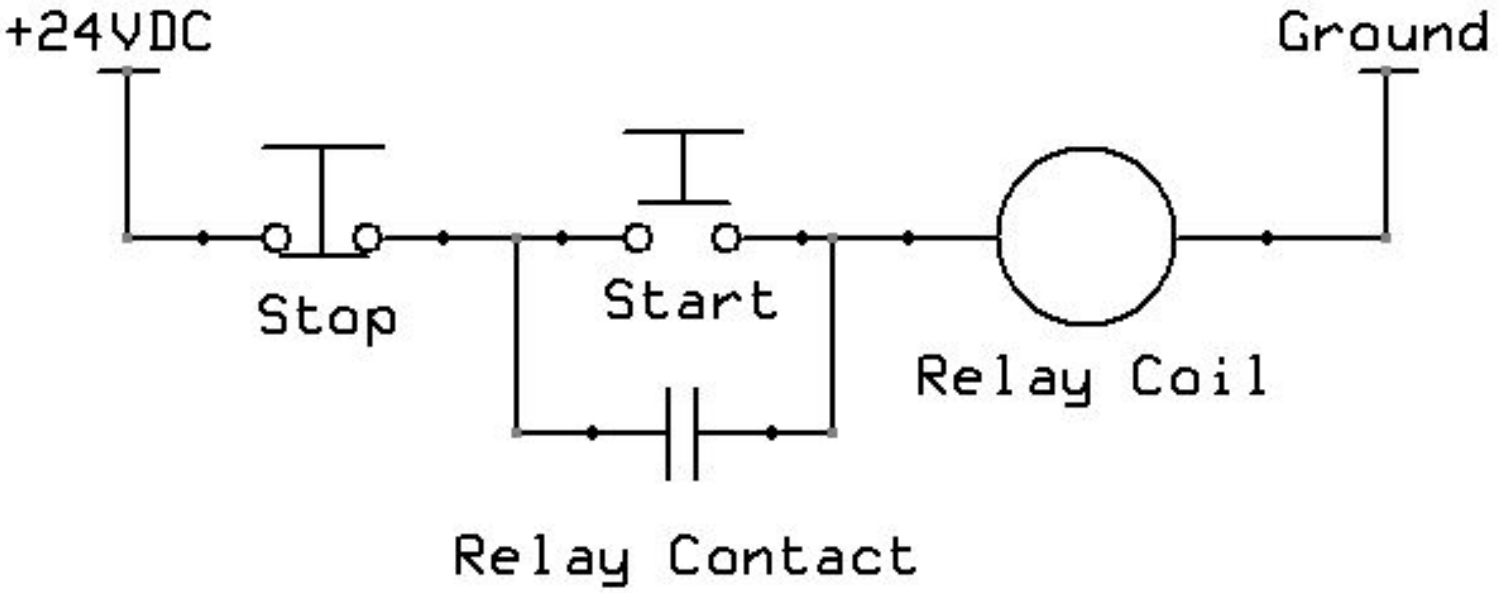

Image: drstienecker.com

Failsafe Circuit

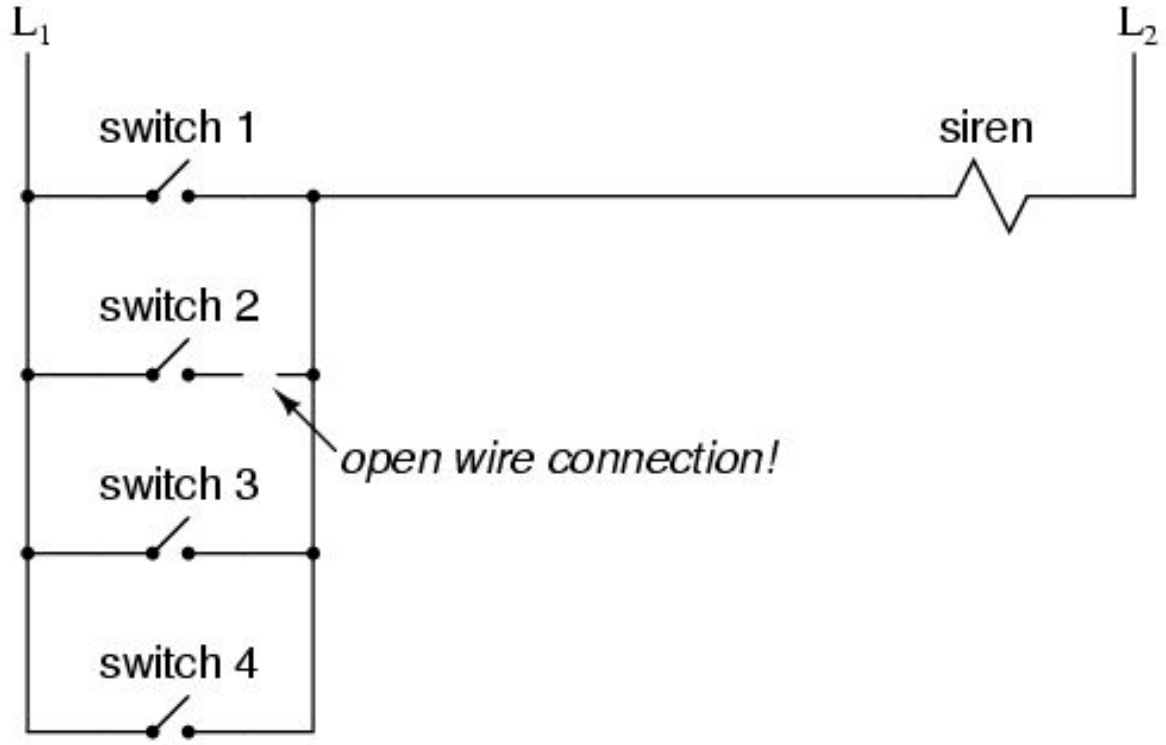

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Image: instrumentationtools.com

Failsafe Circuit

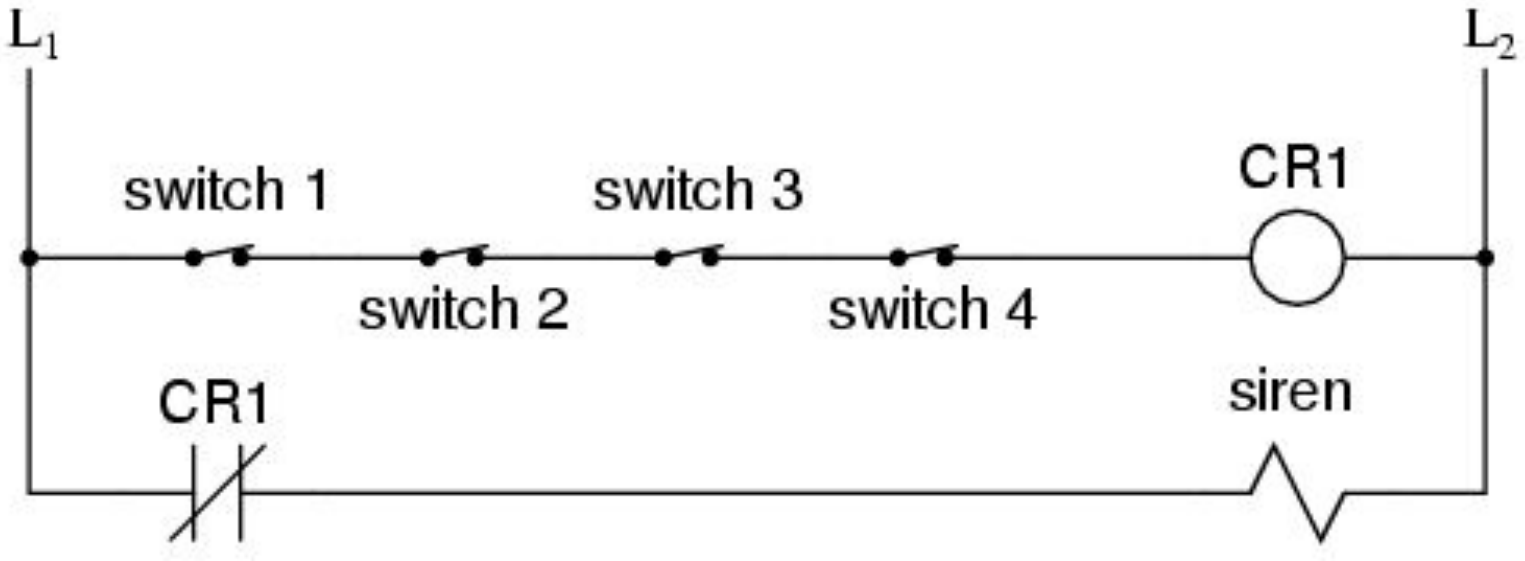

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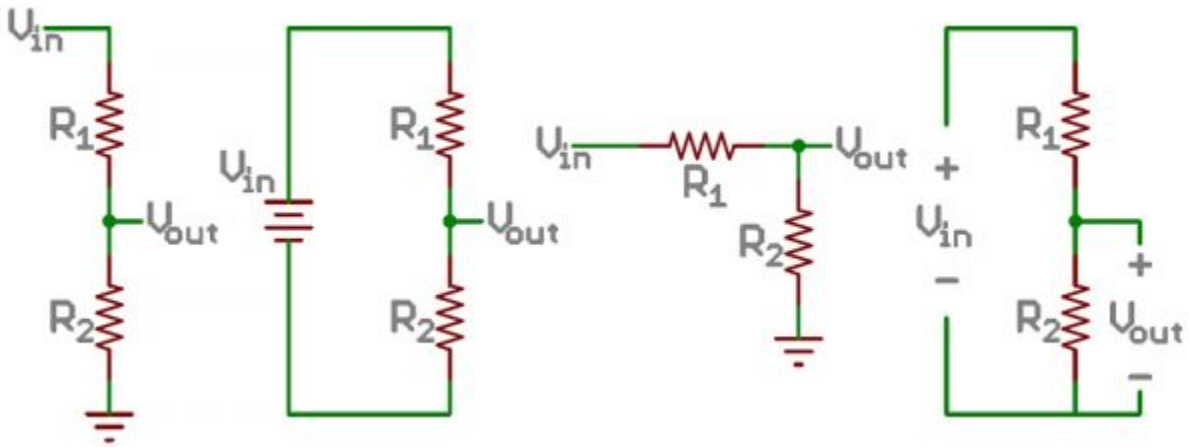
Image: instrumentationtools.com

Voltage dividers are a building block you'll find over and over



$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

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Common Equipment

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Images: Test Equipment Depot, tequipment.net, Tektronix

The DMM is your best friend and a good one can be had for about $50

Roll over image to zoom in

Extech EX330 Autoranging Mini Multimeter with NCV and Type K Temperature, orange and green

Brand: Extech

824 ratings

-8% $54.99

List Price: $59.99

prime

& FREE Returns

or 3 monthly payments of $18.33

Get 5% back ($2.74 in rewards) on the amount charged to your Amazon Prime Rewards Visa Signature Card.

May be available at a lower price from other sellers, potentially without free Prime shipping.

Size: **Autorange Multimeter with Thermometer**

Autorange Multimeter with Thermometer $54.99 prime	Electrical TRMS Multimeter $109.99 prime
Manual Range Multimeter $34.22 prime	Standard Autorange Multimeter 1 option from $182.80

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Images: Amazon

You can go as crazy as you want depending upon the features you need

Roll over image to zoom in

Fluke 117 Digital Multimeter, Non-Contact AC Voltage Detection, Measures Resistance/Continuity/Frequency/Capacitance/Min Max Average, Automatic AC/DC Voltage Selection, Low Impedance Mode

Visit the Fluke Store

3,299 ratings

Amazon's Choice for "fluke meter"

-10% $239.99

List Price: $265.99

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You can get up to **4% off** on Amazon Business — and this past year, you would have **saved** $116.63. Sign up, it's free. More details.

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May be available at a lower price from other sellers, potentially without free Prime shipping.

Enhance your purchase

Payment plans

From $40.00/mo (6 mo) with 0% APR

Roll over image to zoom in

Fluke 289 True-RMS Stand Alone Logging Multimeter

Visit the Fluke Store

127 ratings | 19 answered questions

Amazon's Choice for "fluke 289"

-12% $715.57

List Price: $809.99

prime

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May be available at a lower price from other sellers, potentially without free Prime shipping.

Style:

Fluke 289 True-RMS Logging Multimeter

Brand	Fluke
Power Source	Corded Electric
Style	Fluke 289 True-RMS Logging Multimeter
Item Weight	1.92 Pounds
Item Dimensions LxWxH	0.24 x 0.4 x 0.87 inches

Roll over image to zoom in

Fluke 87V Digital Multimeter with a NIST-Traceable Calibration Certificate with Data

Visit the Fluke Store

42 ratings | 5 answered questions

Amazon's Choice for "fluke 87v"

$552.00

prime

& FREE Returns

Pay ~~$552.00~~ $412.43 after using available Amazon Rewards Visa Card Points.

May be available at a lower price from other sellers, potentially without free Prime shipping.

Enhance your purchase

Payment plans

From $30.67/mo (18 mo) with 0% APR

Brand	Fluke
Style	Fluke 87-V Multimeter w/ NIST Certificate
Measurement Type	Multimeter

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Images: Amazon

Never use these cheap meters or connect to AC unless you know what you are doing - and even then avoid cheap meters!

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YT Channel: DiodesGoneWild

Meter functions are marked with symbols on a dial or in a menu

Symbol	Meaning
V ⎓	V DC
V ∿	V AC
mV	millivolts (.001V or 1/1,000V)
A	Amps
mA	milliamps (.001A or 1/1000A)
µA	microA (.000001A or 1/1,000,000A)
Ω	Resistance (Ohms)
k Ω , M Ω	kilo-Ohms, Megohms
))))	Continuity beeper

Symbol	Meaning
⊣⊢	Capacitance (uF: Microfarads) (nF: Nanofarads)
⊣▶⊢	Diode test
Hz	Hertz (cycles/sec)
REL Δ	Relative or offset reading
Range	Manual override of autorange
Hold H	Touch Hold-last stable reading
MIN MAX	Highest, lowest recorded readings
ϟ	Dangerous voltage levels
⚠	Caution: see manual

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Images: Fluke

Voltage measurement is the most common task

- Select correct voltage function (AC/DC)
- Plug black probe into COM jack and red into V jack
- Select highest range if the meter is not autoranging
- Touch probes across DUT in parallel to the voltage to be measured

Image: electrical-engineering-portal.com

Resistance Measurement

- Select the resistance function
- Plug black probe into COM jack and red into Ohms jack
- Touch probes across resistance to be measured, watch the units!
- OL is open circuit
- Continuity beeper function is great!

Image: electrical-engineering-portal.com

Current measurements require a different hookup structure

- Select the current function (AC or DC), use mA for small currents
- Ensure the circuit is powered off and break the circuit
- Insert the probes in series at the circuit break
- Plug black probe into COM jack and red into correct current jack
- Power the circuit

Image: electrical-engineering-portal.com

Pay attention to the mA/A connector - you may even need a current clamp device for higher current measurements

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Images: Fluke

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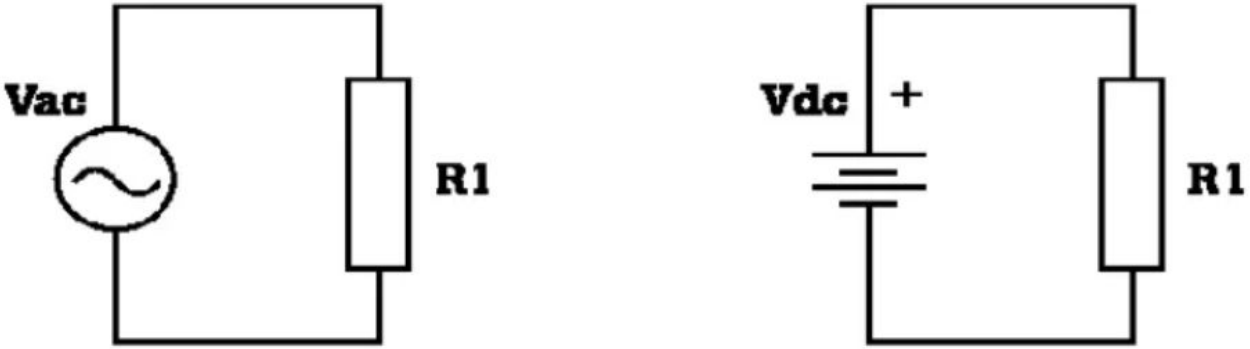
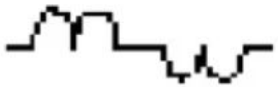
What is RMS and why you do or don't need it



Power consumed in R1 is same for both AC and DC source if the Vac_{RMS} = Vdc.

Images: Fluke

When would you need an RMS meter?

Multimeter Type	Average	True RMS
 Response to sine wave	Correct	Correct
 Response to square wave	10% High	Correct
 Response to single phase diode rectifier	40% low	Correct
 Response to 3 phase diode rectifier	5-30% low	Correct

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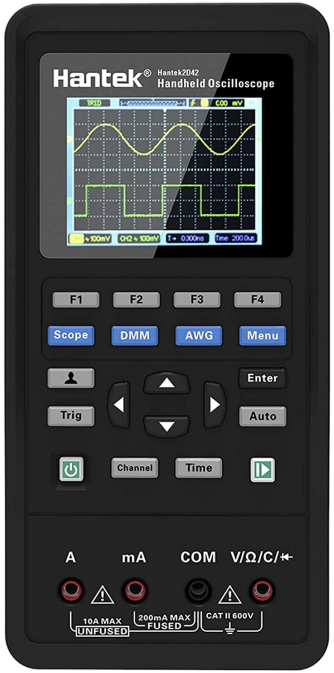
Images: Fluke

Oscilloscopes are the second most used tool and are available at many price points and form factors



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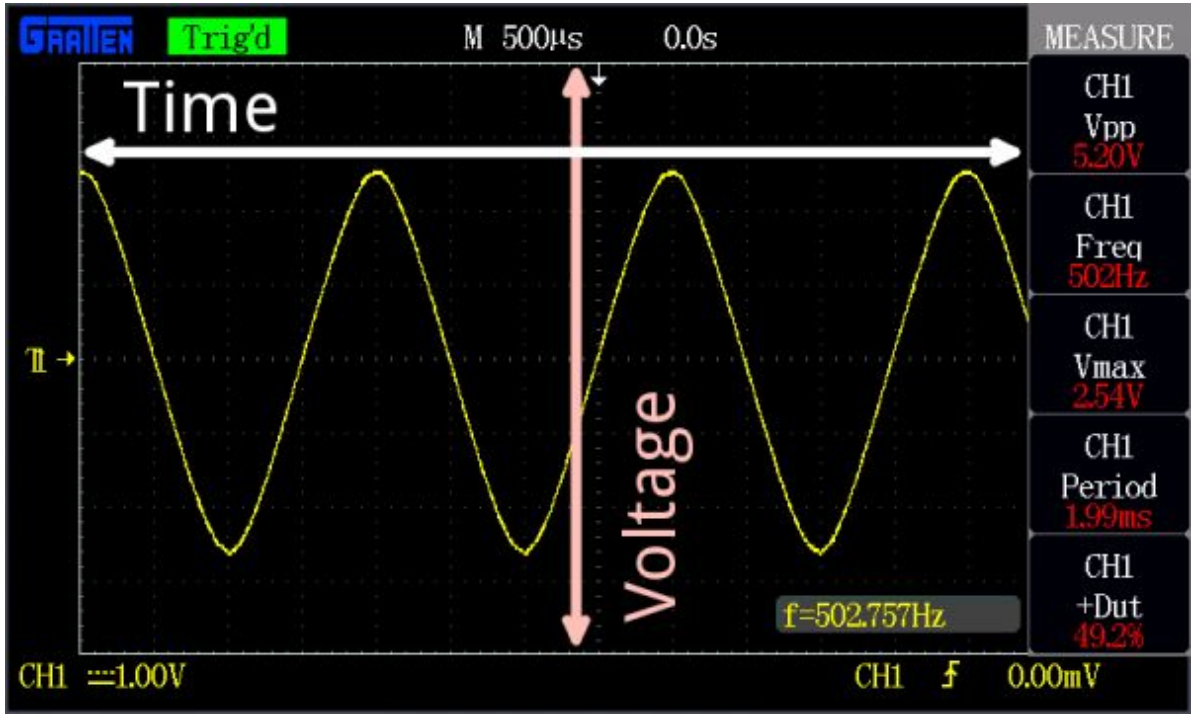
Oscopes graph voltage over time with generally large bandwidths



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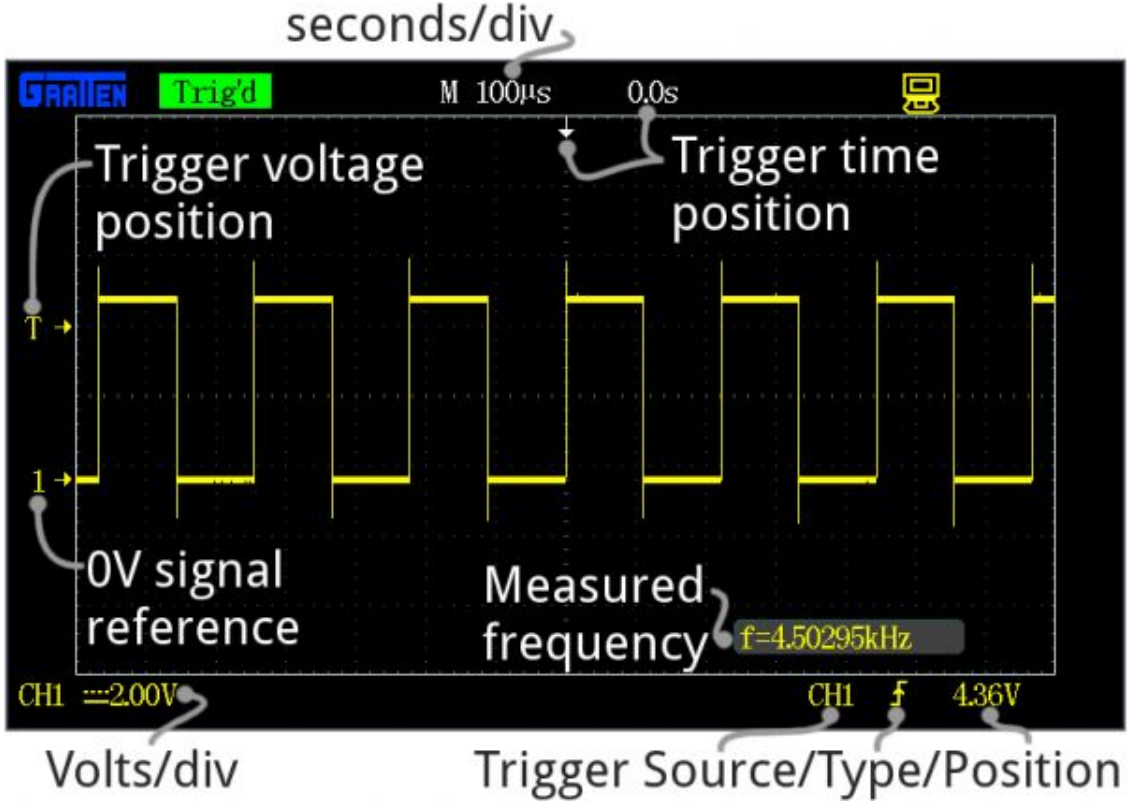
Images: Sparkfun

The main screen generally tells you most of the things you need



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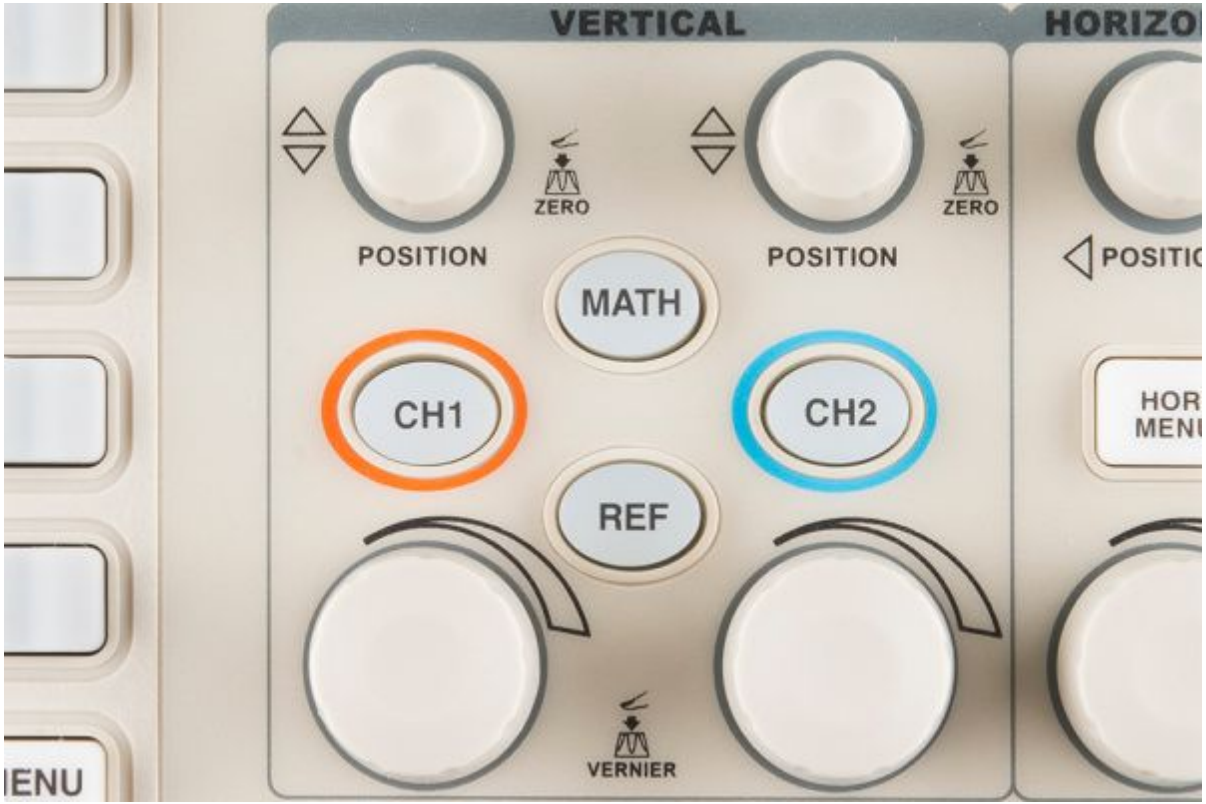
Images: Sparkfun

The vertical system controls the volts/div and offset of **each channel**



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Images: Sparkfun

The horizontal system controls time scale of trigger offset

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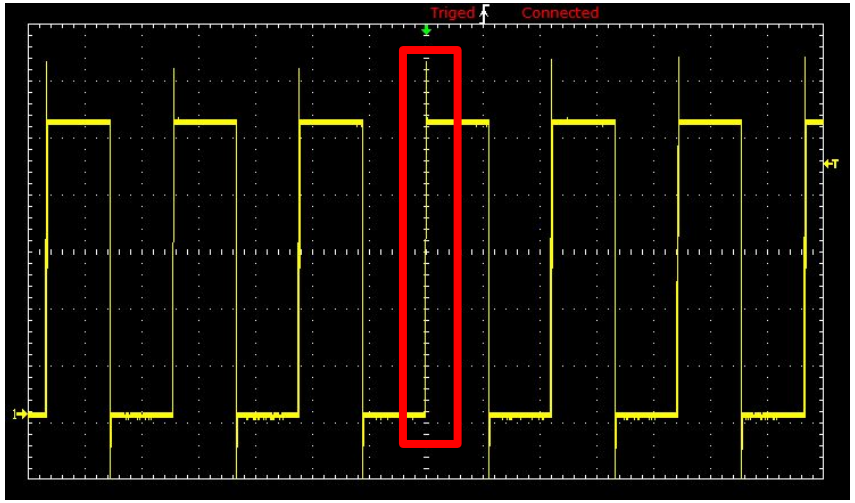
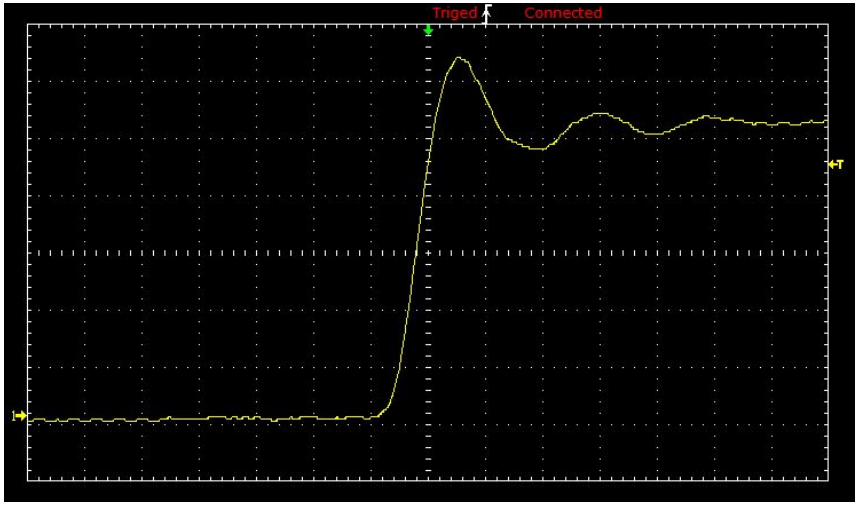
Images: Sparkfun

Choosing the right time base lets you see what you're interested in





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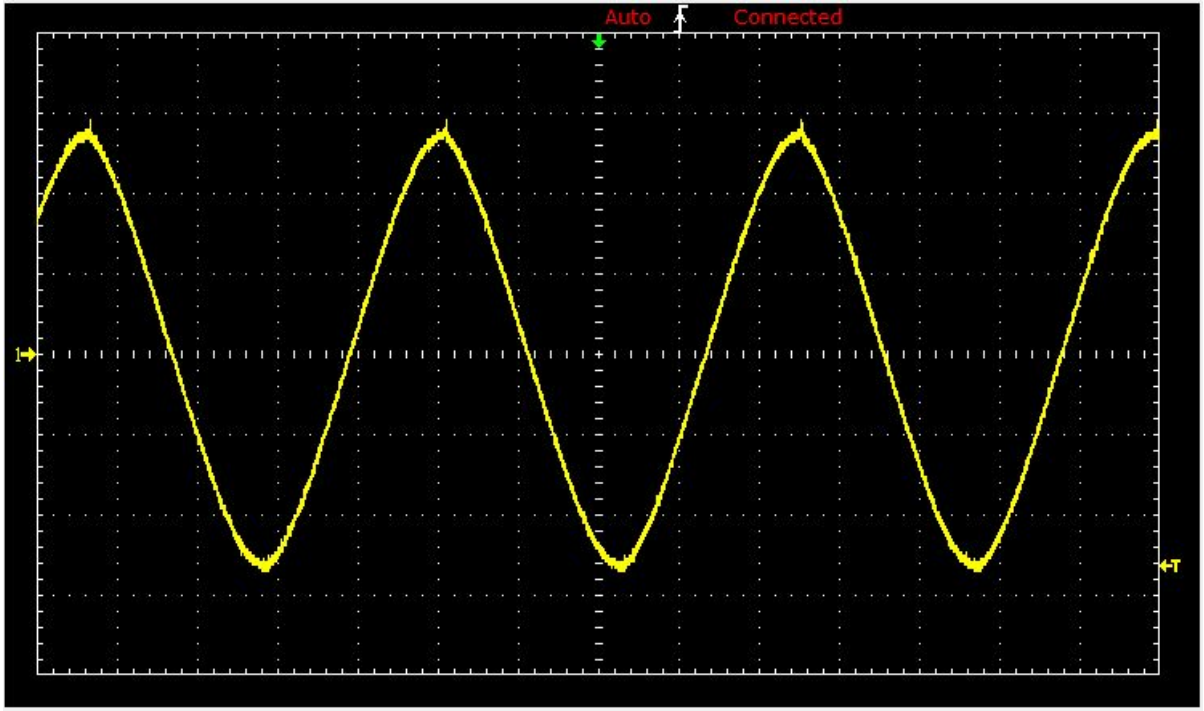
Images: Sparkfun

Just free-running in time can produce nauseating displays



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Images: Sparkfun

The trigger system is designed to “freeze” a waveform

- Trigger level
- Type (edge, pulse, slope)
- 50%
- Force
- Trigger Hold Off

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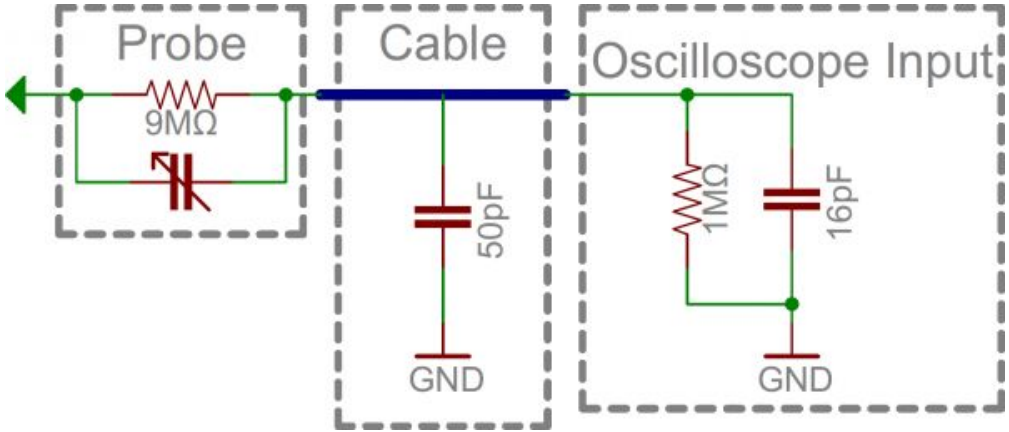
Images: Sparkfun

Probes should be “invisible”, but at high frequencies this means some RF magic



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Images: Sparkfun

Full size scopes have test points for probe compensation

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Images: Sparkfun

Scopes can be easily smoked (along with you) when probing non-isolated circuits

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Images: Digikey

There are a number of specs to consider when buying a scope

- Bandwidth
- Analog vs. Digital
- Channel Count
- Sampling Rate
- Rise Time
- Maximum Input Voltage
- Resolution
- Vertical Sensitivity
- Time Base
- Input Impedance

Images: Sparkfun

Function generators can create known signals to feed into systems and can be found from a few hundred dollars

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Images: Amazon

END

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DEMO TIME!
38
...WHAT COULD POSSIBLY GO WRONG
makeameme.org


DEMO TIME!
LET'S HOPE THE DEMO-GODS ARE SMILING!
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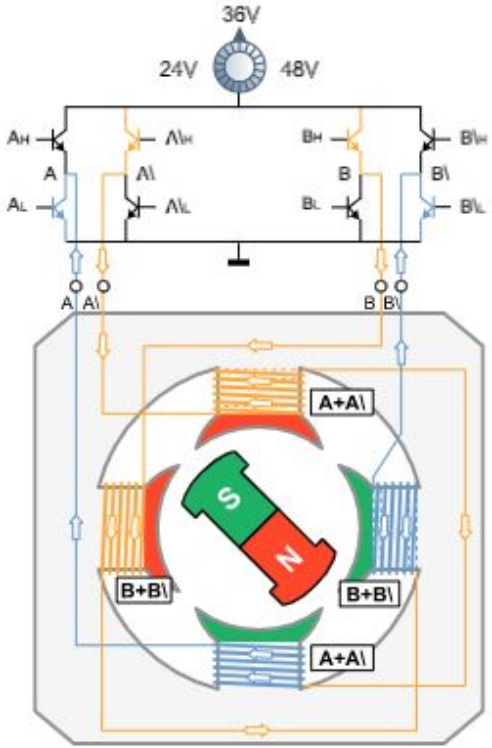
IT'S DEMO TIME!

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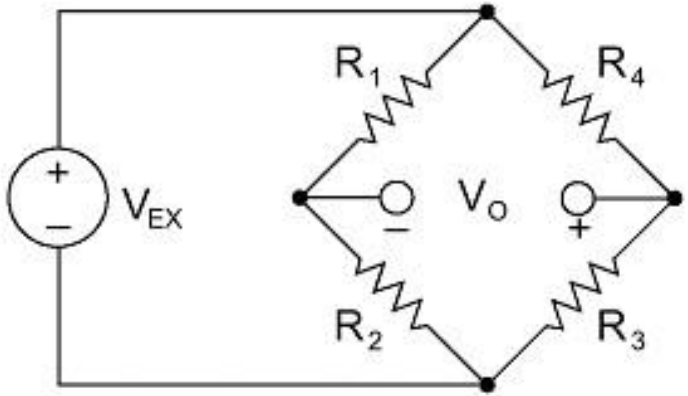
Image: https://us.nanotec.com/knowledge-base/stepper-motor-animation#

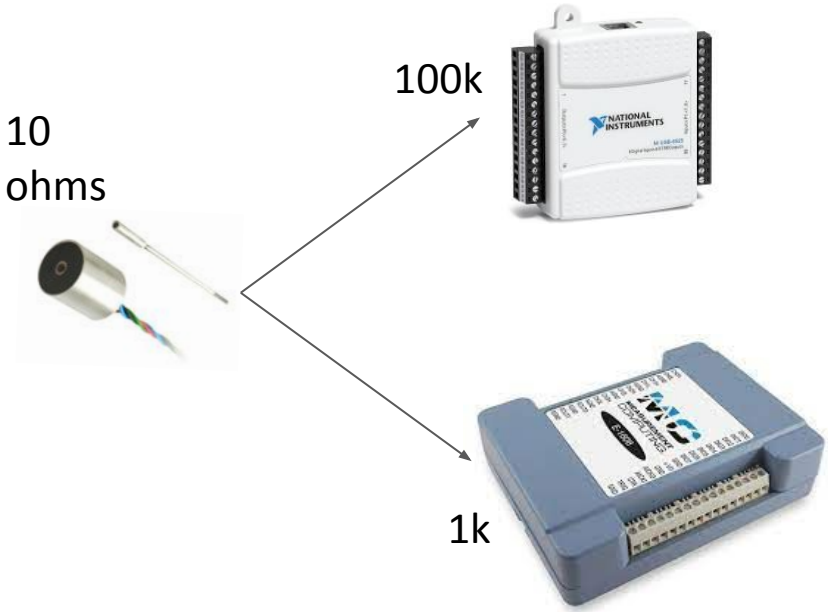
Bridge circuits are a common configuration

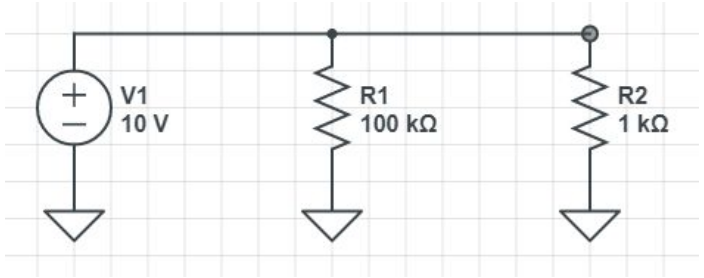


$$V_o = V_i \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right]$$

Images: National Instruments

This can also be a factor when connecting two DAQ systems





Rtotal = 990 ohms!

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Image: TransTek, National Instruments, MCCDAQ

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

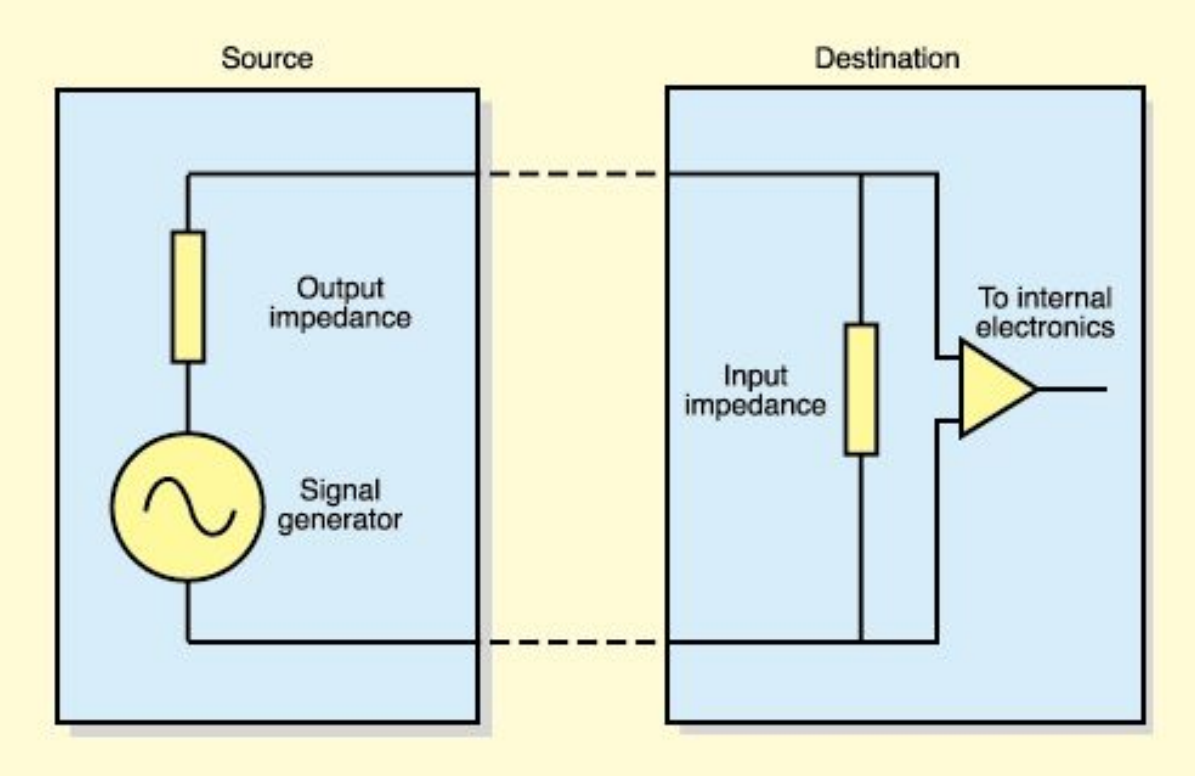

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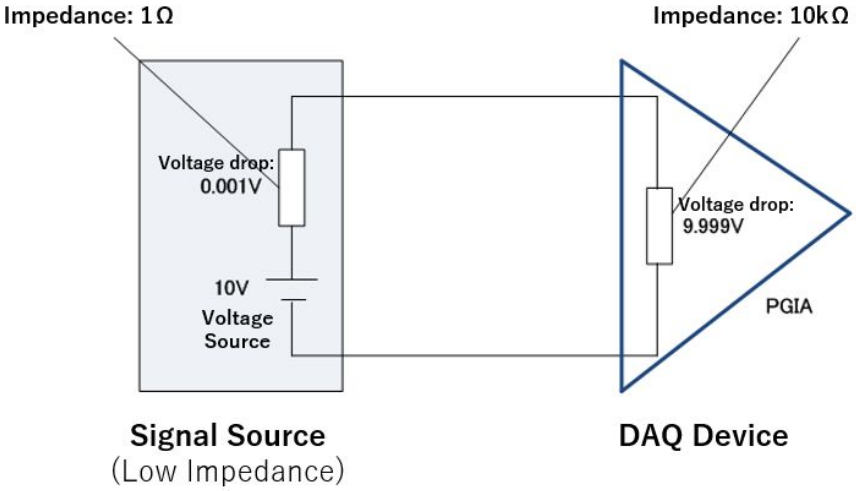
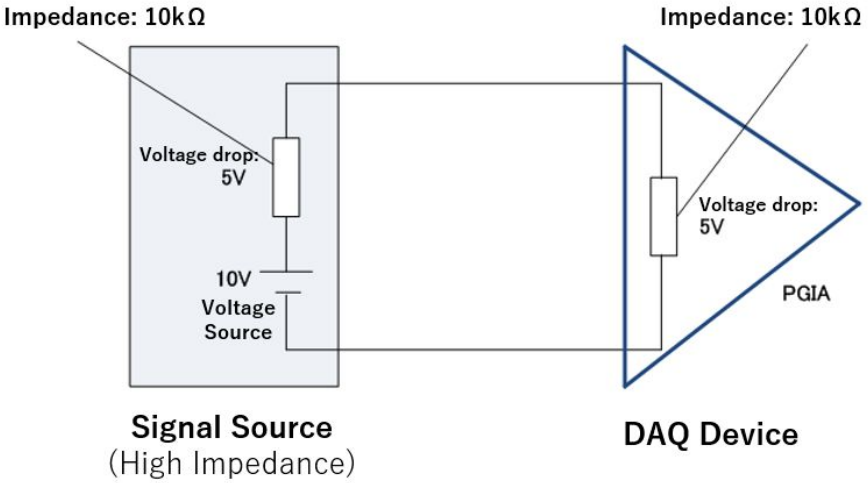
Image: Sound On Sound

Mismatched impedance can cause puzzling behavior





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Images: National Instruments

Impedance is really “AC resistance”

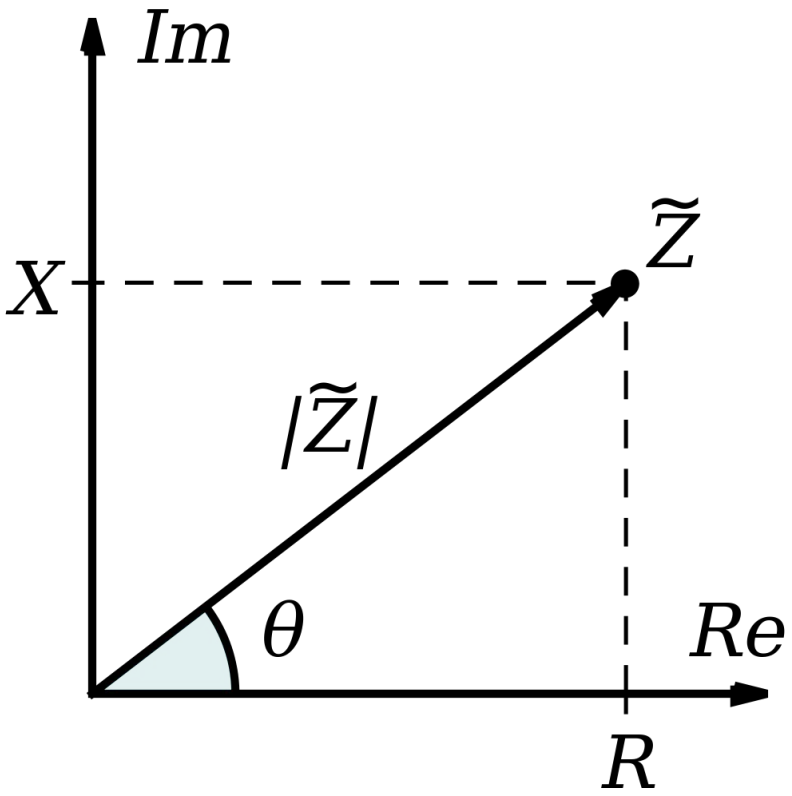

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Image: Wikipedia