Circuits & Microcontrollers

September 3, 2019

Reminders

Bring something to hack on Thursday

You should have a class buddy

What is an Interactive Device?

image from https://www.pocket-lint.com/games/reviews/nintendo/140007-nintendo-switch-review-console-specs-price-and-features


IFIXIT

What is an Interactive Device?

Inputs (buttons, joysticks, touchscreen)

Outputs (display, speakers, vibration motors)

Wireless Connectivity (bluetooth, wifi)

Sensors (light, IR emitter detector)

Connectors (USB-C, microSD slot)

Power management

Battery

Storage (NAND Flash IC)

Microcontroller & other Integrated Circuits

And all these parts are connected in *circuits*.

Circuits

Common Components | Voltage | Current | Resistance

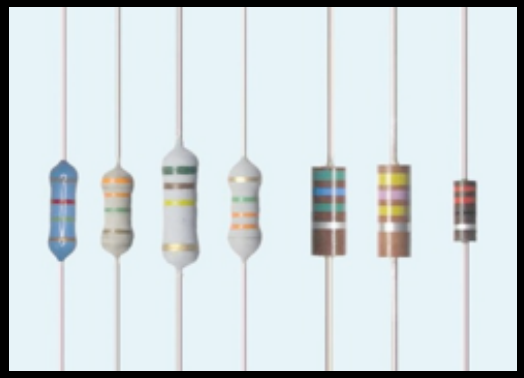
Ohms Law | Watt's Law | Series and Parallel Circuits

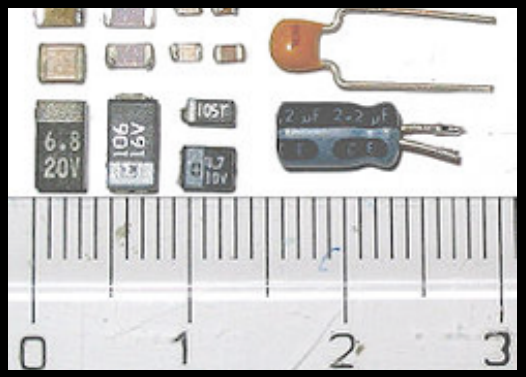
Voltage Divider | Pull-up and Pull-down circuits

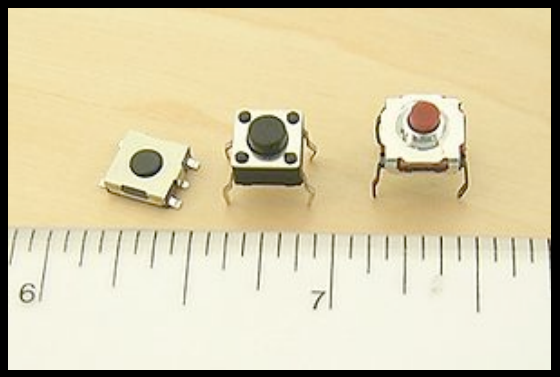
Electrical circuits are networks of electrical elements that contain a closed loop which allows electrons to flow through the elements.

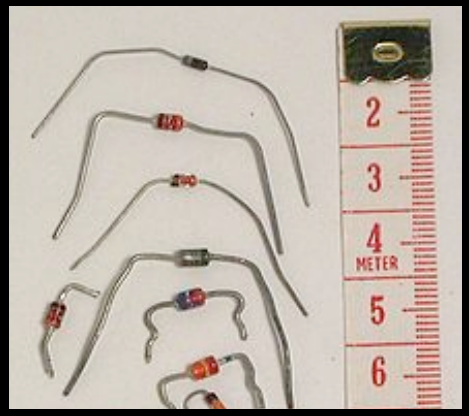
This electron flow allows the circuits to do things.

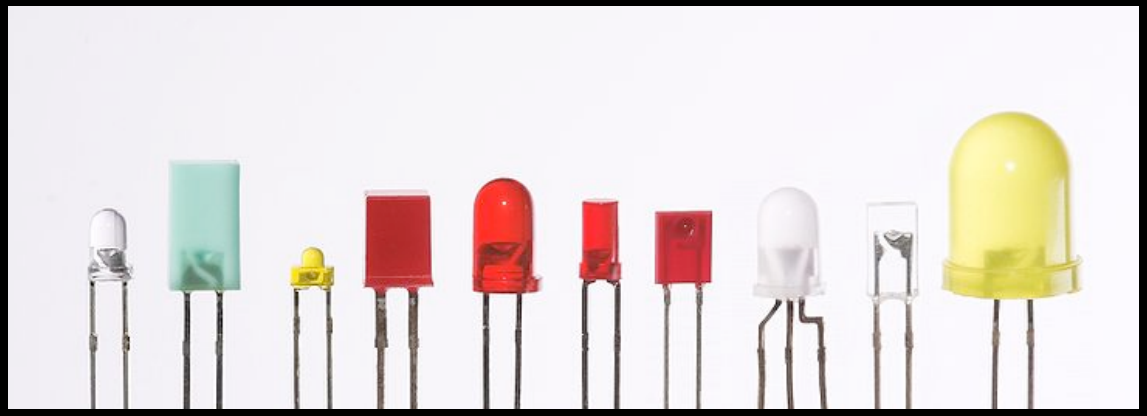
Examples of Electrical Components











images from Wikipedia

V — Voltage (measured in Volts) is the potential difference in electrical charge between two points in a circuit.

I — Current (measured in Amperes or Amps) is the quantity of electrons passing through a point in a circuit.

R — Resistance (measured in Ohms - Ω) is the capacity of a circuit element to impede the flow of electrons in an electrical circuit.

Ohm's Law states that Voltage = Current X Resistance

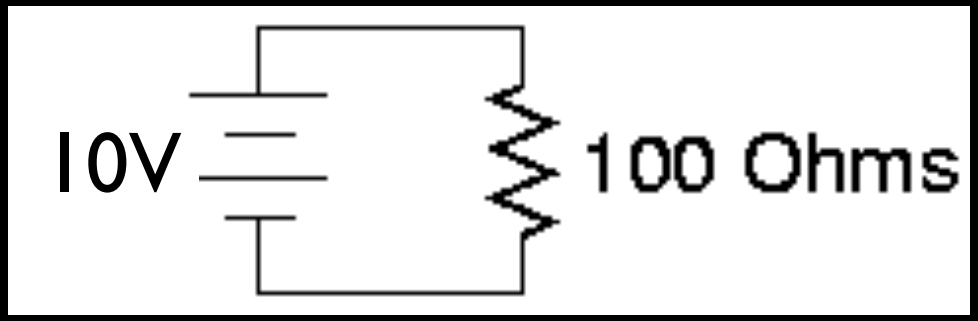
$$V=IR$$

Watt's Law states that Power = Voltage x Current

$$P=VI= I^2R$$

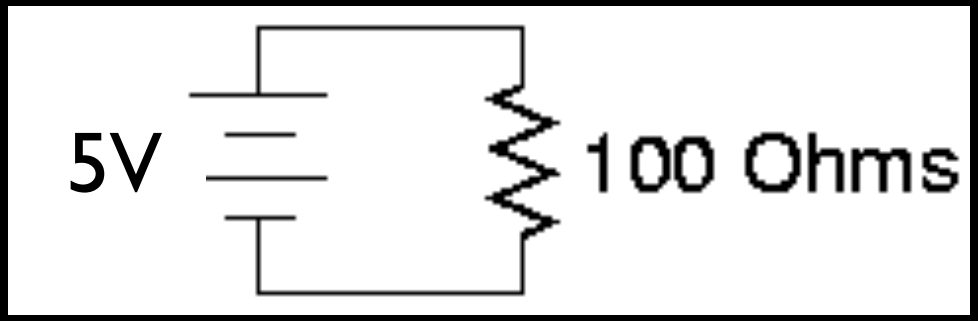
Ohm's Law states that Voltage = Current X Resistance

$V=IR$



Ohm's Law states that Voltage = Current X Resistance

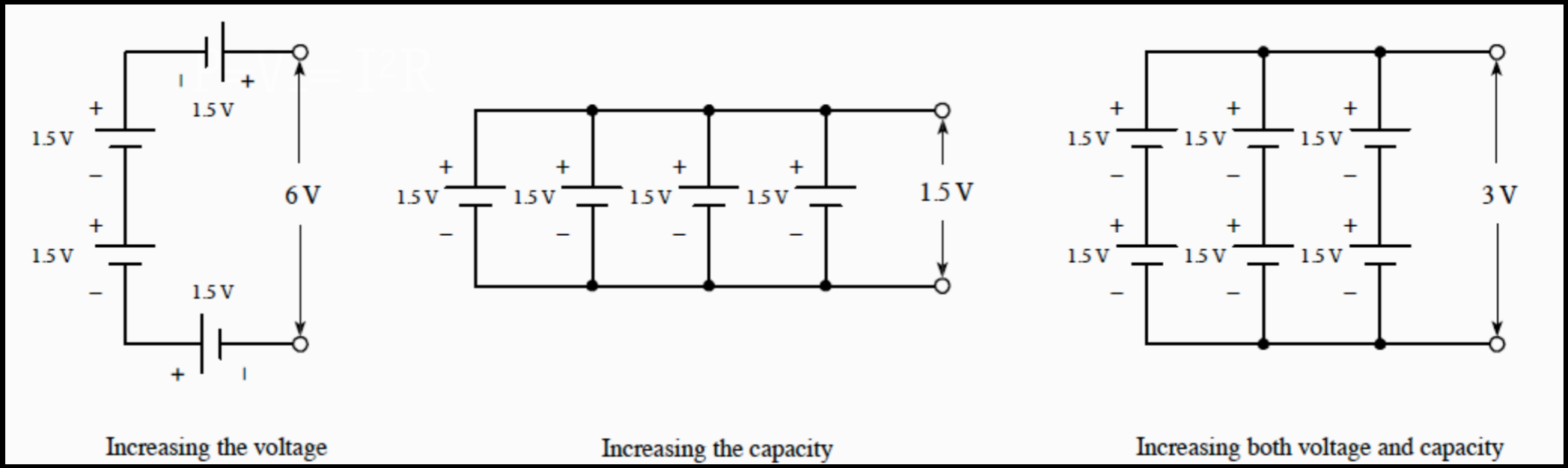
$$V=IR$$



Where does Voltage come from?

images from Wikipedia

Power can come from supplies or batteries.

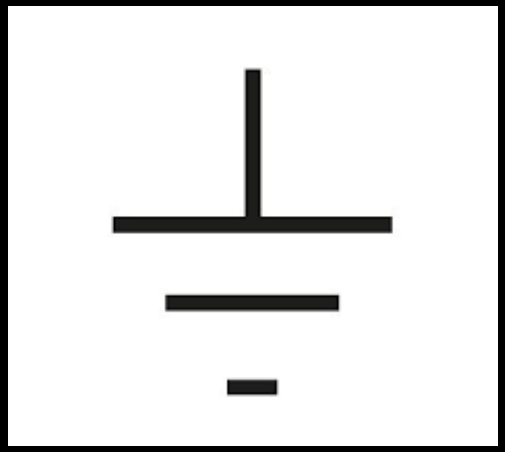


Increasing the voltage

Increasing the capacity

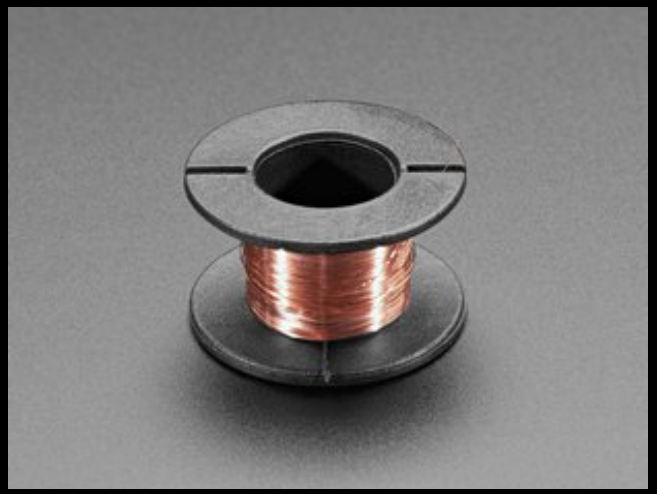
Increasing both voltage and capacity

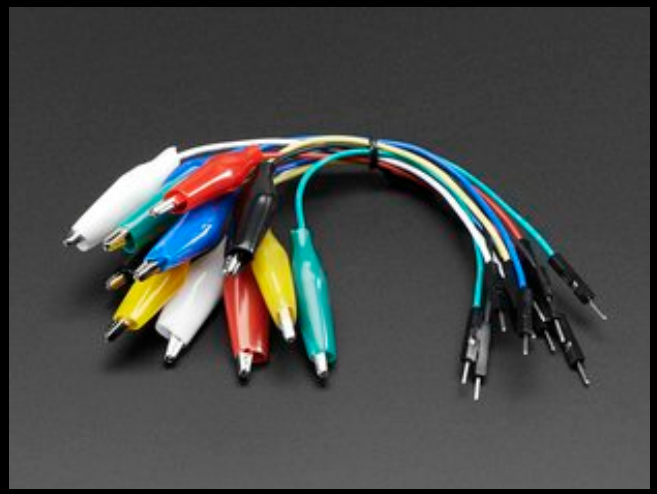
Ground symbol

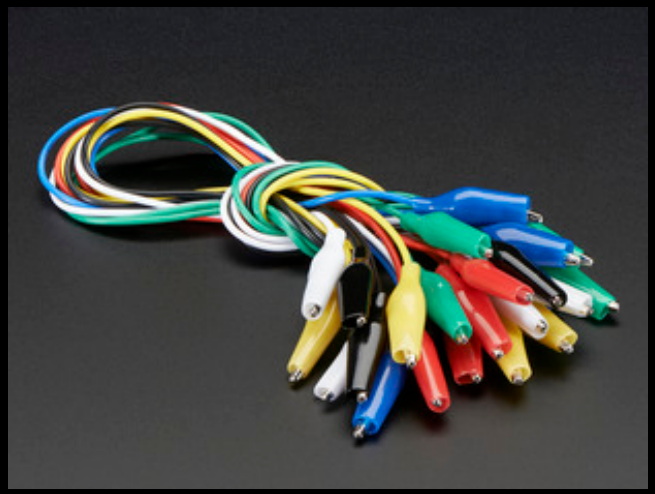


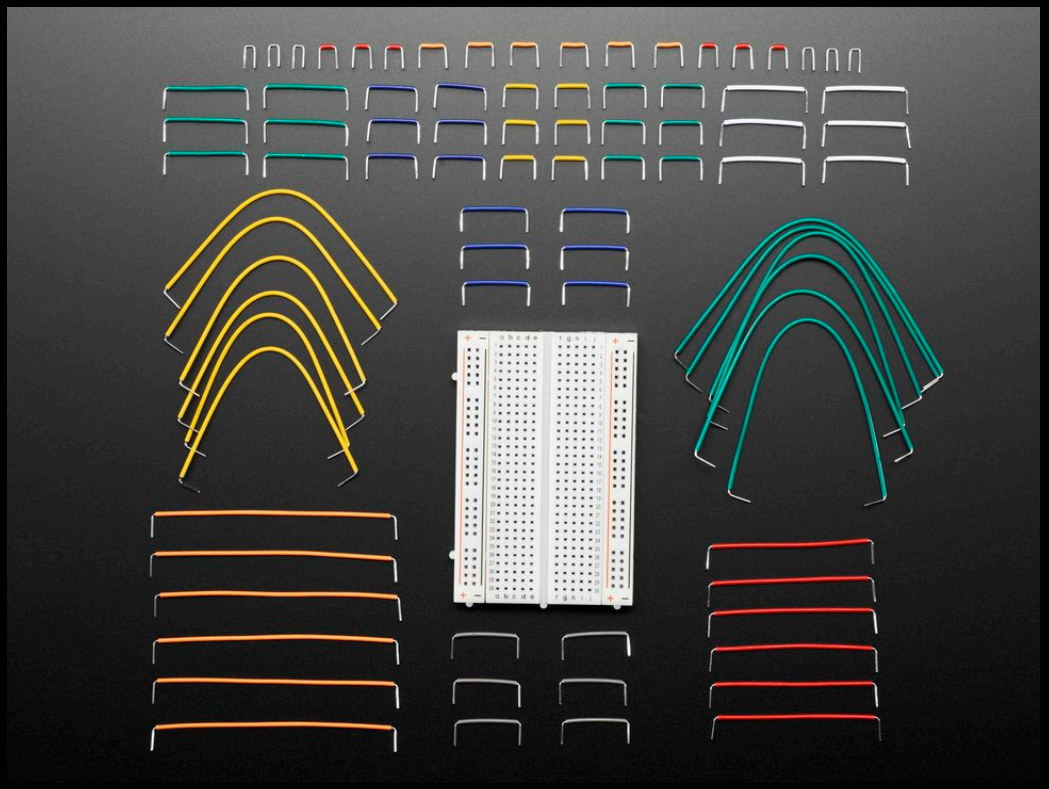
Current flows with almost no resistance in metal.

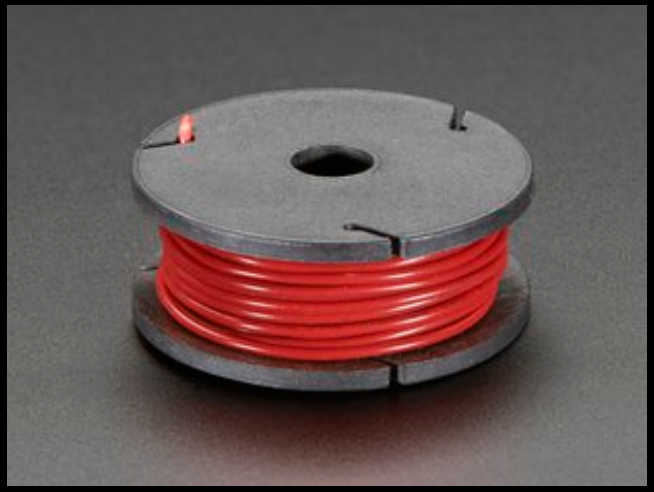
Things that are connected by direct metal-on-metal contact share the same voltage.











images from Adafruit

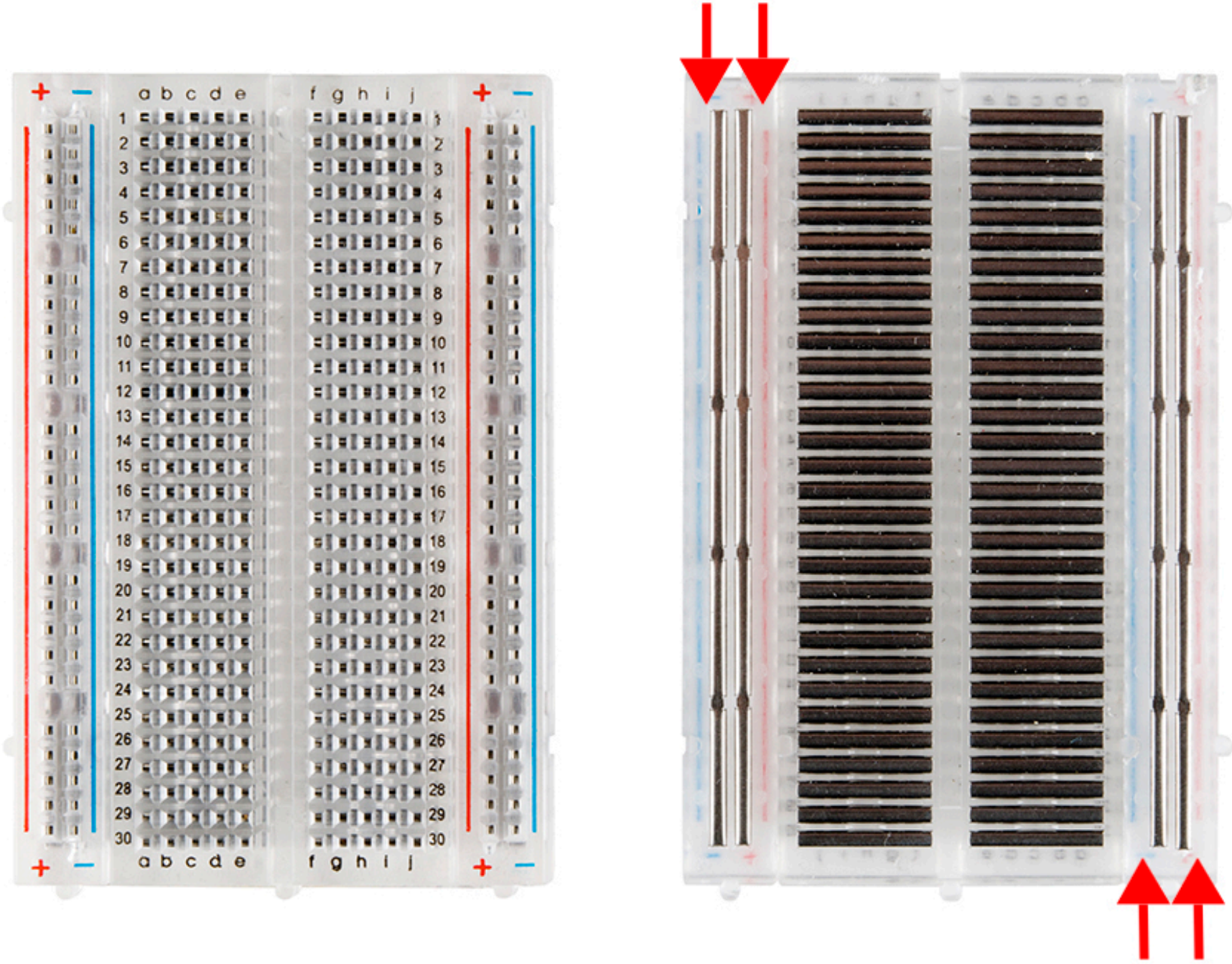
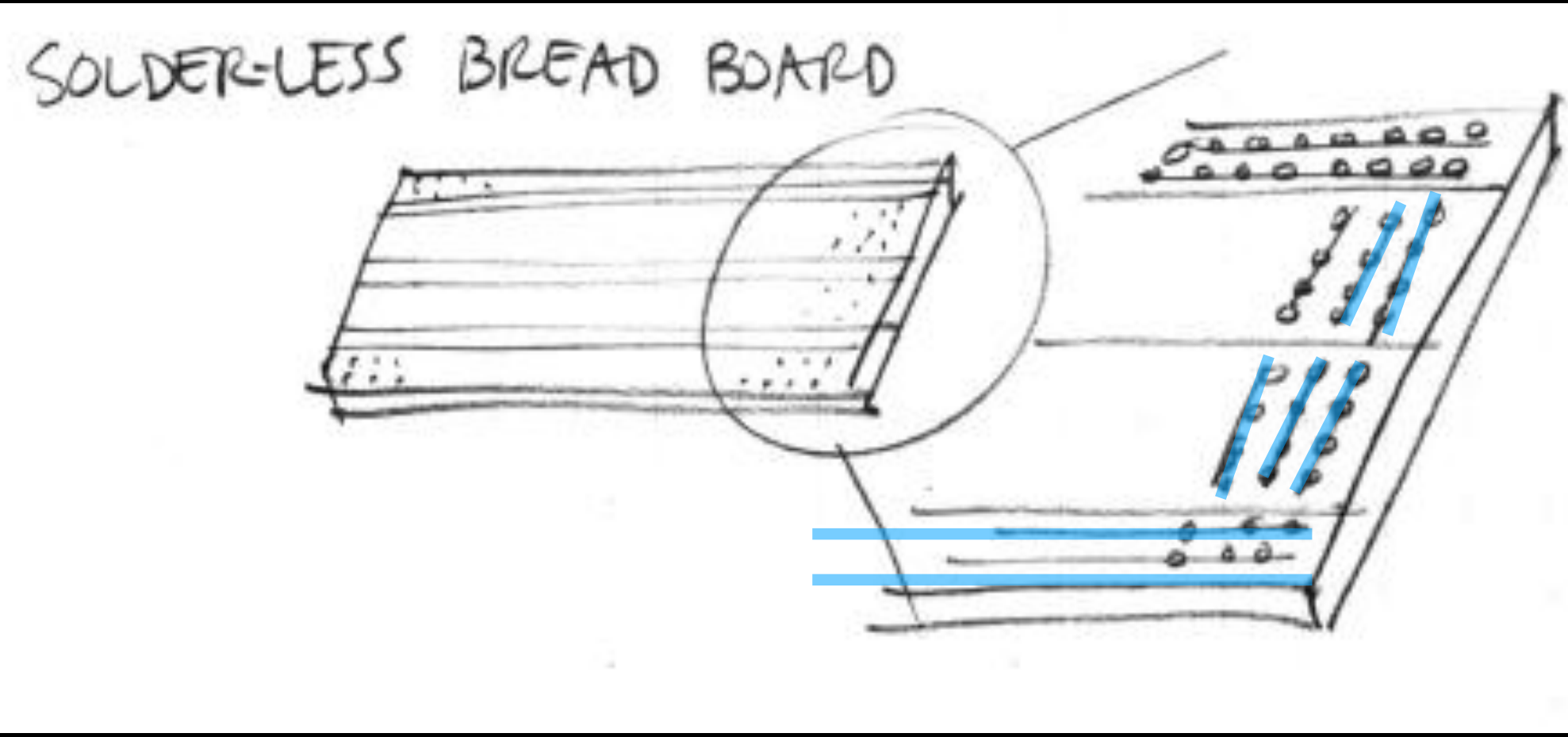
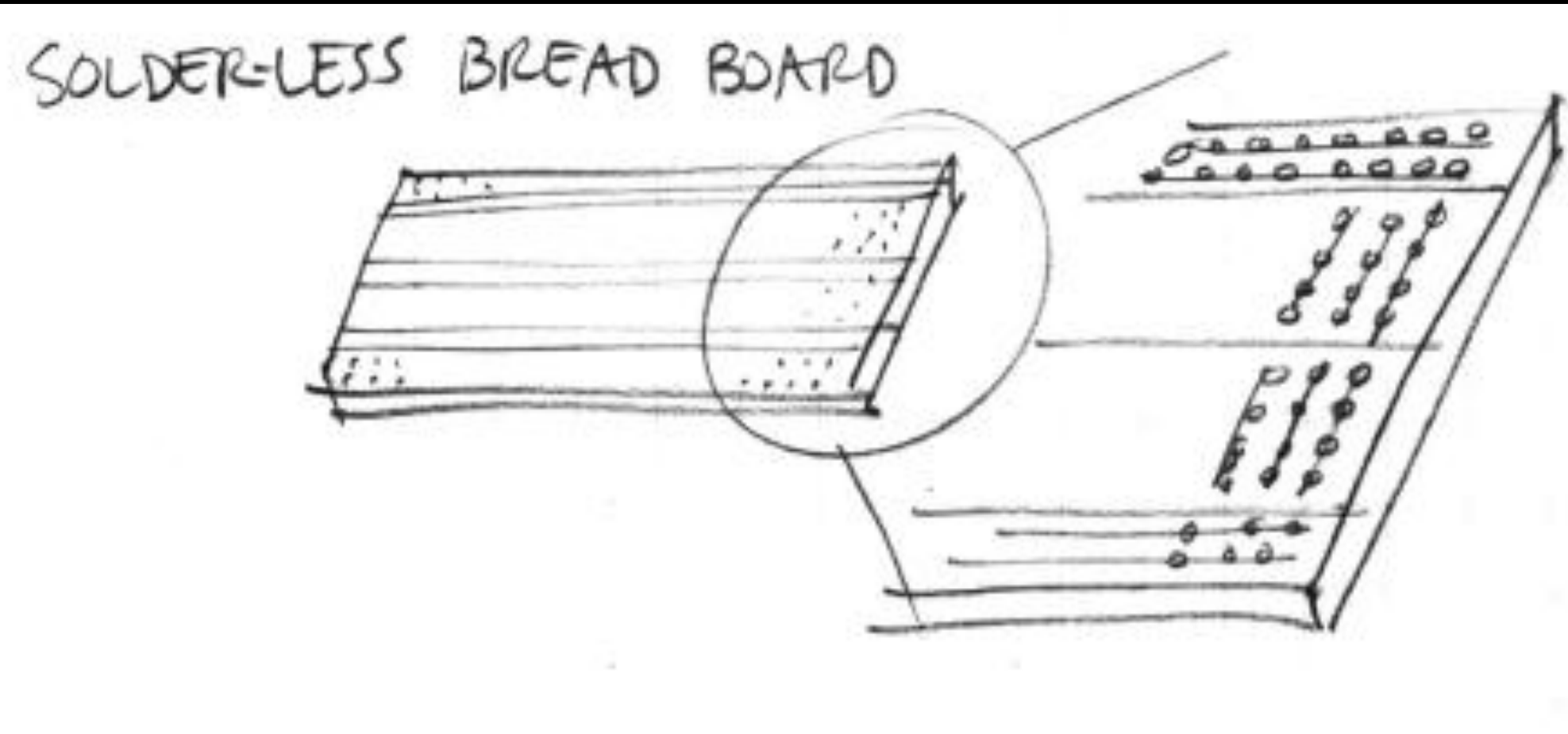


image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

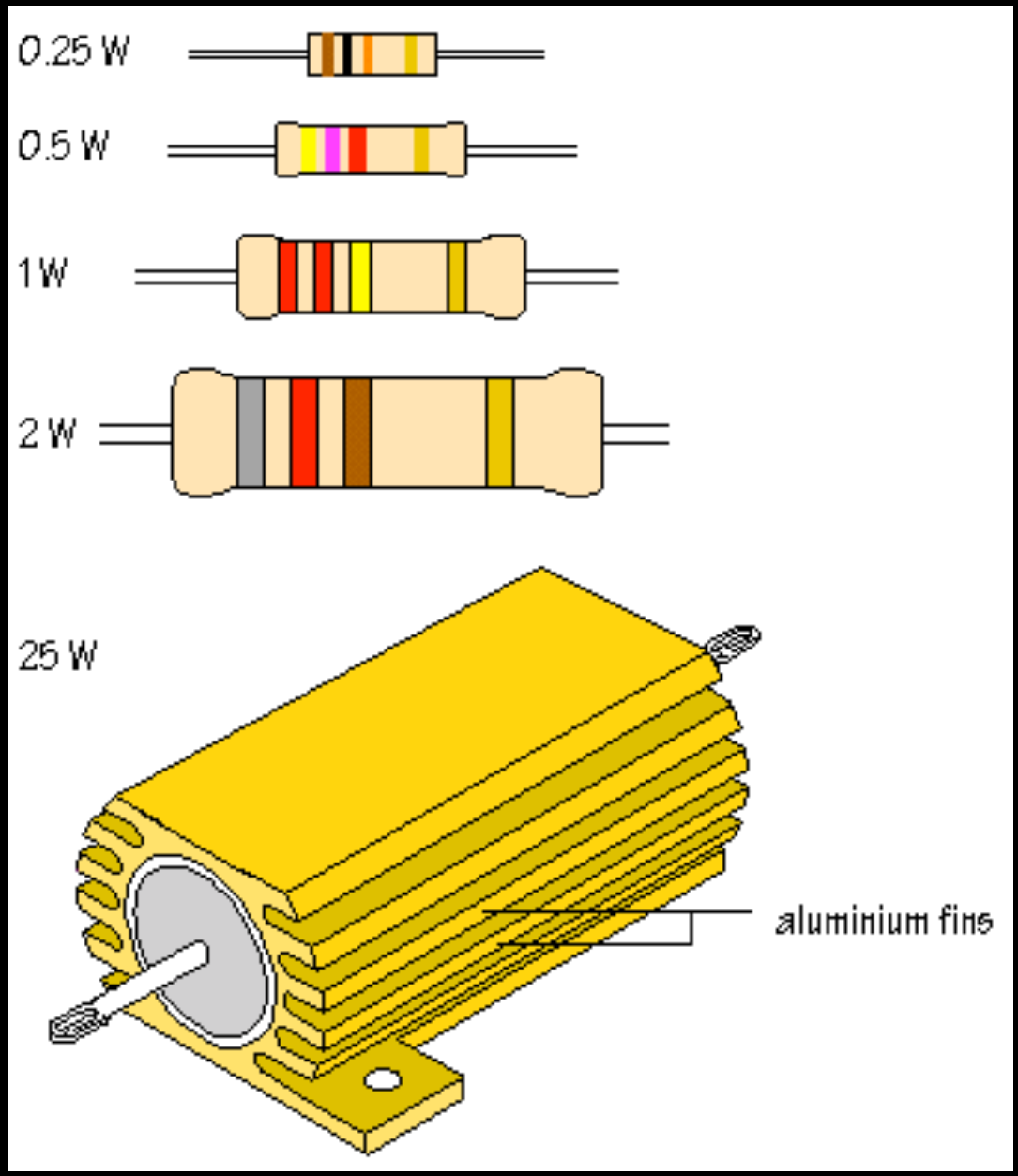


sketch by Bill Verplank



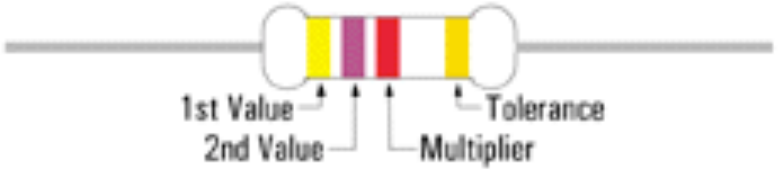
sketch by Bill Verplank

Resistance regulates the current in a circuit.



images from www.steiniche.dk/.../resistors-filer

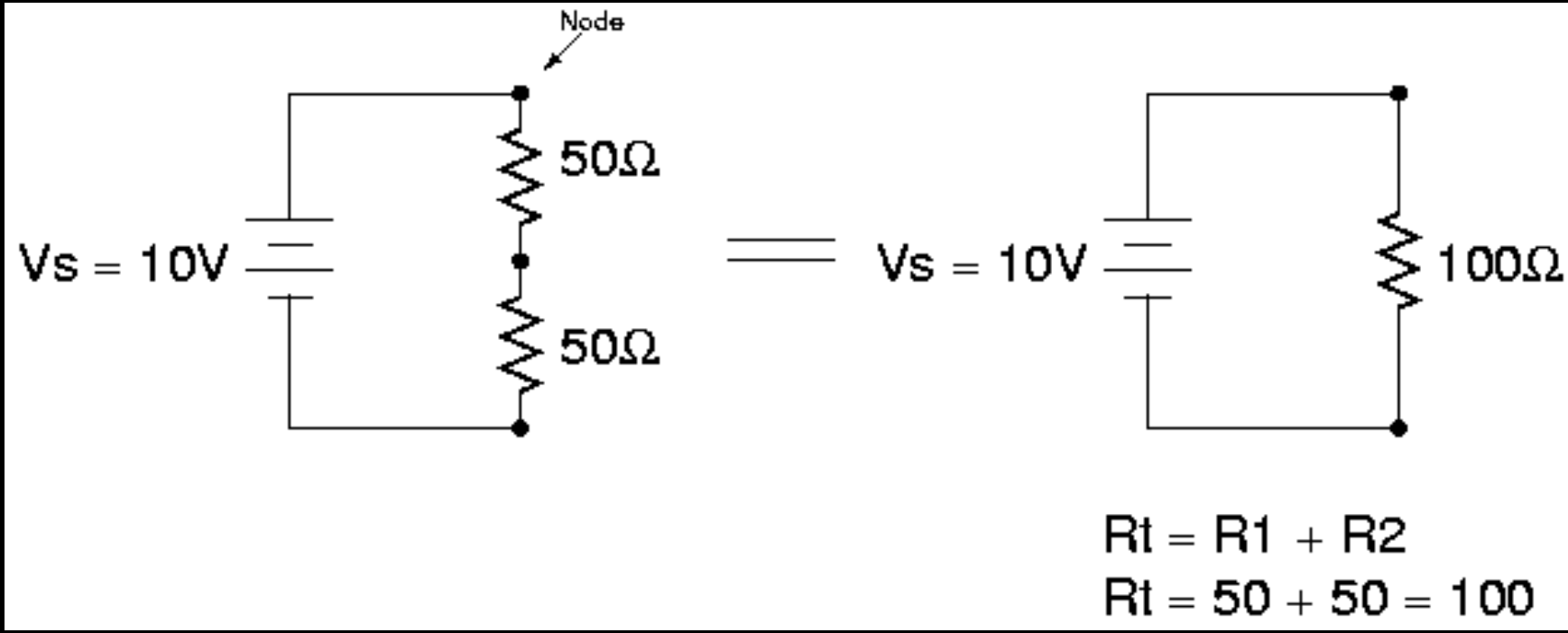
READING RESISTANCE VALUES



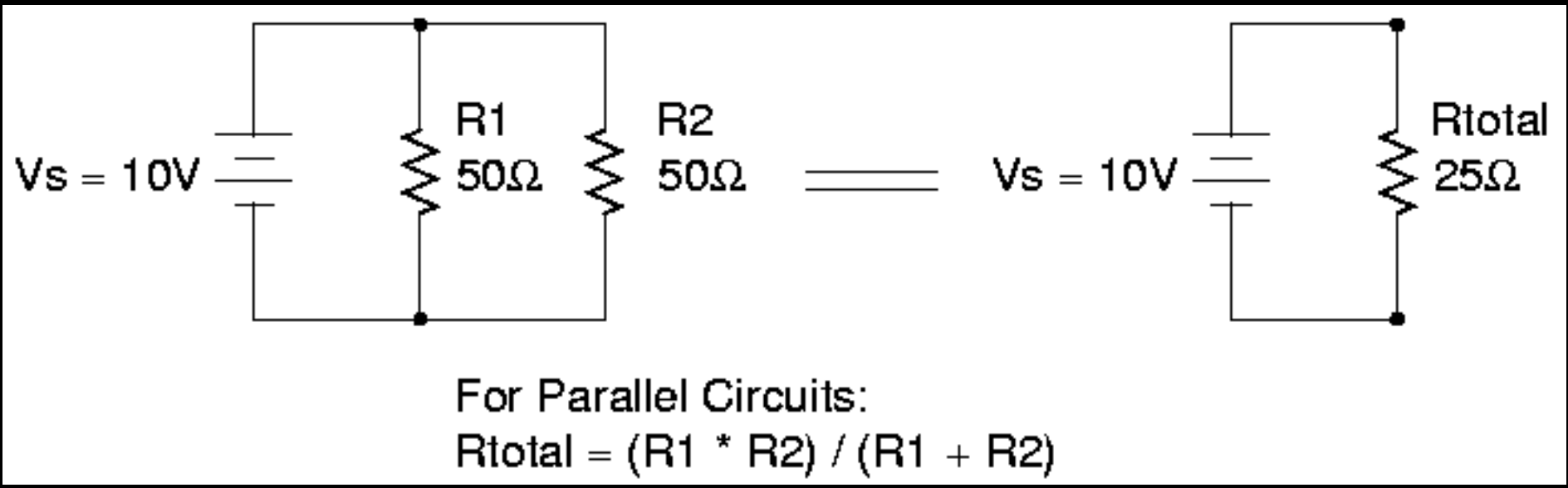
Example: 4 7 x100 –5%
4700Ω–5%

COLOR	VALUE	MULTIPLIER	TOLERANCE
Black	0	1	·
Brown	1	10	–1%
Red	2	100	–2%
Orange	3	1K	·
Yellow	4	10K	·
Green	5	100K	–.5%
Blue	6	1M	–.25%
Violet	7	10M	–.1%
Gray	8	100M	–.05%
White	9	1000M	·
Gold	·	1/10	–5%
Silver	·	1/100	–10%
None	·	·	–20%

Resistors in series ADD



Resistors in parallel DIVIDE



For Parallel Circuits:

Rtotal = (R1 * R2) / (R1 + R2)

Ohm's Law states that Voltage = Current X Resistance

$$V=IR$$

Watt's Law states that Power = Voltage x Current

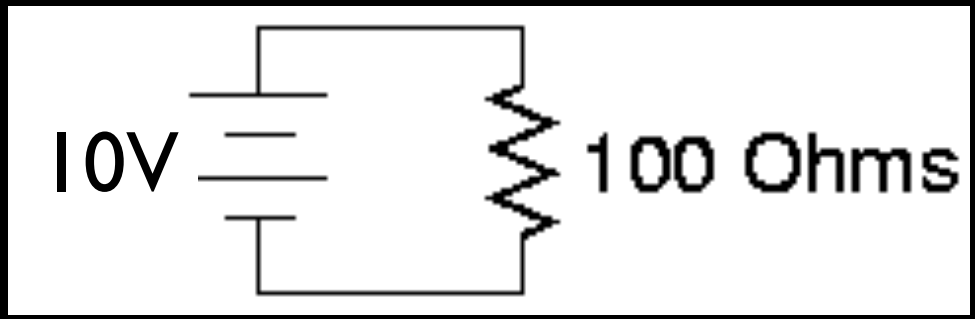
$$P=VI= I^2R$$

$V=IR$ $P=VI$

$V=?$

$I=?$

$P=?$

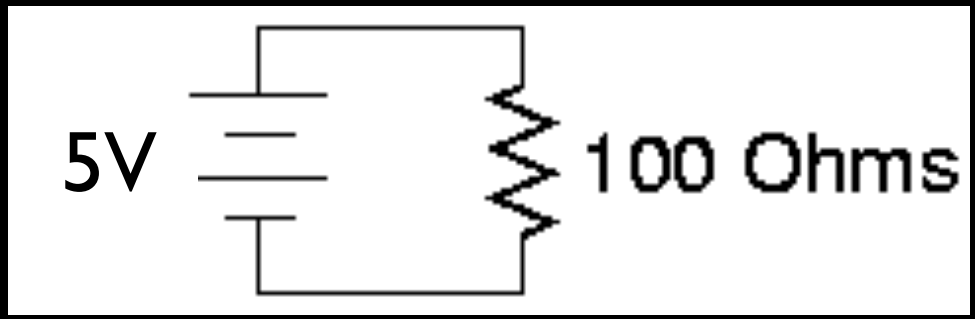


V=IR P=VI

V=?

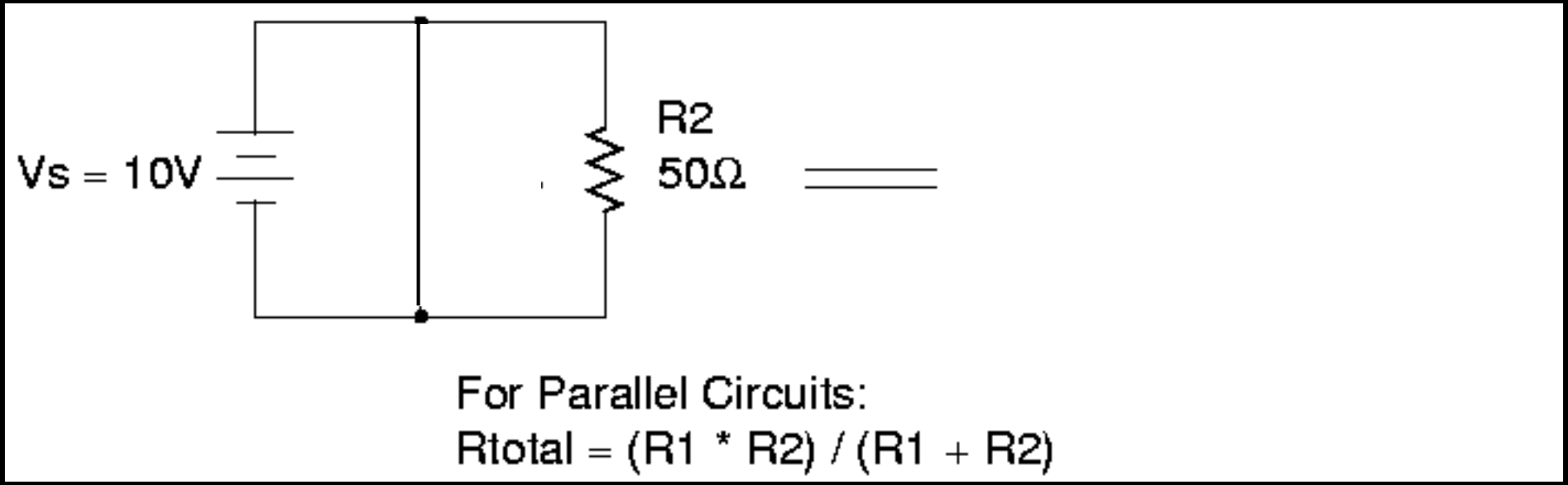
I=?

P=?



What is a SHORT CIRCUIT???

Why is this bad?



For Parallel Circuits:

Rtotal = (R1 * R2) / (R1 + R2)

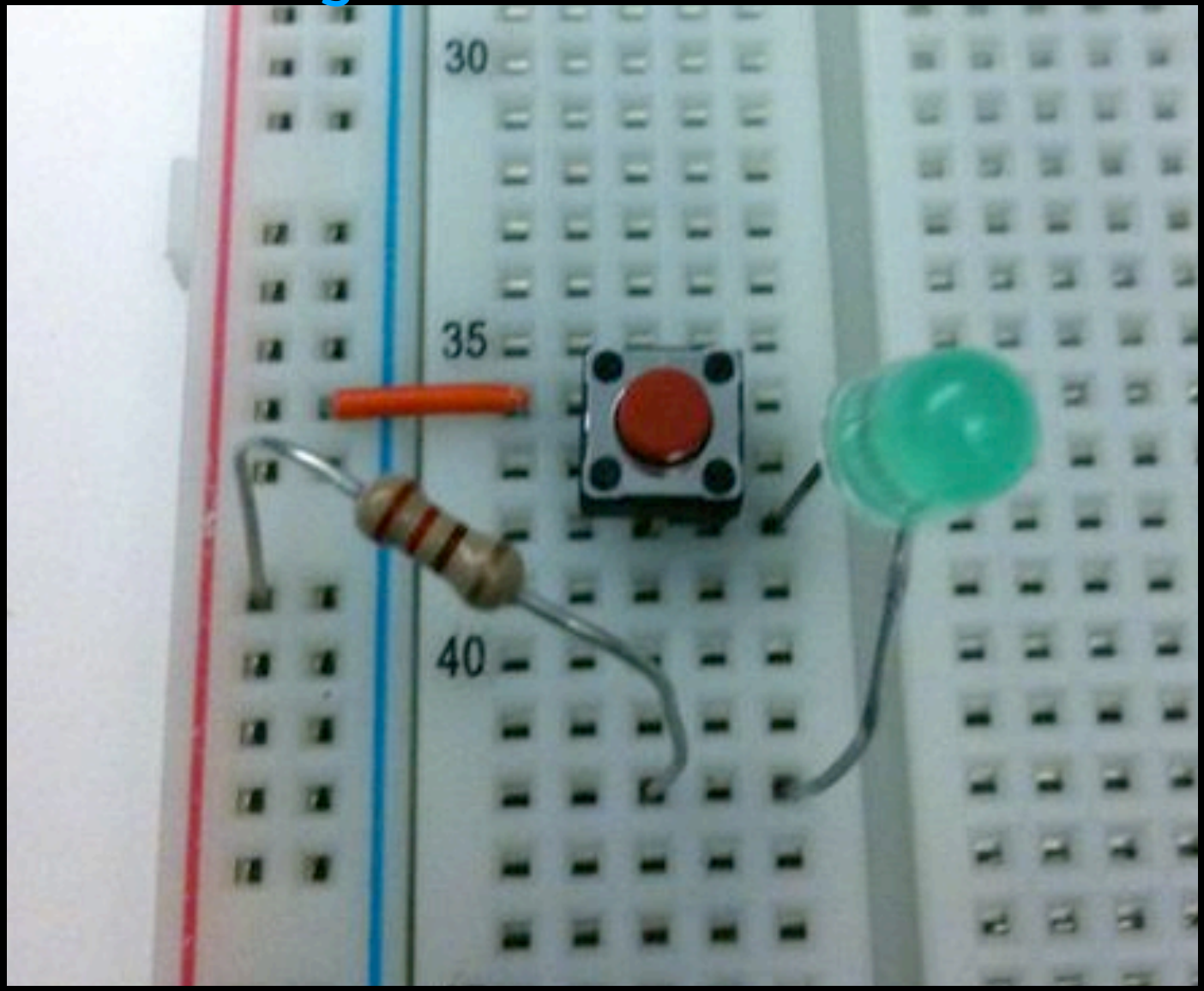
$$V=IR$$

$$I=V/R$$

$$\text{If } R=0, I=\infty$$

DON’T SHORT POWER TO GROUND

A Tour through a Pushbutton LED circuit



Pushbutton LED circuit breadboard drawing

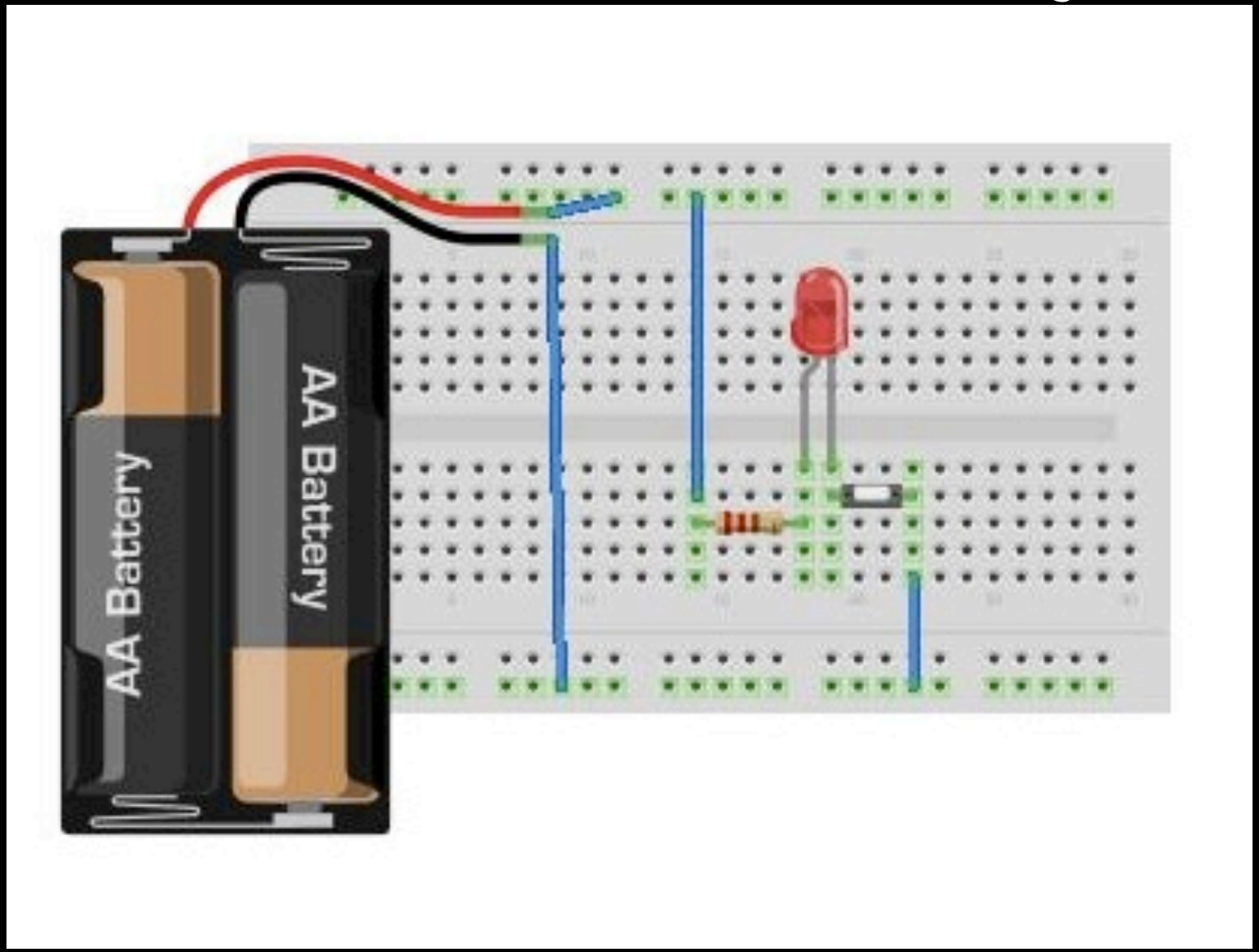
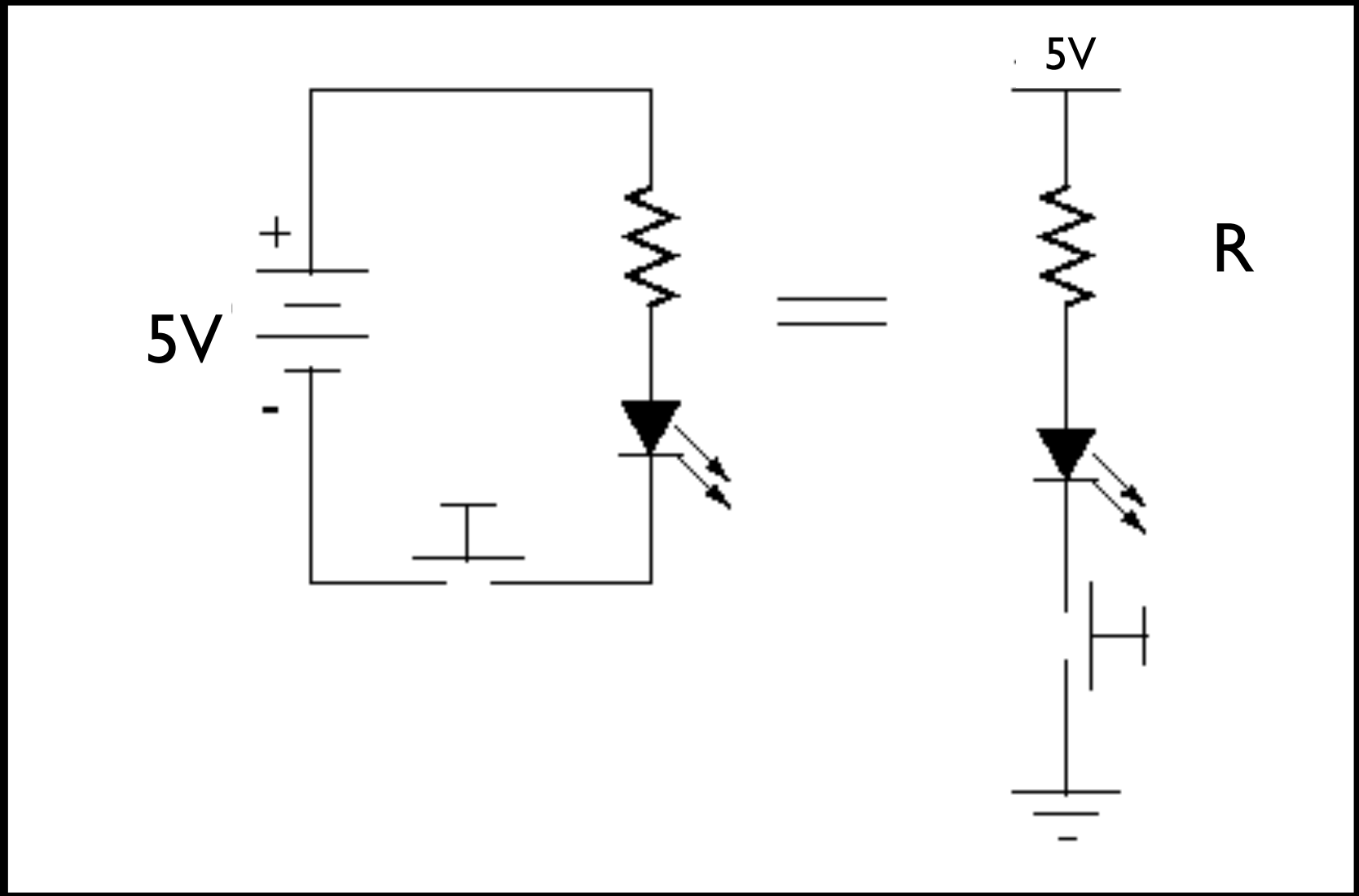


diagram made in Fritzing

Equivalent Pushbutton LED circuit

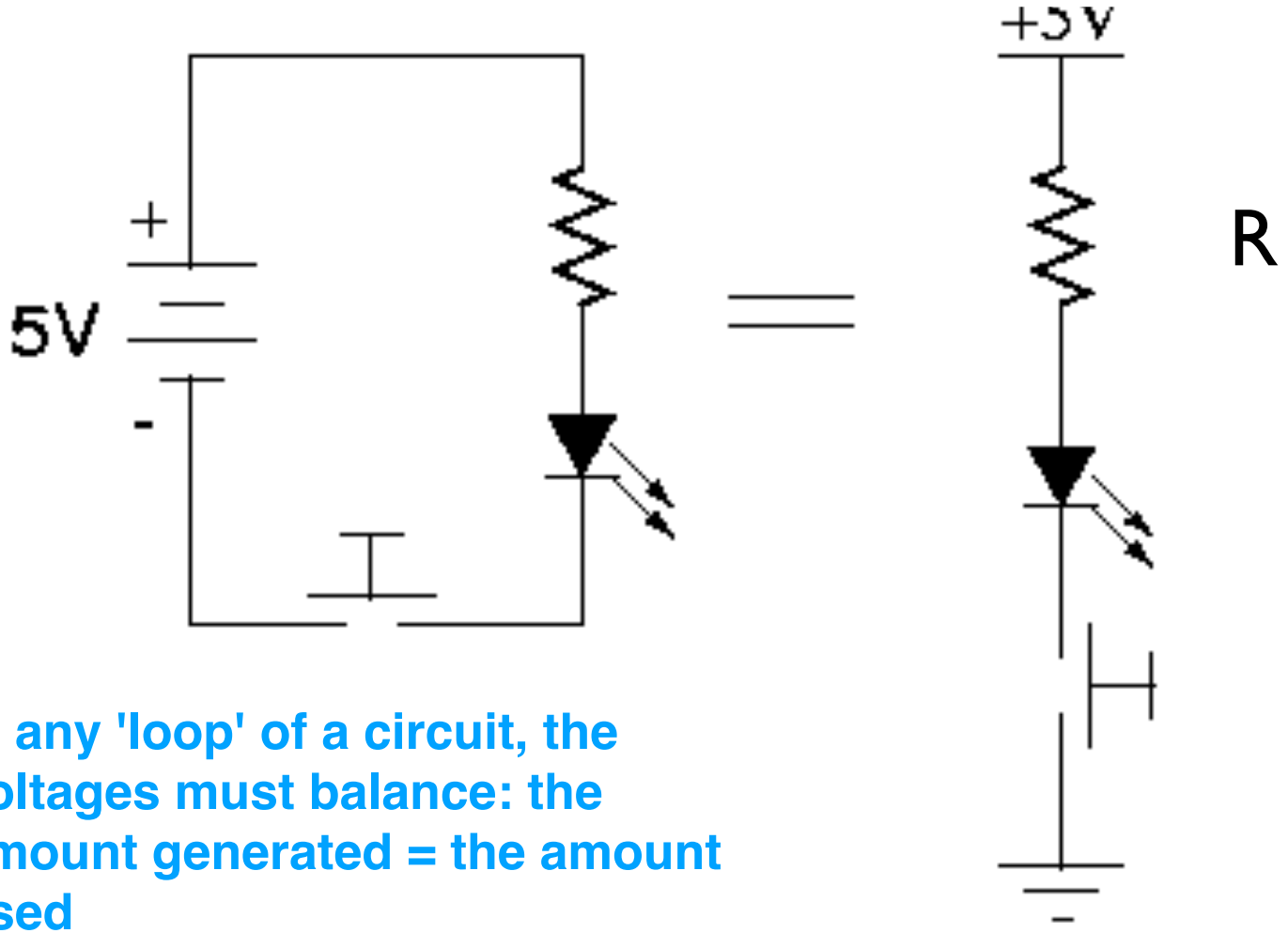


Sketching in Hardware

image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

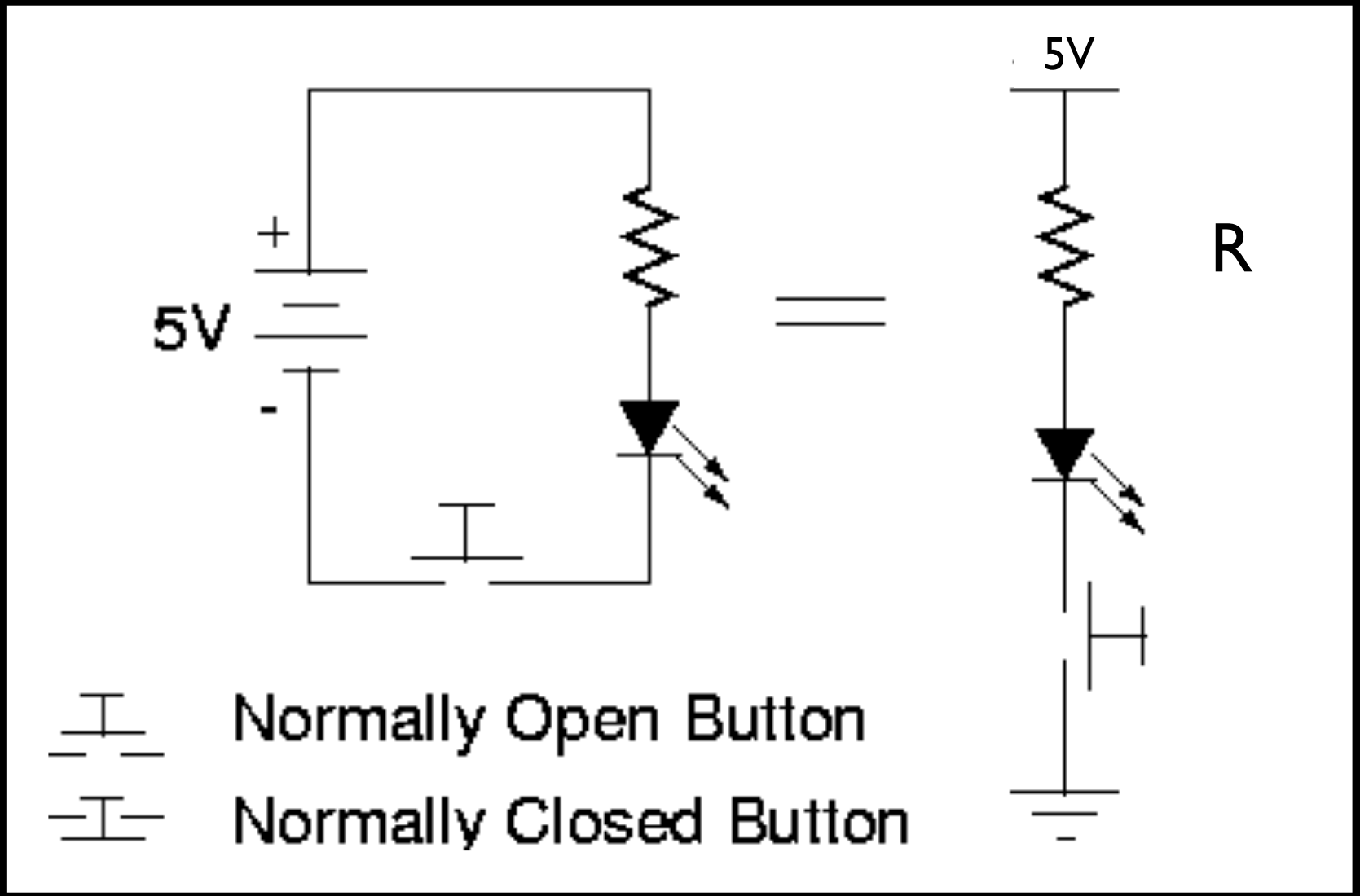
originally from http://www.instructables.com/id/Use-a-real-Bread-Board-for-prototyping-your-circui/

KIRCHOFF'S LAW in the Pushbutton LED circuit

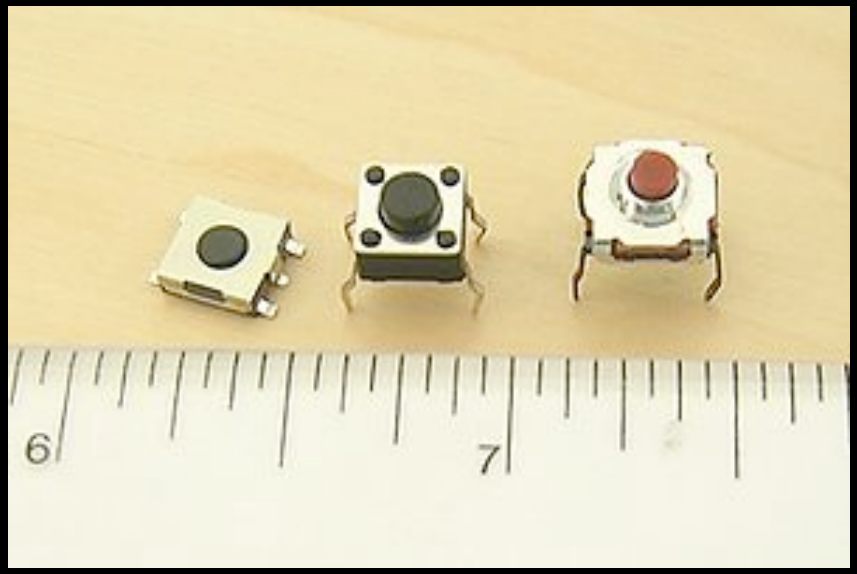


In any 'loop' of a circuit, the voltages must balance: the amount generated = the amount used

Input in the Pushbutton LED circuit

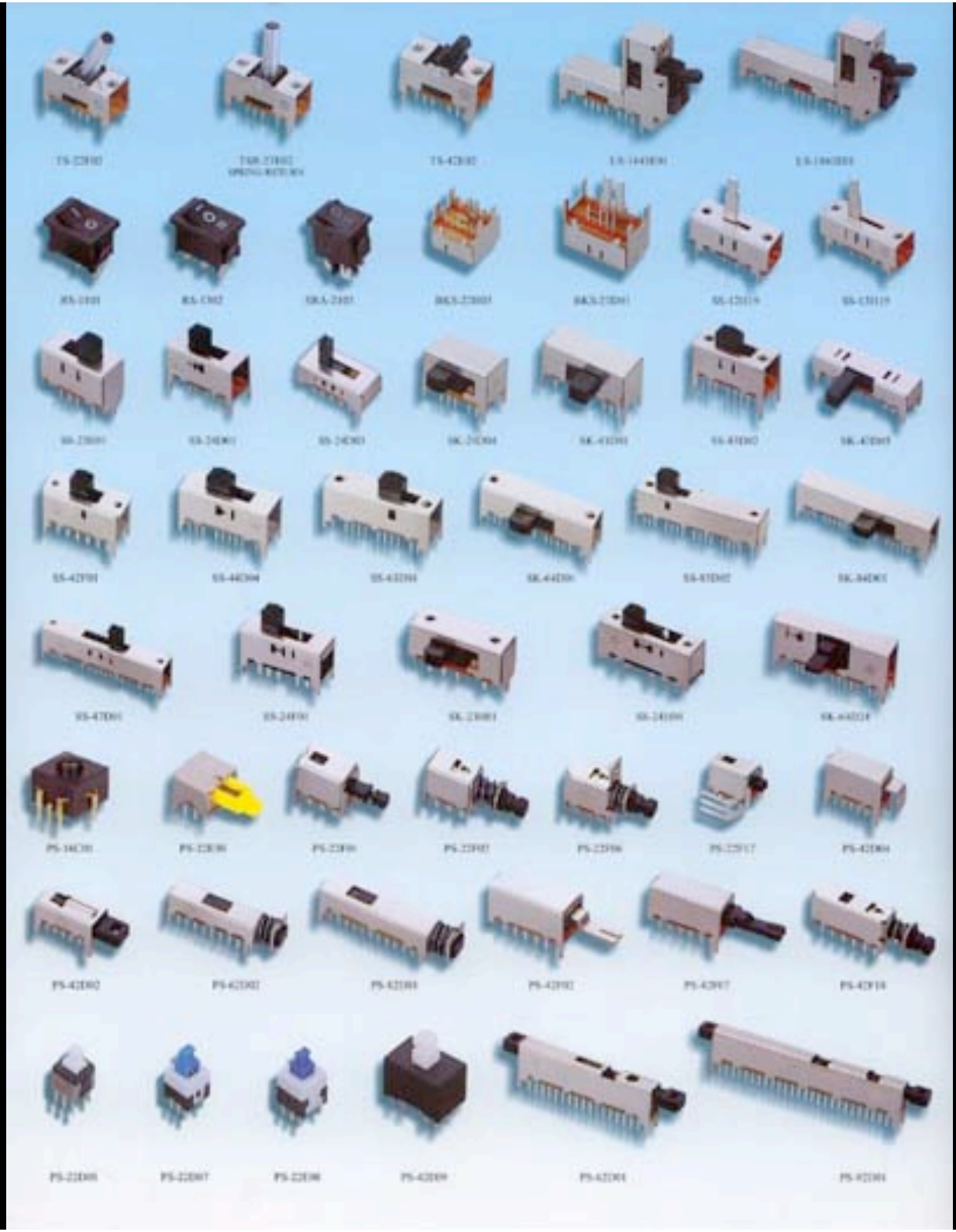


Switches/Buttons

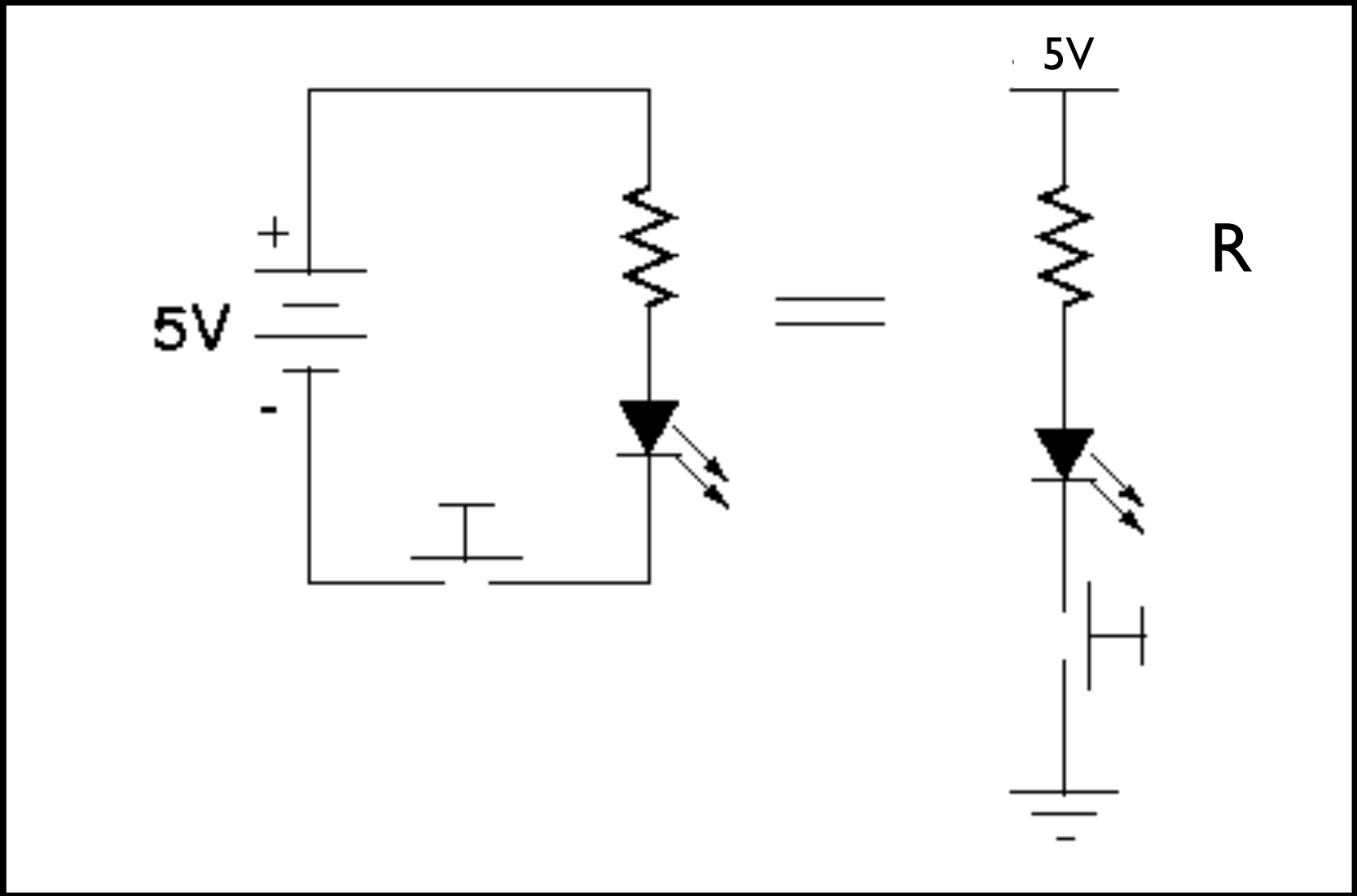


images from Wikipedia

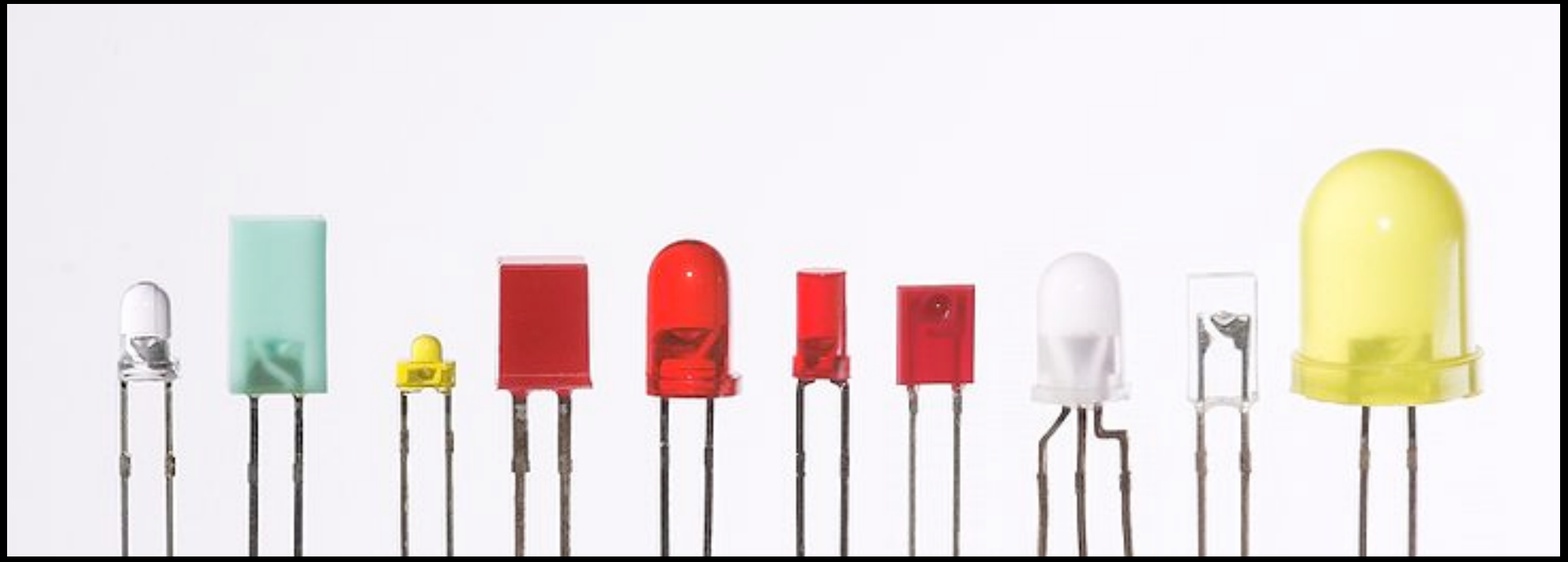
Switches/Buttons



Output in the Pushbutton LED circuit



LEDs



images from Wikipedia

LED datasheet

https://learn.adafruit.com/all-about-leds/the-led-datasheet

Kingbright

T-1 3/4 (5mm) SOLID STATE LAMP

Part Number: WP7113SRD/D Super Bright Red

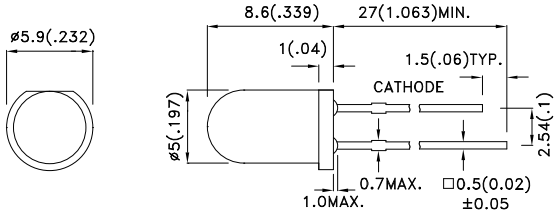
Features

- LOW POWER CONSUMPTION.
- POPULAR T-1 3/4 DIAMETER PACKAGE.
- GENERAL PURPOSE LEADS.
- RELIABLE AND RUGGED.
- LONG LIFE - SOLID STATE RELIABILITY.
- AVAILABLE ON TAPE AND REEL.
- RoHS COMPLIANT.

Description

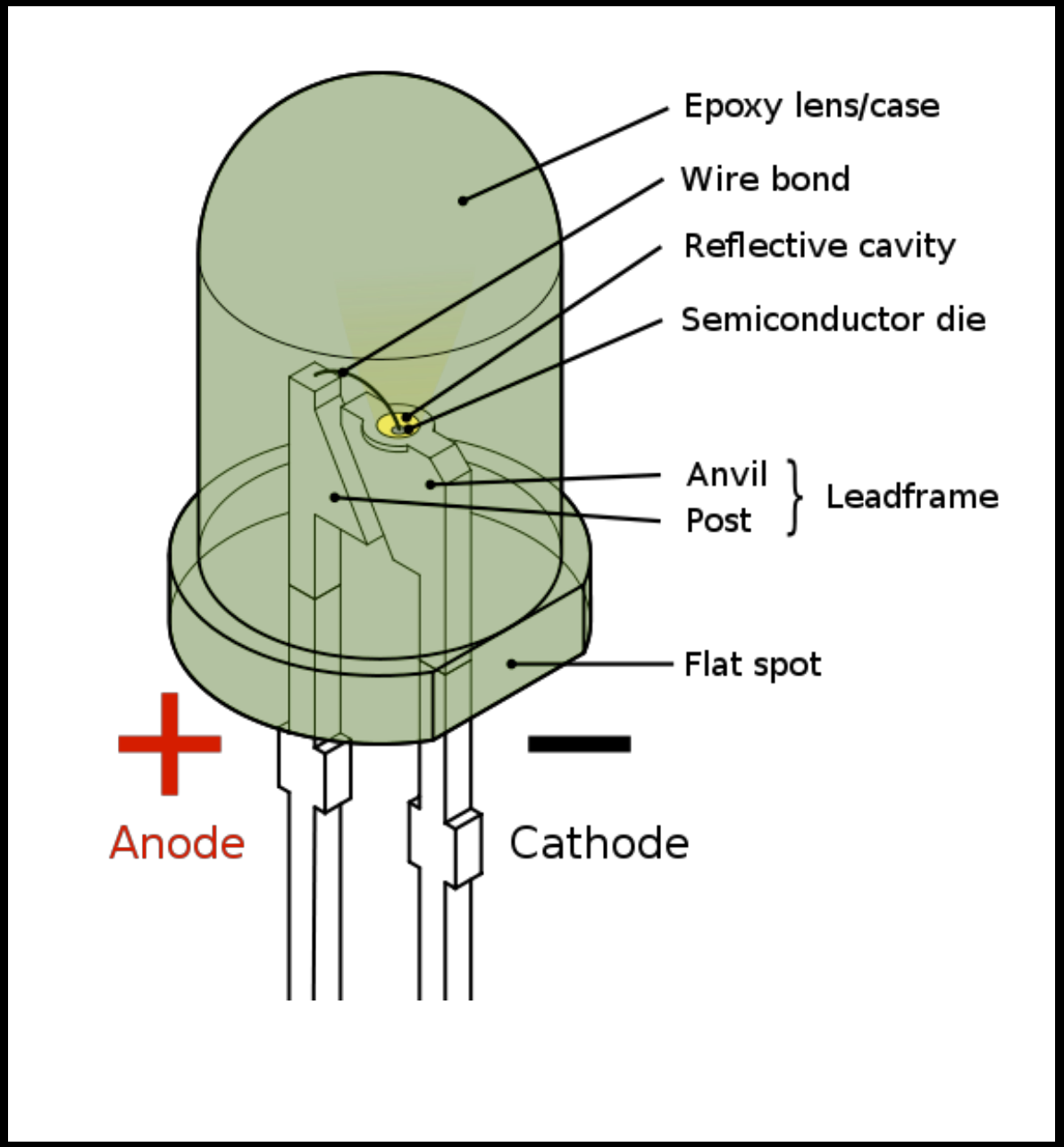
The Super Bright Red source color devices are made with Gallium Aluminum Arsenide Red Light Emitting Diode.

Package Dimensions

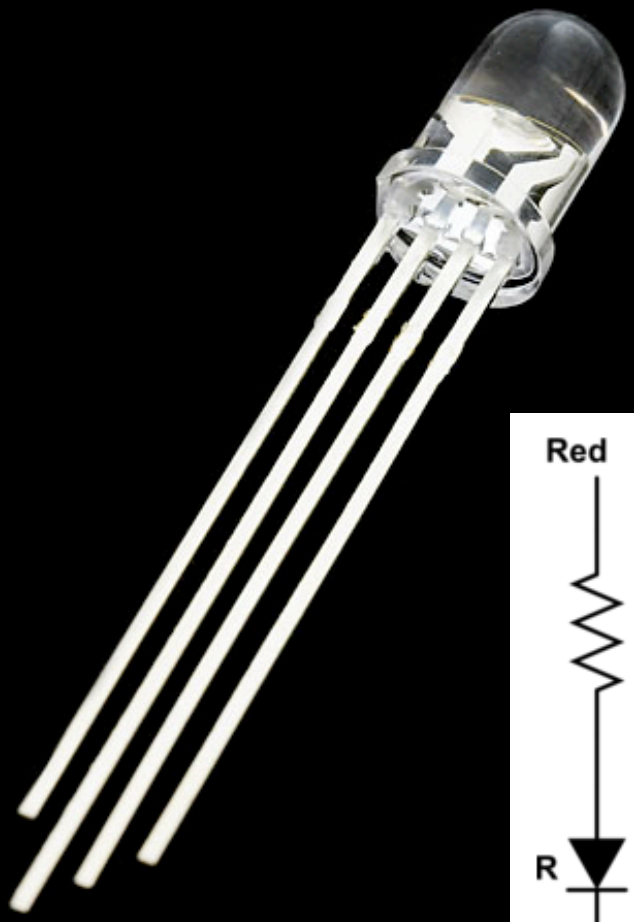


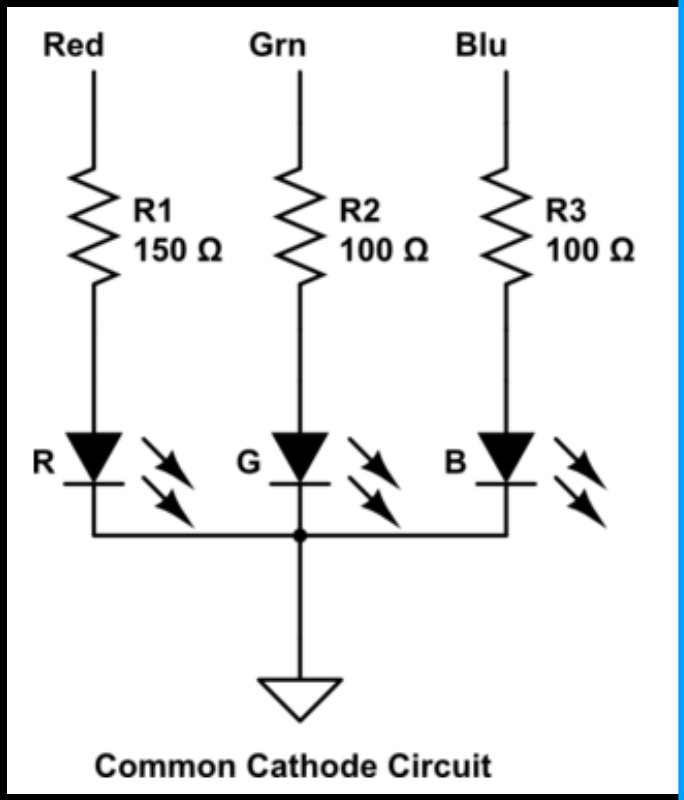
Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the leads emerge from the package.
4. Specifications are subject to change without notice.

Inside LEDs

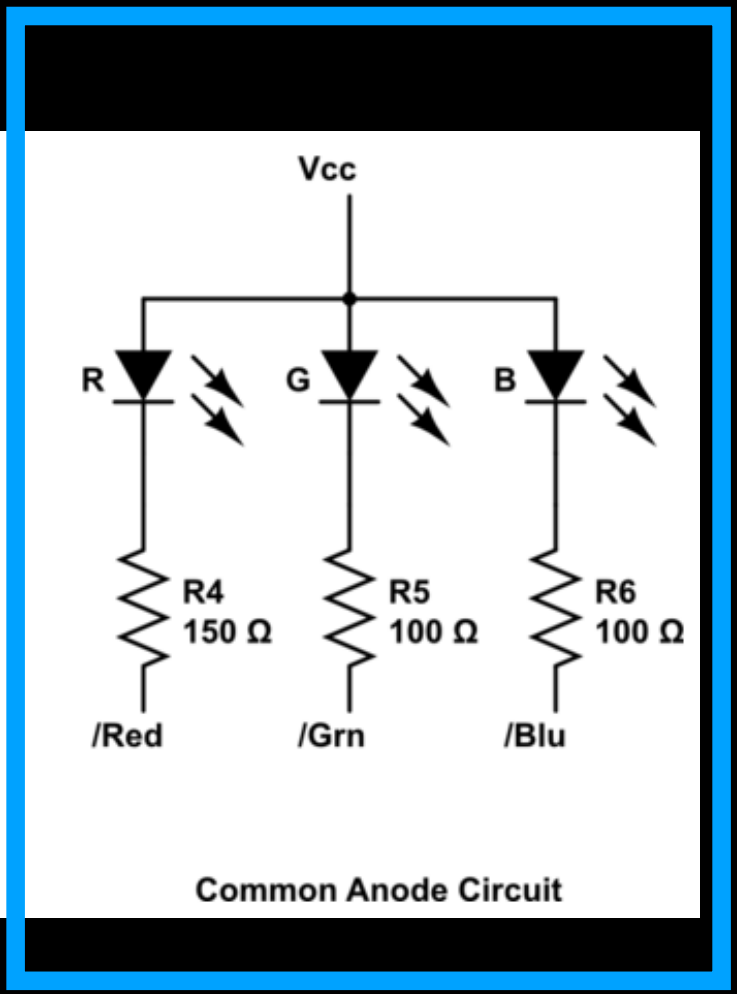

Epoxy lens/case
Wire bond
Reflective cavity
Semiconductor die
Anvil
Post
Leadframe
Flat spot
Anode
Cathode

RGB LEDs



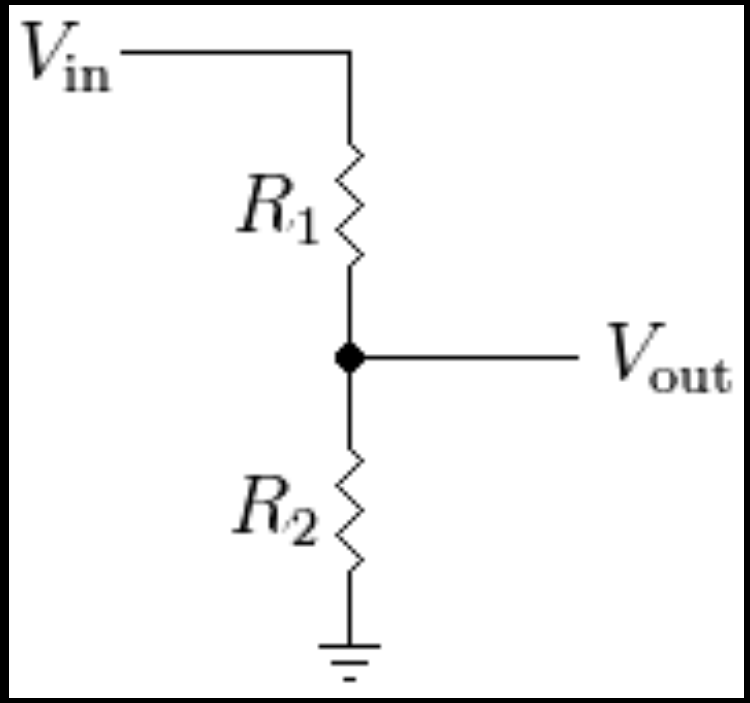


Common Cathode Circuit

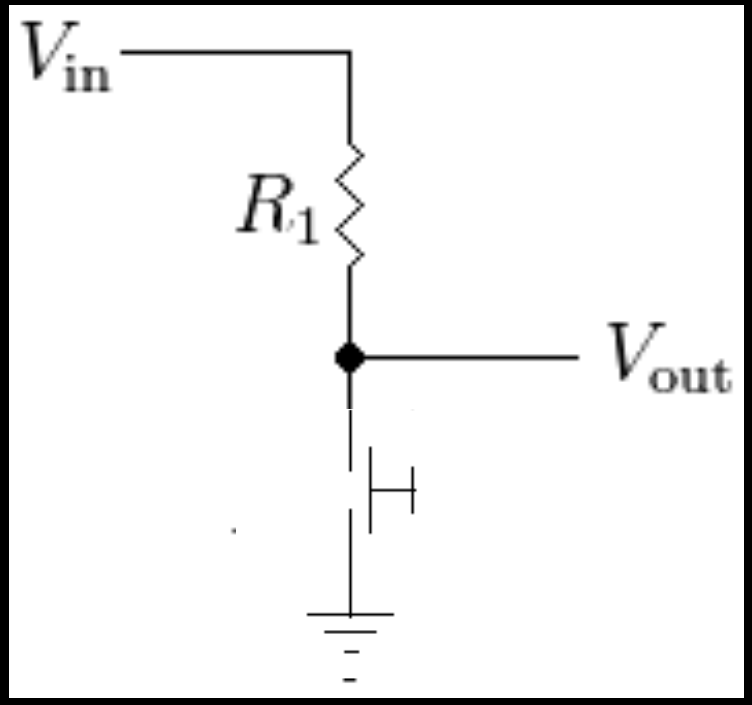


Common Anode Circuit

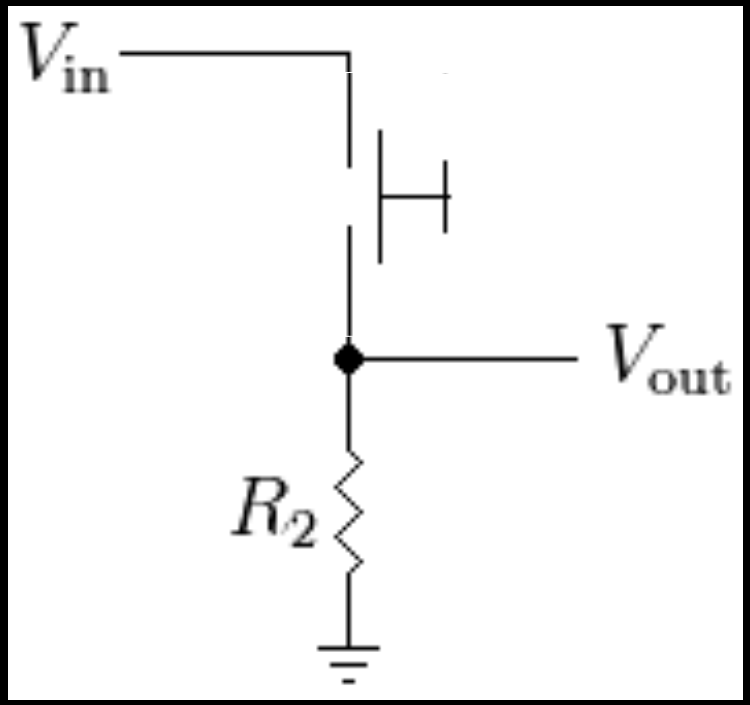
VOLTAGE DIVIDER CIRCUIT



PULL UP RESISTOR



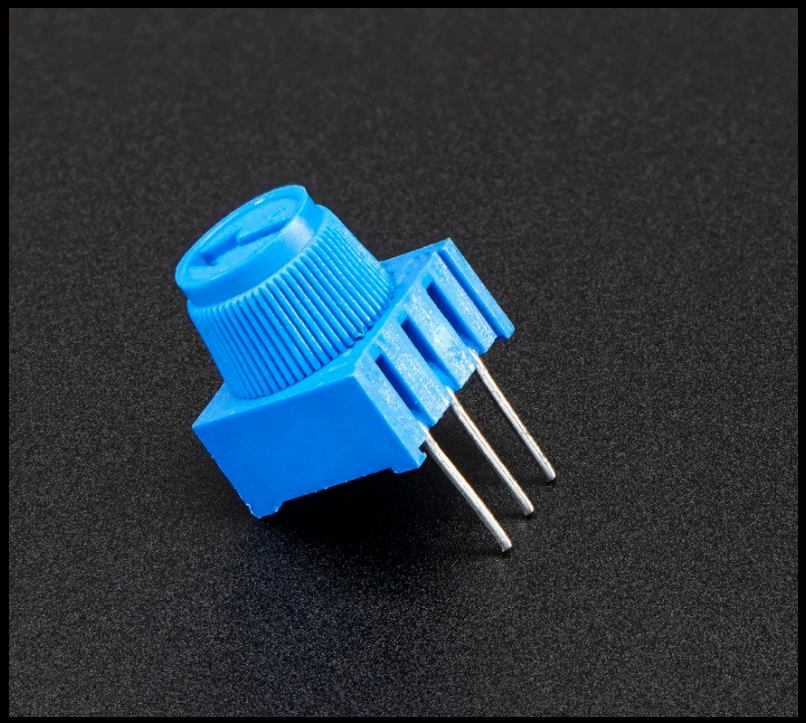
PULL DOWN RESISTOR

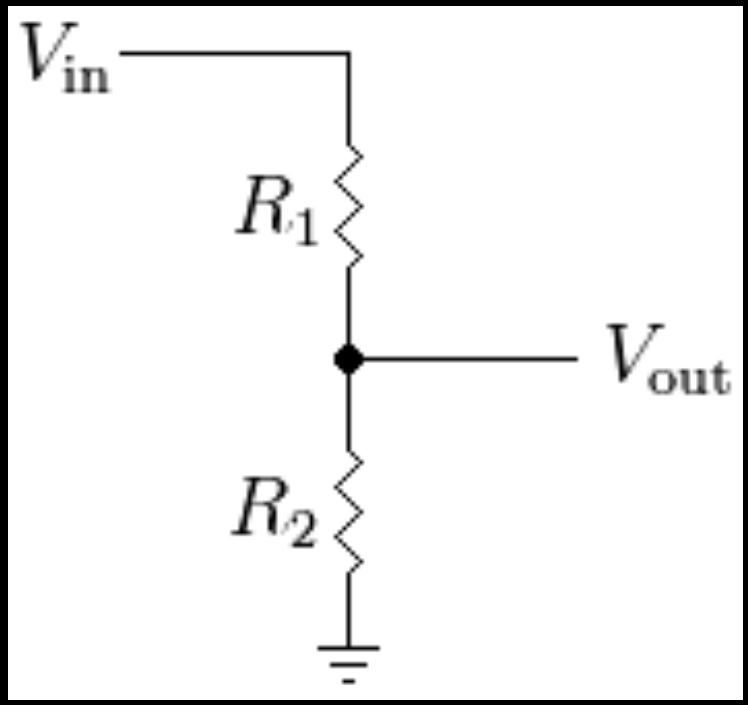


Adjusting the brightness of your LEDs

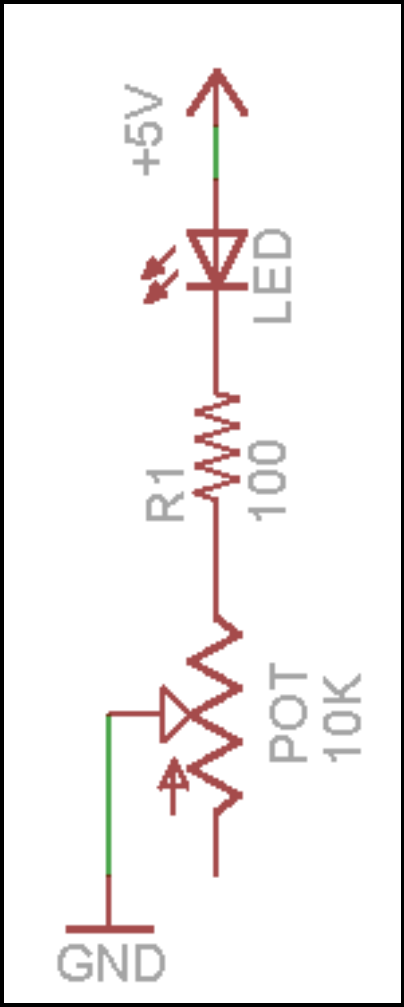
A potentiometer is a variable resistor,

a voltage divider in a package.





Adjusting the brightness of your LEDs



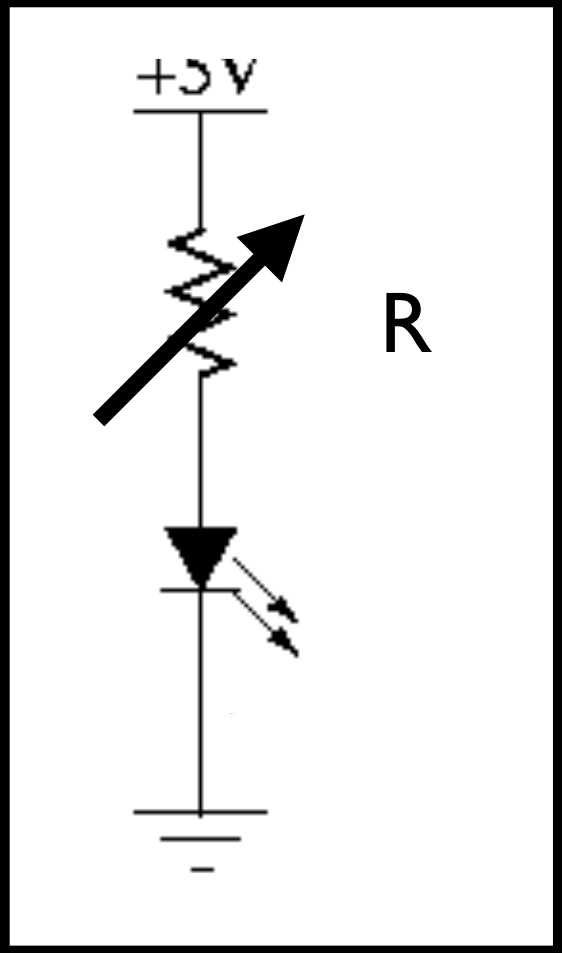
The LED is a diode, with a fixed voltage drop.

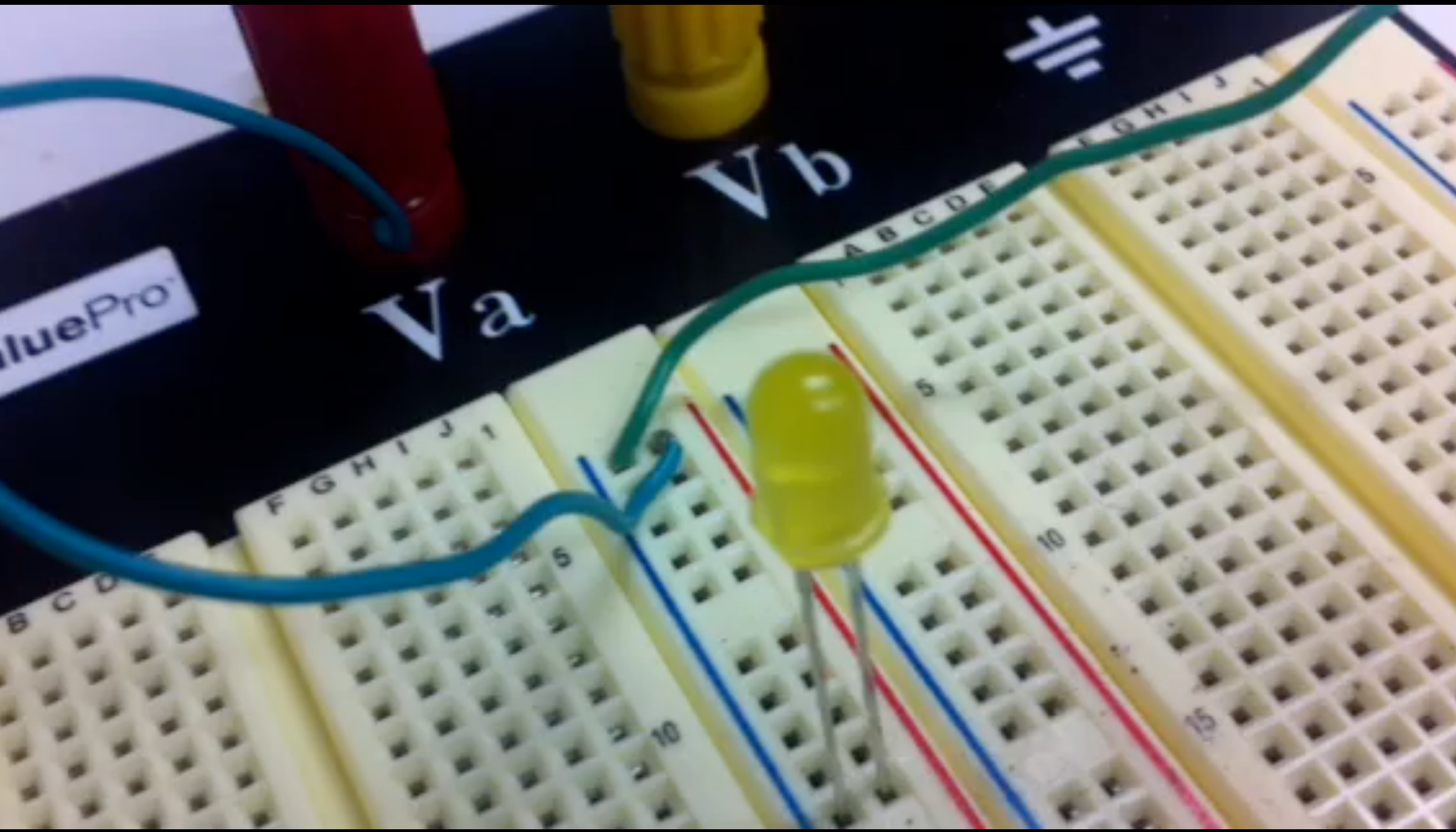
The Current is set by the series resistor

The brightness of the LED is a function of the current, created by the resistance.

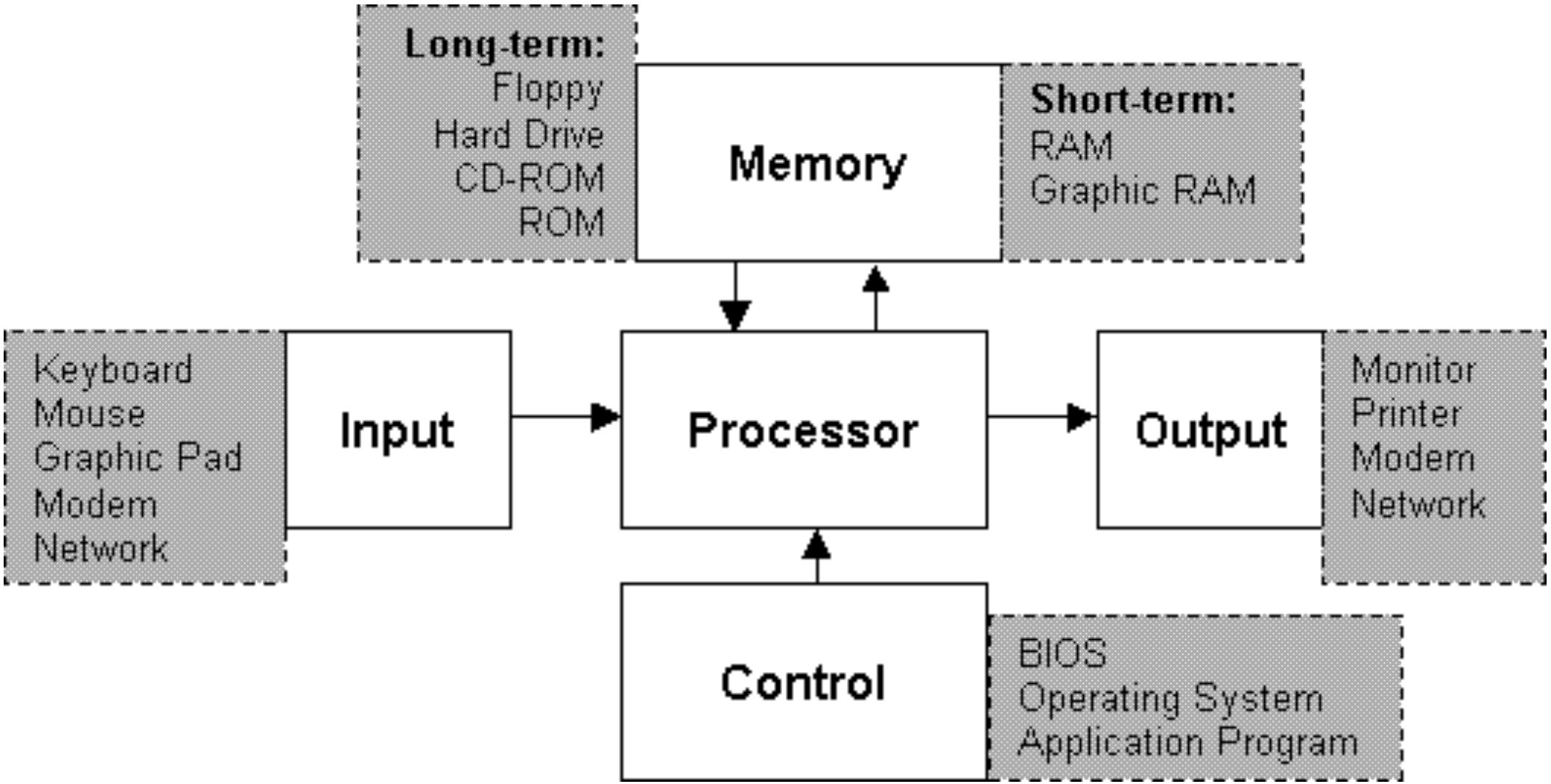
I= V/R

Why is this a BAD circuit?




Va
Vb

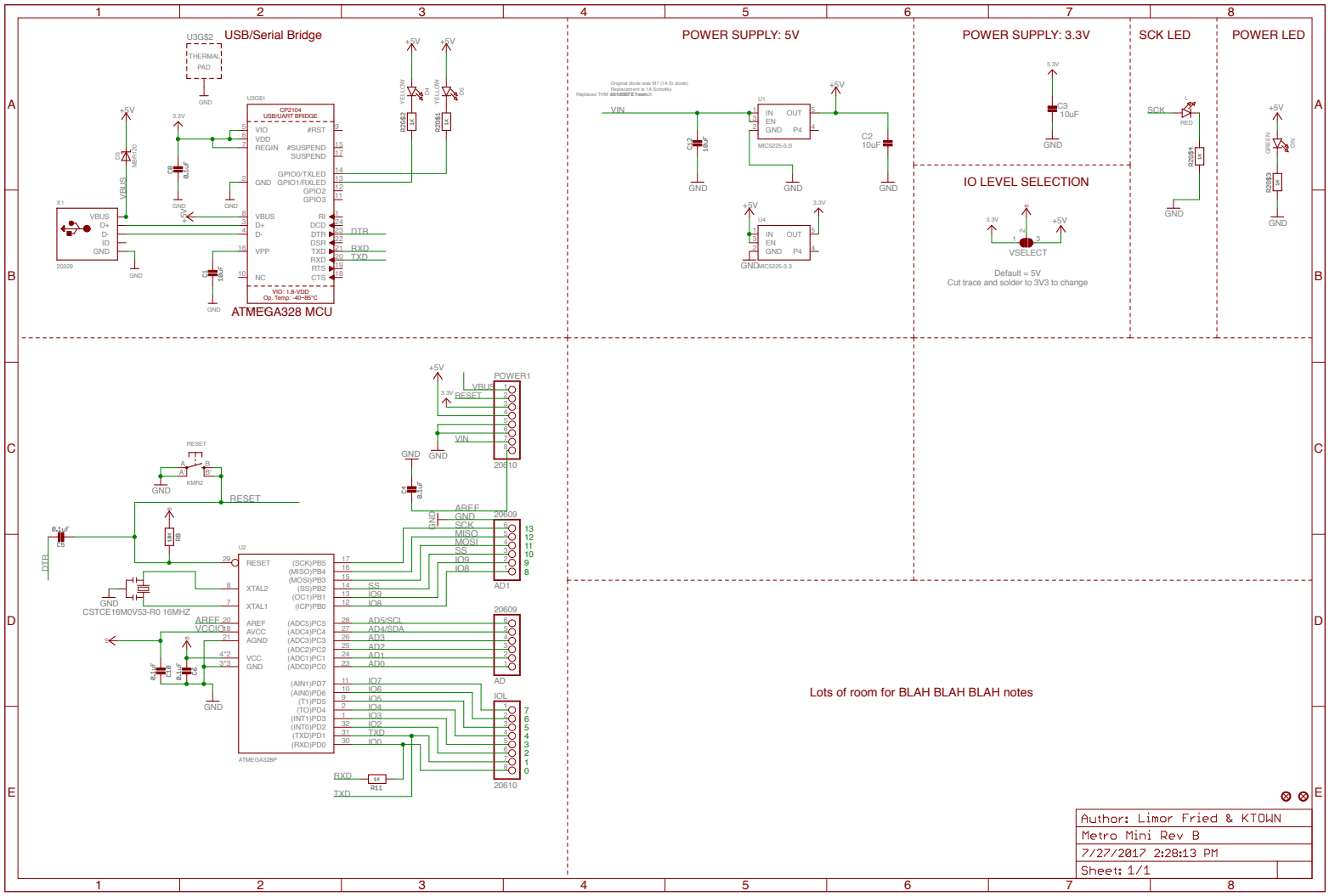
Microcontrollers are very small computers


Long-term:
Floppy
Hard Drive
CD-ROM
ROM
Memory
Short-term:
RAM
Graphic RAM
Keyboard
Mouse
Graphic Pad
Modem
Network
Input
Processor
Output
Monitor
Printer
Modem
Network
Control
BIOS
Operating System
Application Program

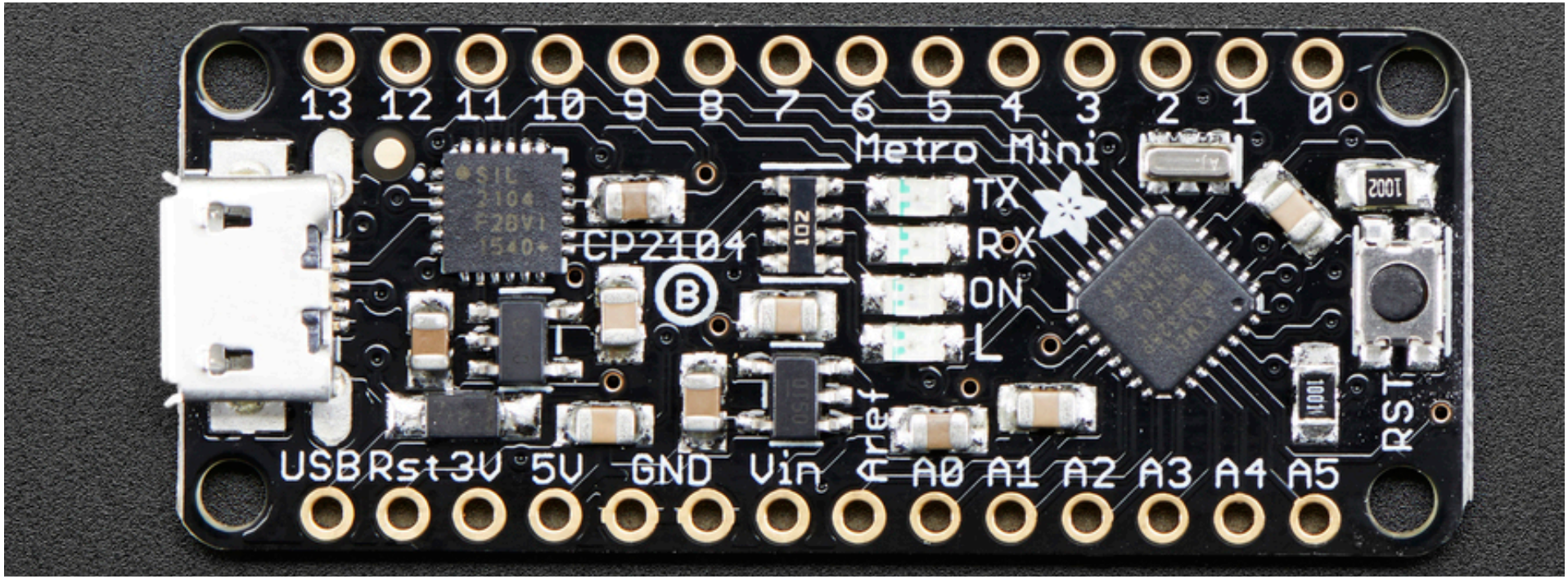
We are using Arduino.

This is a family of microcontroller boards and an associated integrated development environment (IDE)

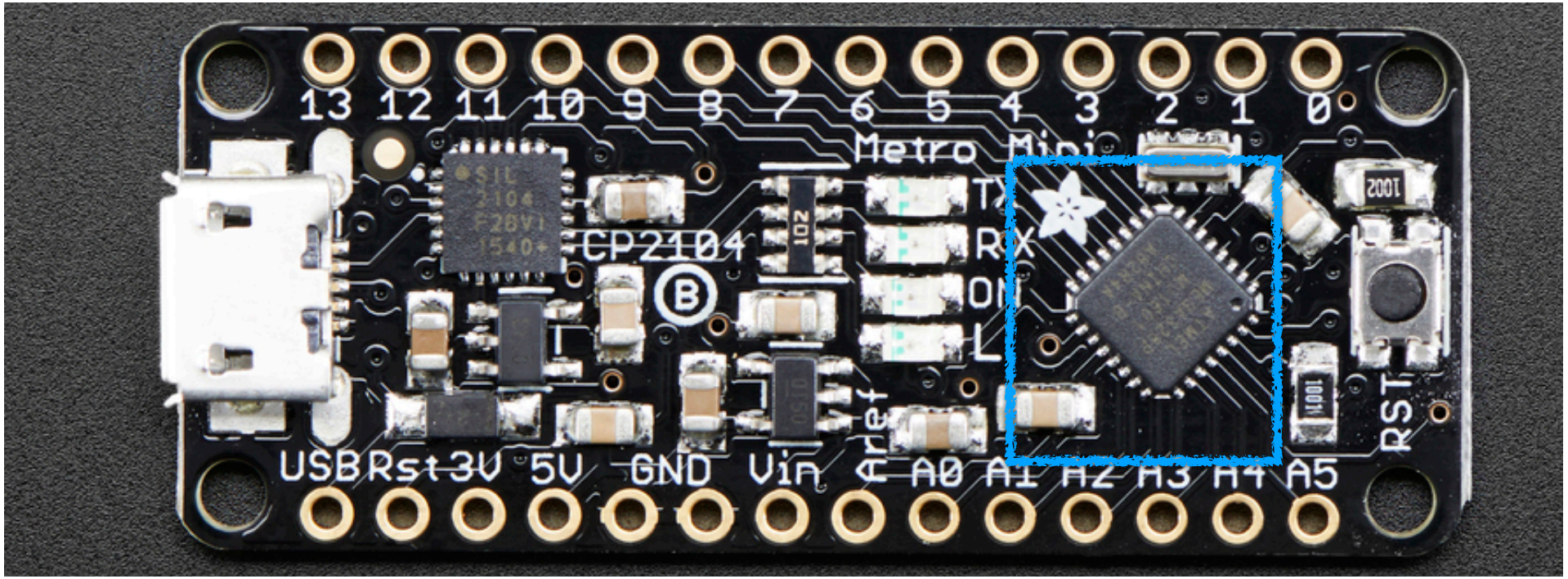
Schematic

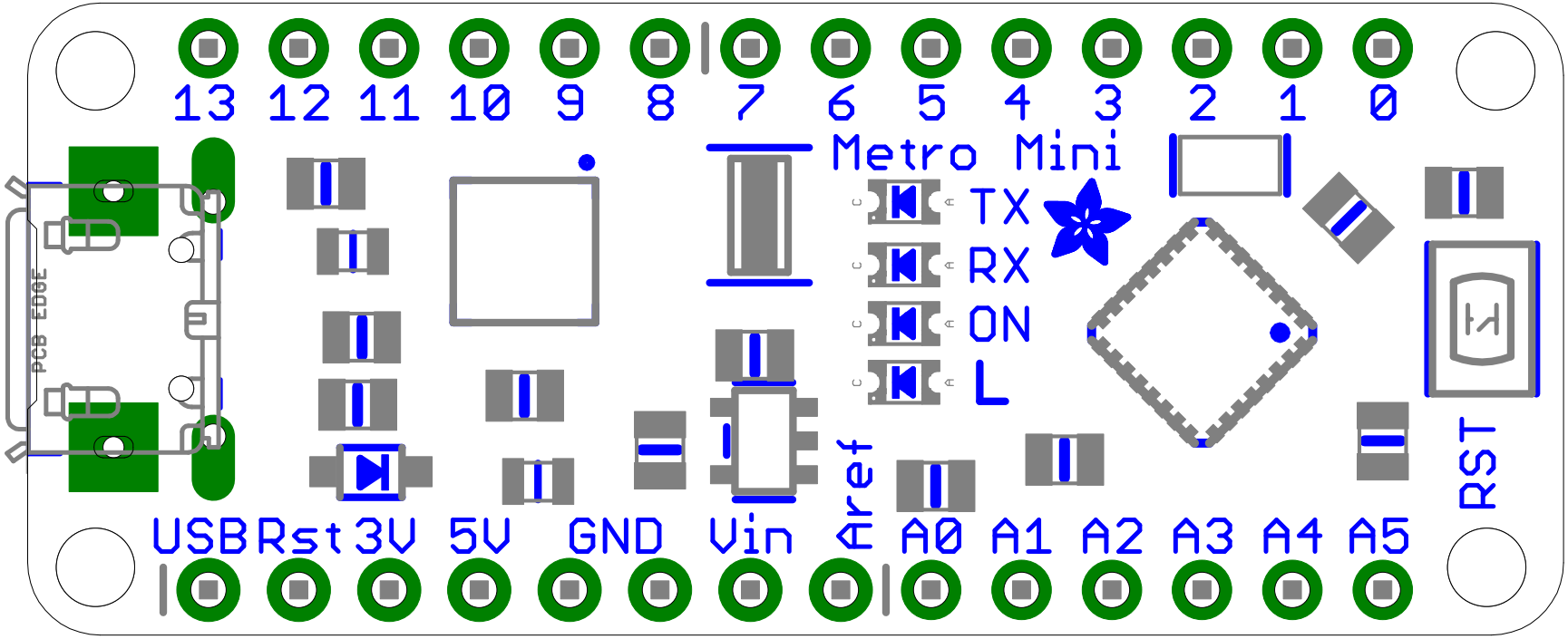


Physical Hardware



Microcontroller



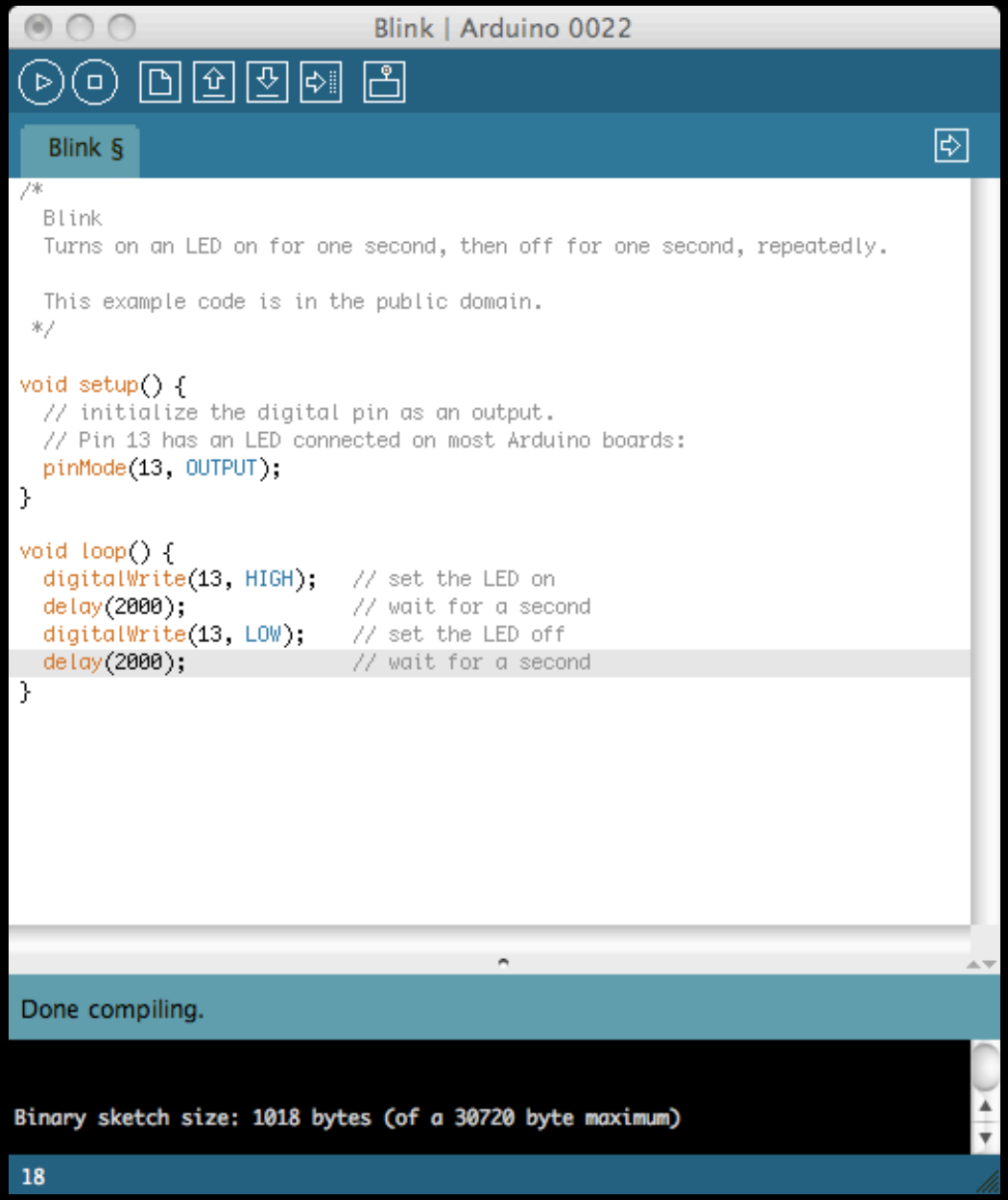

13
12
11
10
9
8
7
6
5
4
3
2
1
0
Metro Mini
TX
RX
ON
L
PCB EDGE
USB
Rst
3V
5V
GND
Vin
Aref
A0
A1
A2
A3
A4
A5
RST

Arduino Software Environment

IDE | Structure of Arduino programs |

Flashing programs

Sketch


Blink | Arduino 0022
Blink §
/*
Blink
Turns on an LED on for one second, then off for one second, repeatedly.
This example code is in the public domain.
*/
void setup() {
// initialize the digital pin as an output.
// Pin 13 has an LED connected on most Arduino boards:
pinMode(13, OUTPUT);
}
void loop() {
digitalWrite(13, HIGH); // set the LED on
delay(2000); // wait for a second
digitalWrite(13, LOW); // set the LED off
delay(2000); // wait for a second
}
Done compiling.
Binary sketch size: 1018 bytes (of a 30720 byte maximum)
18

Sketch

```
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  This example code is in the public domain.
 */

void setup() {
  // initialize the digital pin as an output.
  // Pin 13 has an LED connected on most Arduino boards:
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);  // set the LED on
  delay(2000);             // wait for a second
  digitalWrite(13, LOW);   // set the LED off
  delay(2000);             // wait for a second
}
```

What happens when we flash code?

1. Code from libraries (if any) are included (linked).
2. Code is checked for errors (verified).
3. Code is “cross-compiled” into machine code (a.k.a machine code or hex code) using avr-gcc.
4. Code is written to the program memory of the Arduino over USB using avrdude.

Flash Demonstration