Circuits & Microcontrollers

September 1, 2020

INTERACTIVE DEVICE DESIGN

September 1, 2020

Tour of class kit and toolbox

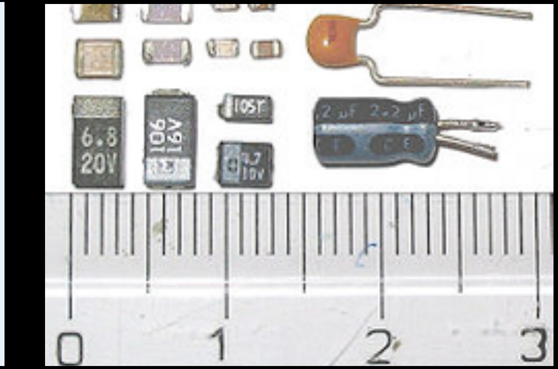
Circuits

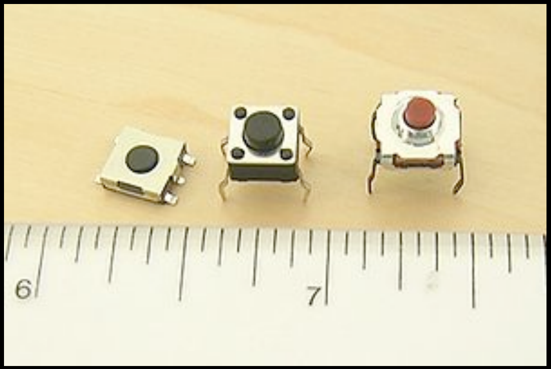
Common Components | Voltage | Current | Resistance
Ohms Law | Watt’s Law | Series and Parallel Circuits
Voltage Divider | Pull-up and Pull-down circuits

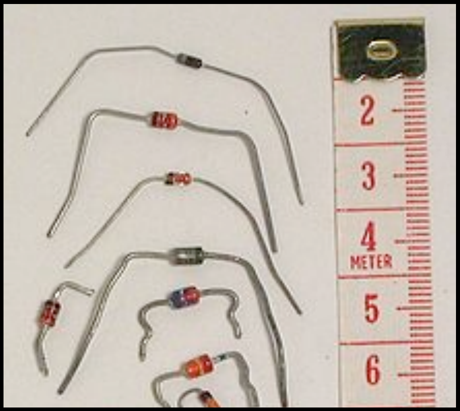
Electrical circuits are networks of electrical elements that contain a closed loop which allows electrons to flow through the elements.

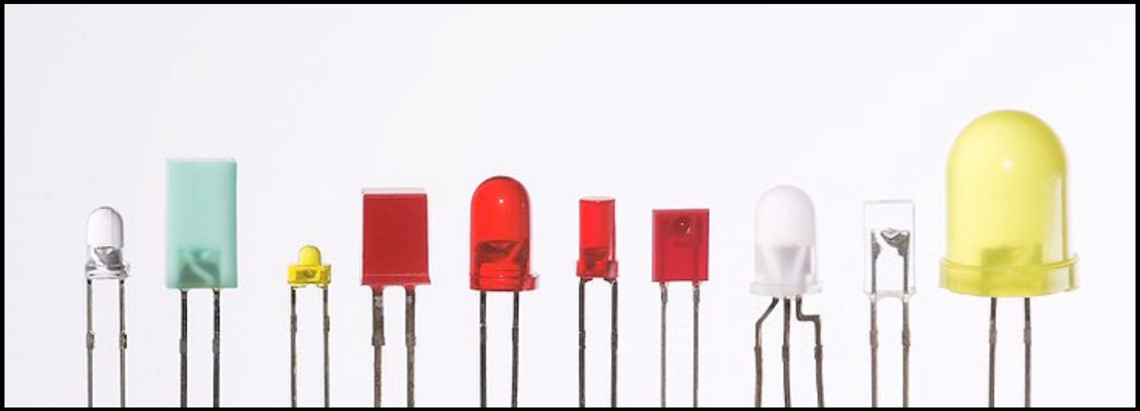
This electron flow allows the circuits to do things.

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

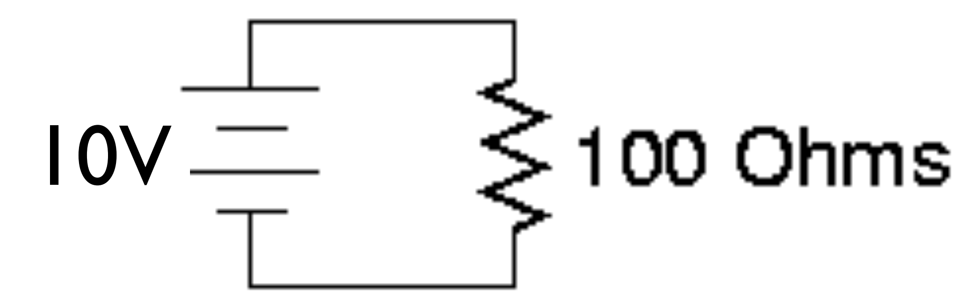
$$V=IR$$

Watt’s Law states that Power = Voltage x Current

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

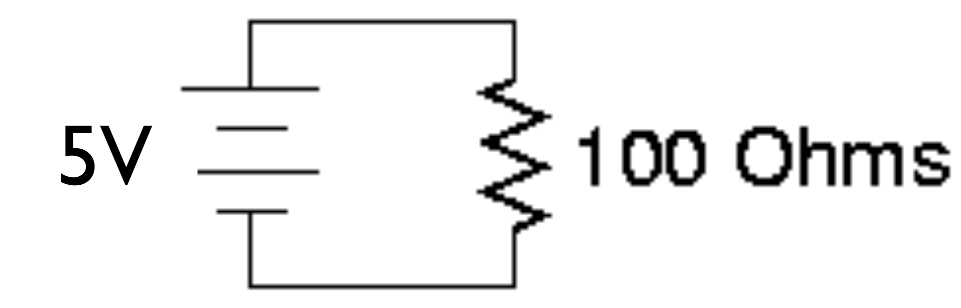
Ohm’s Law states that Voltage = Current X Resistance

V=IR



Ohm's Law states that Voltage = Current X Resistance

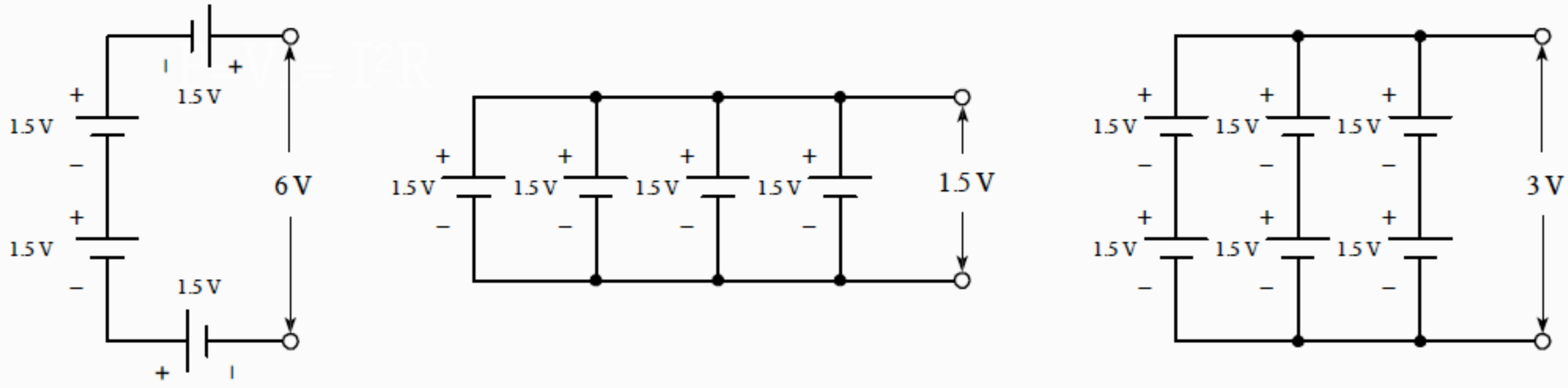
$V=IR$



Where does Voltage come from?

images from Wikipedia

Power can come from supplies or batteries.

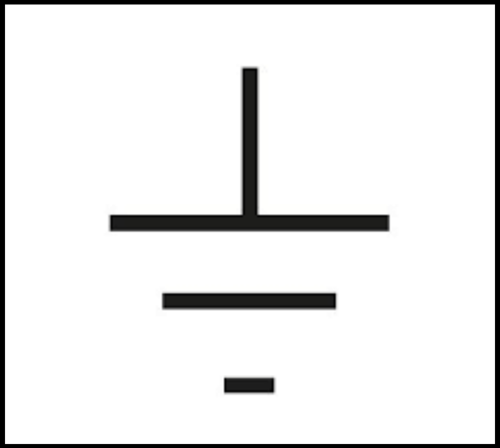


Increasing the voltage

Increasing the capacity

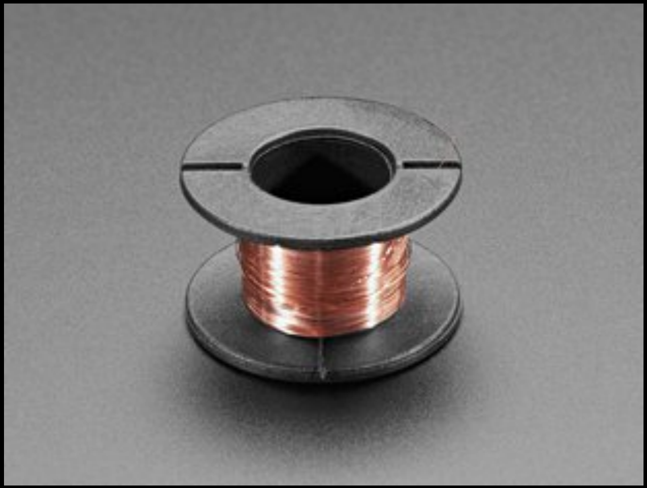
Increasing both voltage and capacity

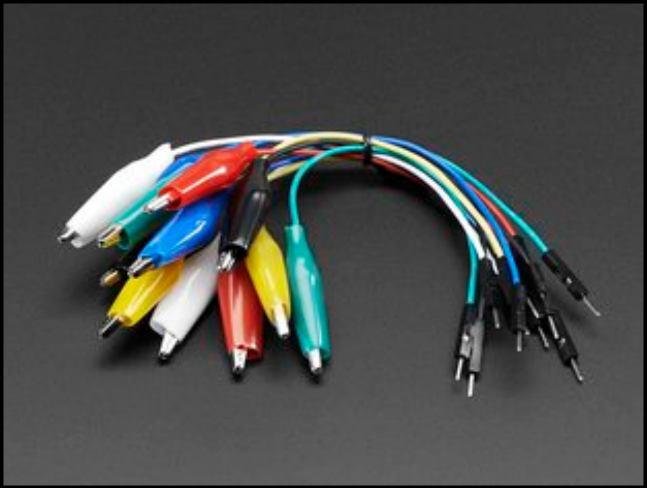
Ground symbol

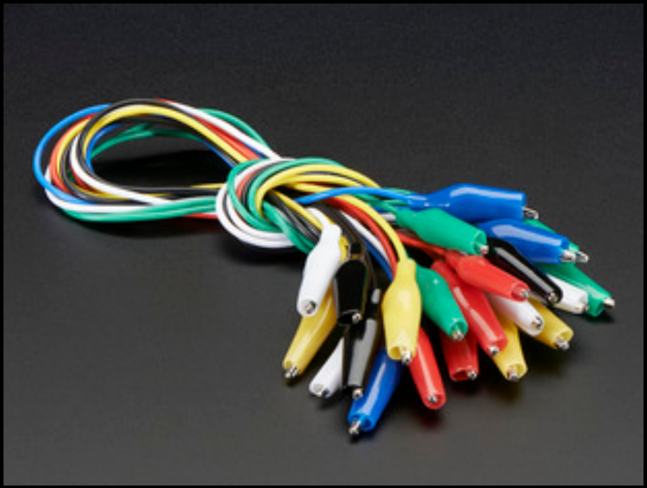


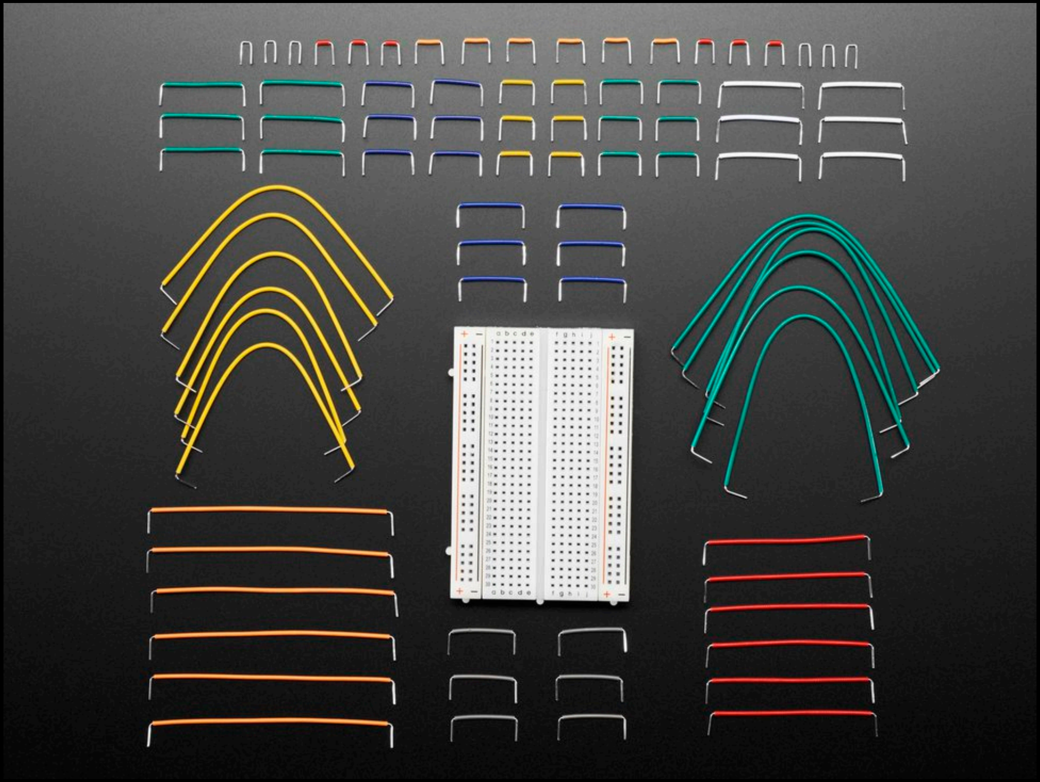
Current flows with almost no resistance in metal.

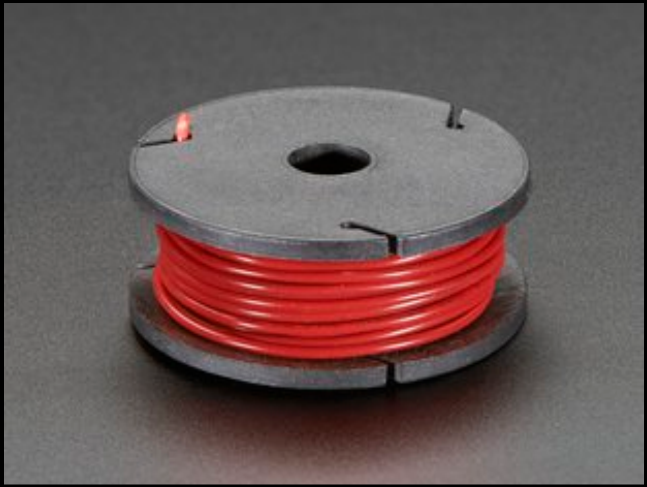
Things that are connected by direct metal-on-metal contact share the same voltage.



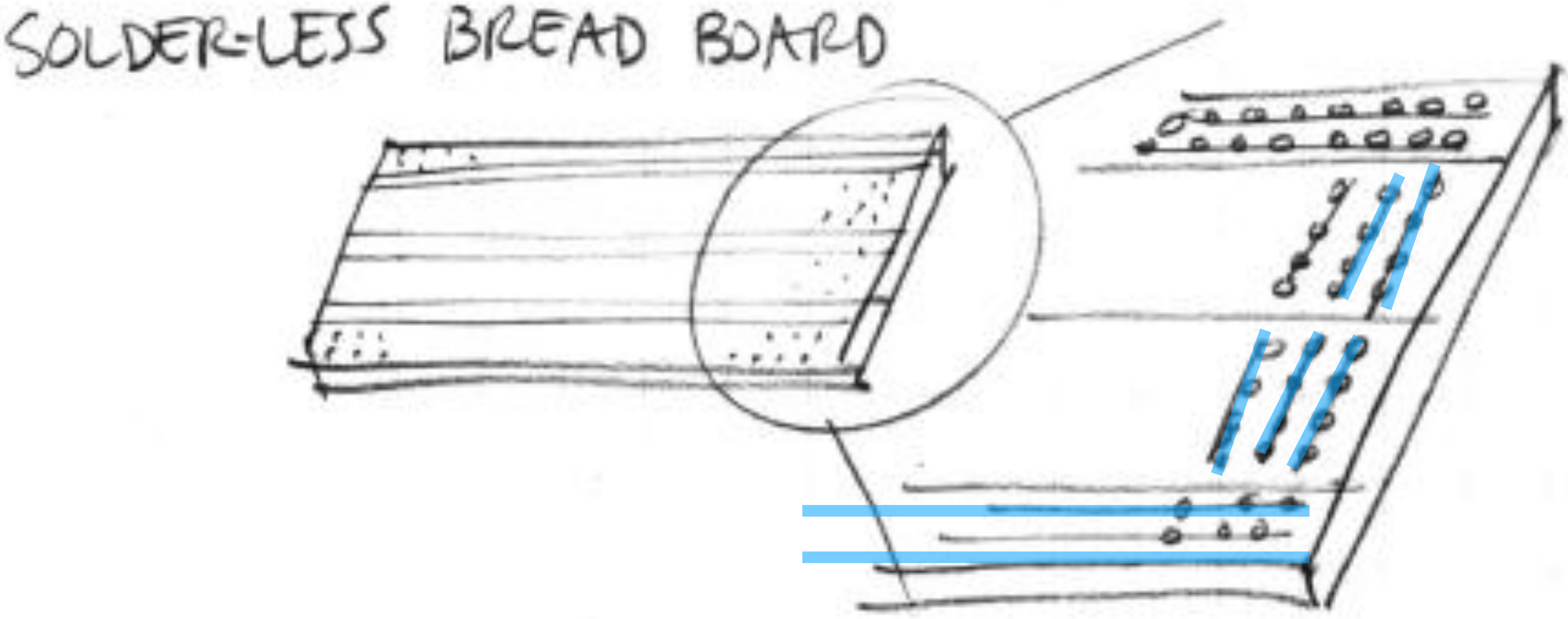








images from Adafruit



sketch by Bill Verplank

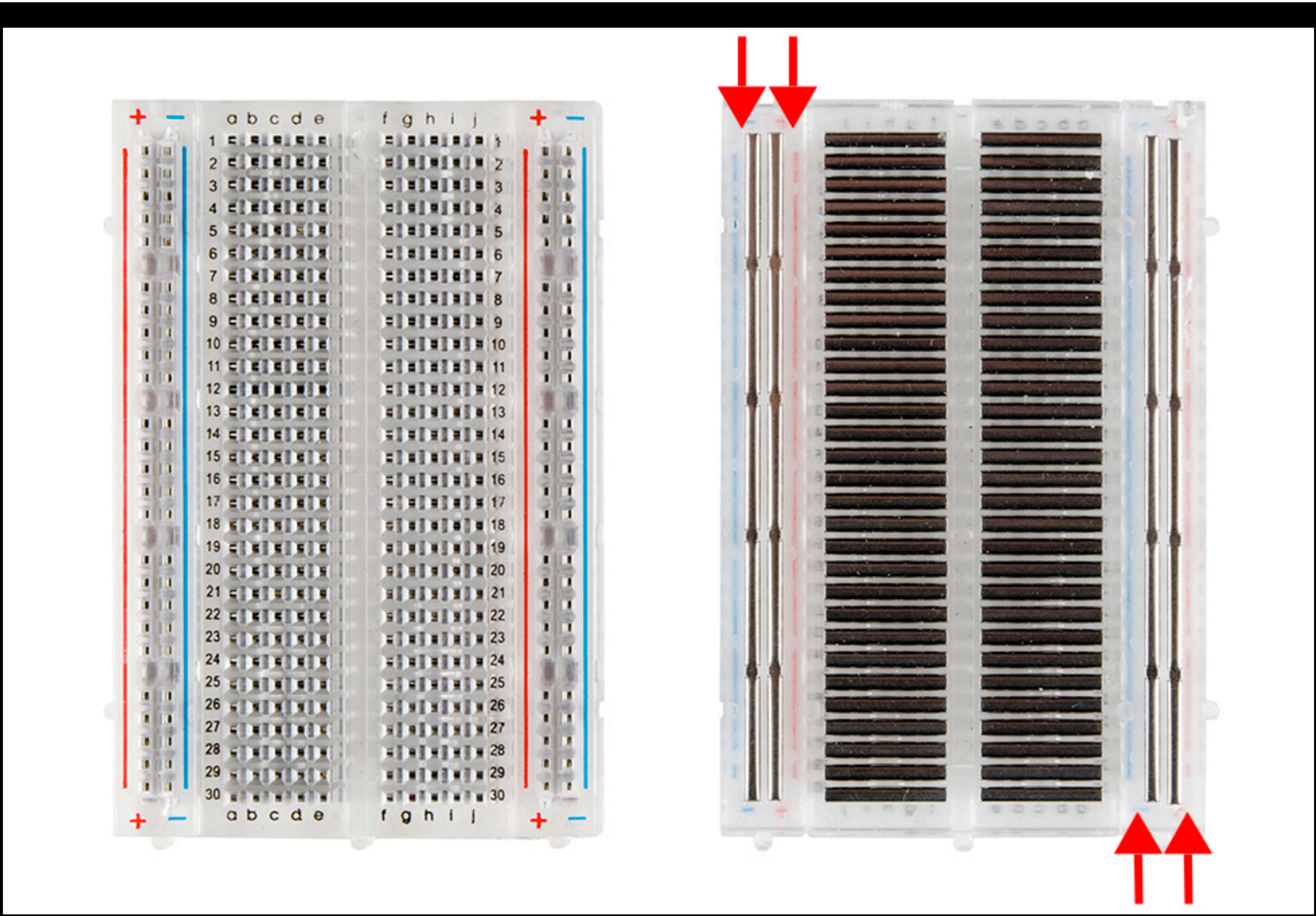


image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

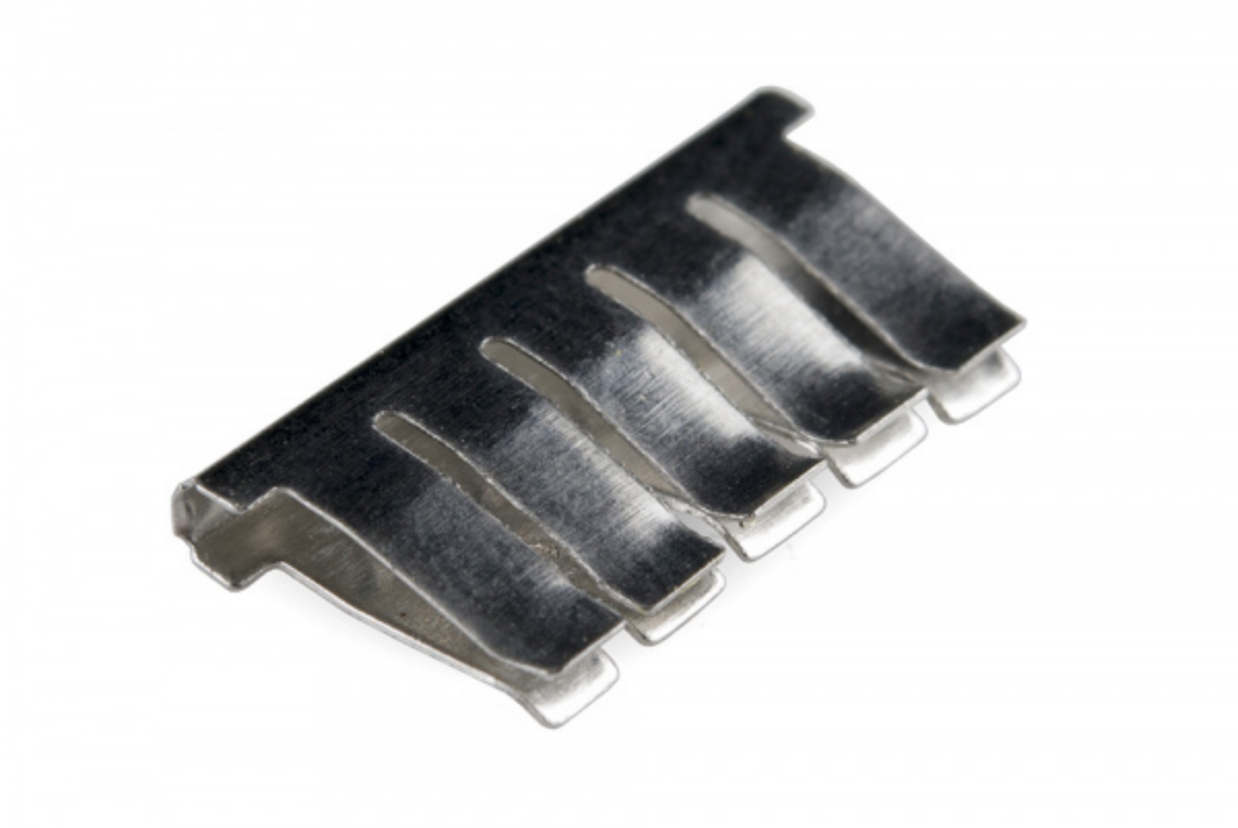
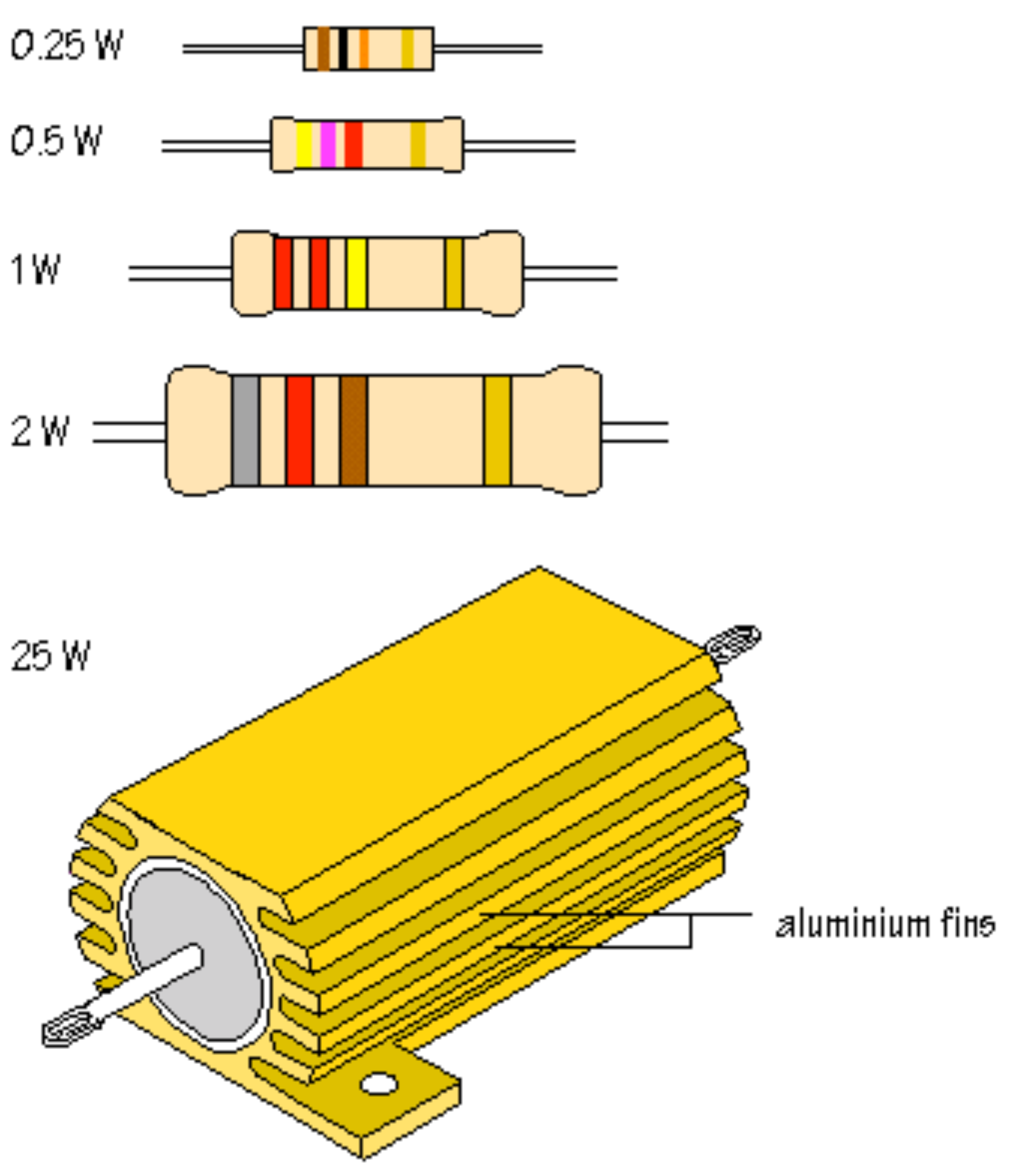


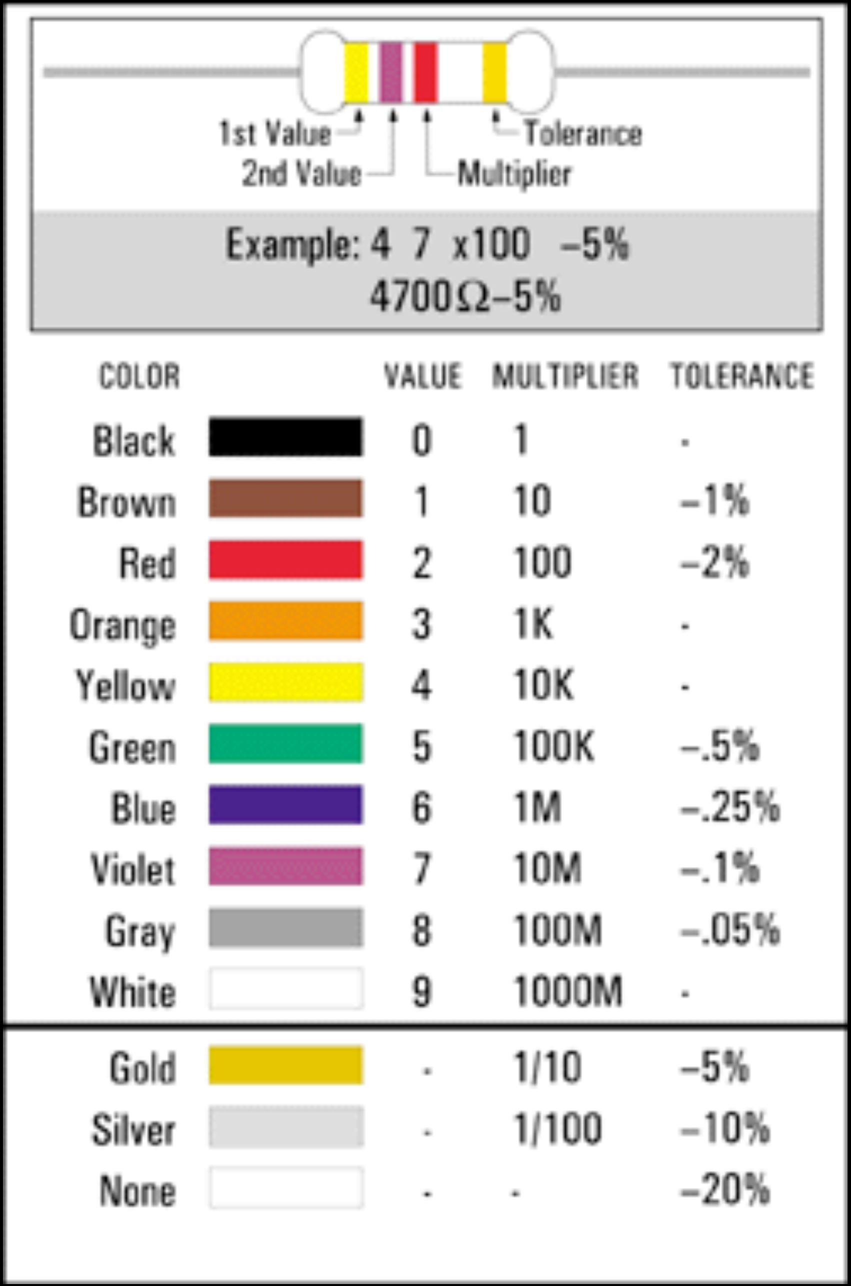
image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard

Resistance regulates the current in a circuit.



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

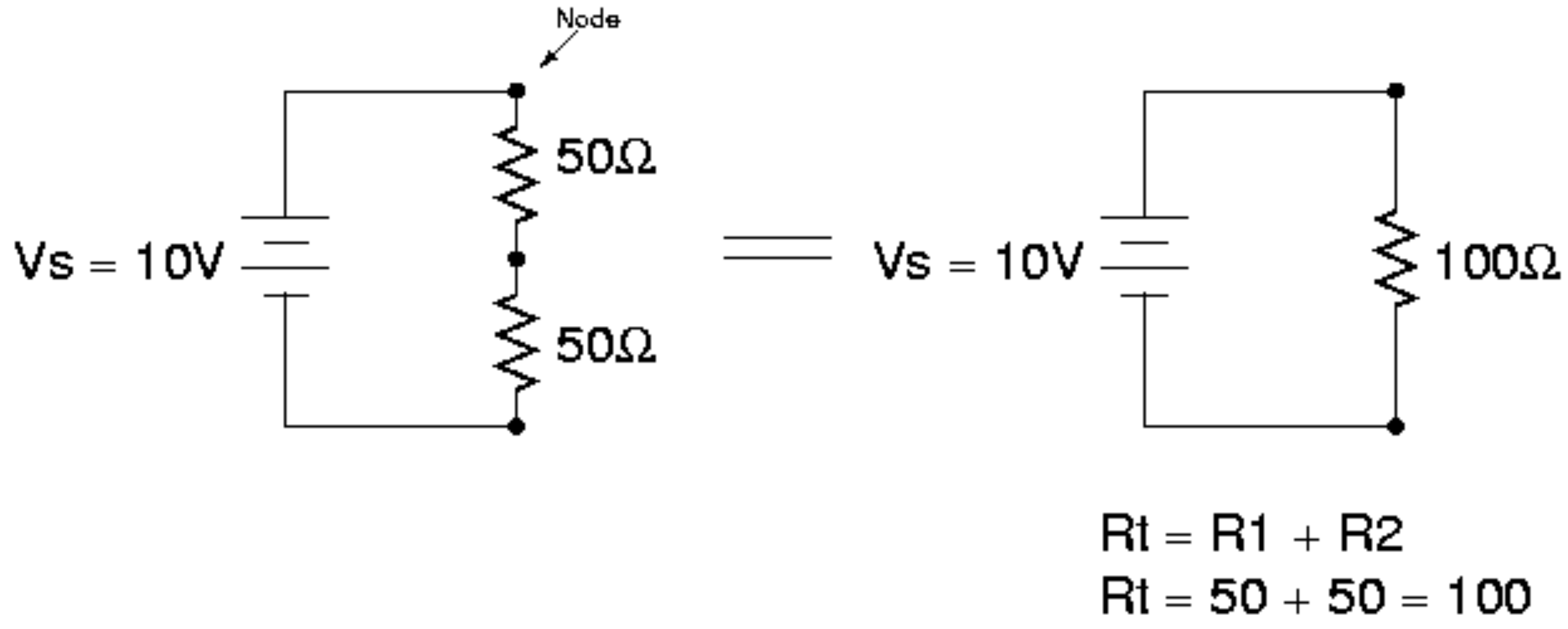
READING RESISTANCE VALUES


1st Value
2nd Value
Multiplier
Tolerance

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%

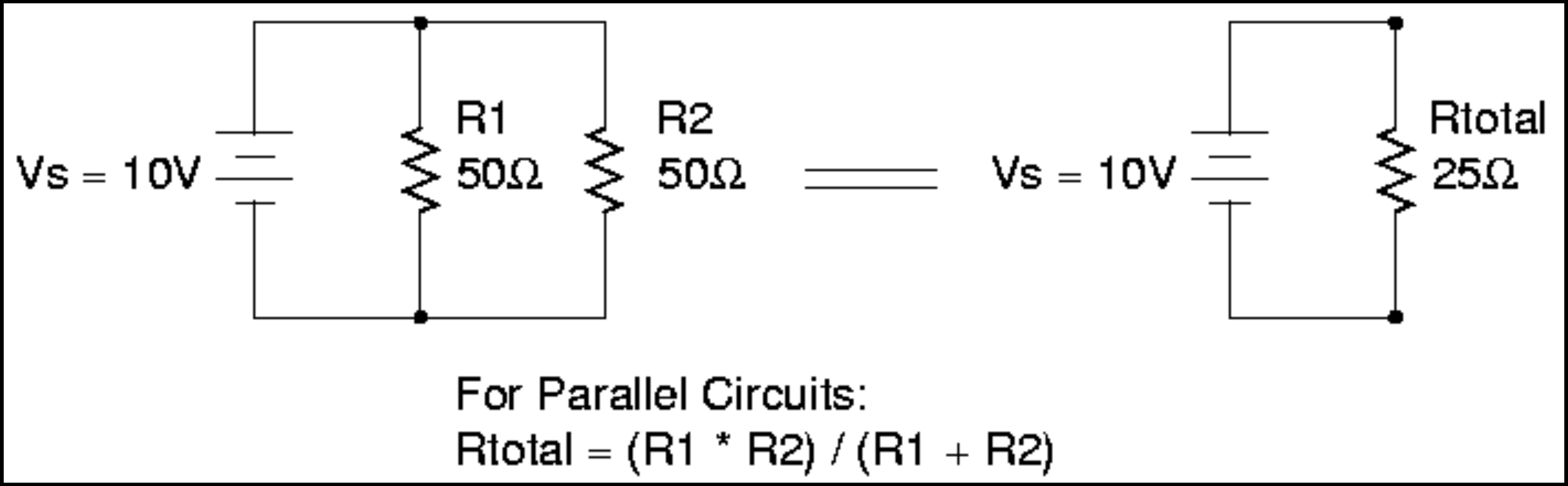
Resistors in series ADD



Rt = R1 + R2

Rt = 50 + 50 = 100

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

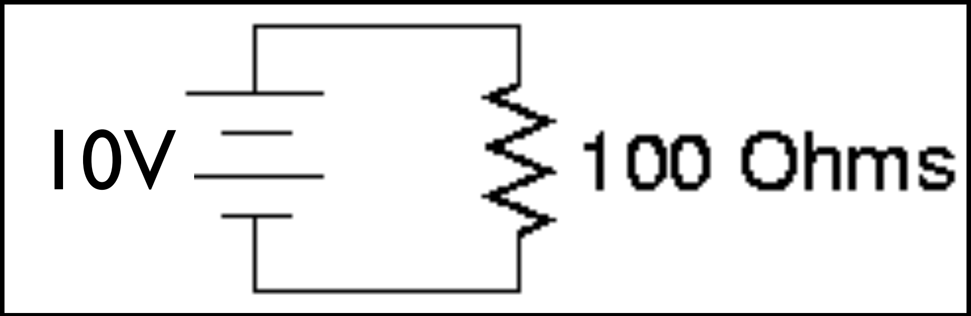
$$P=VI= I^2R$$

V=IR P=VI

V=?

I =?

P=?

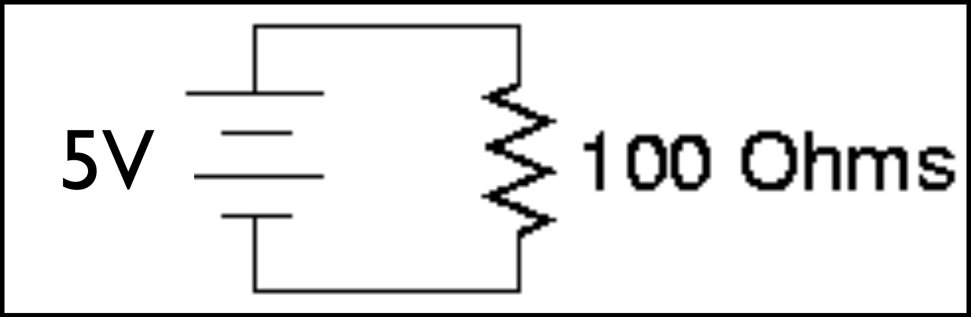


V=IR P=VI

V=?

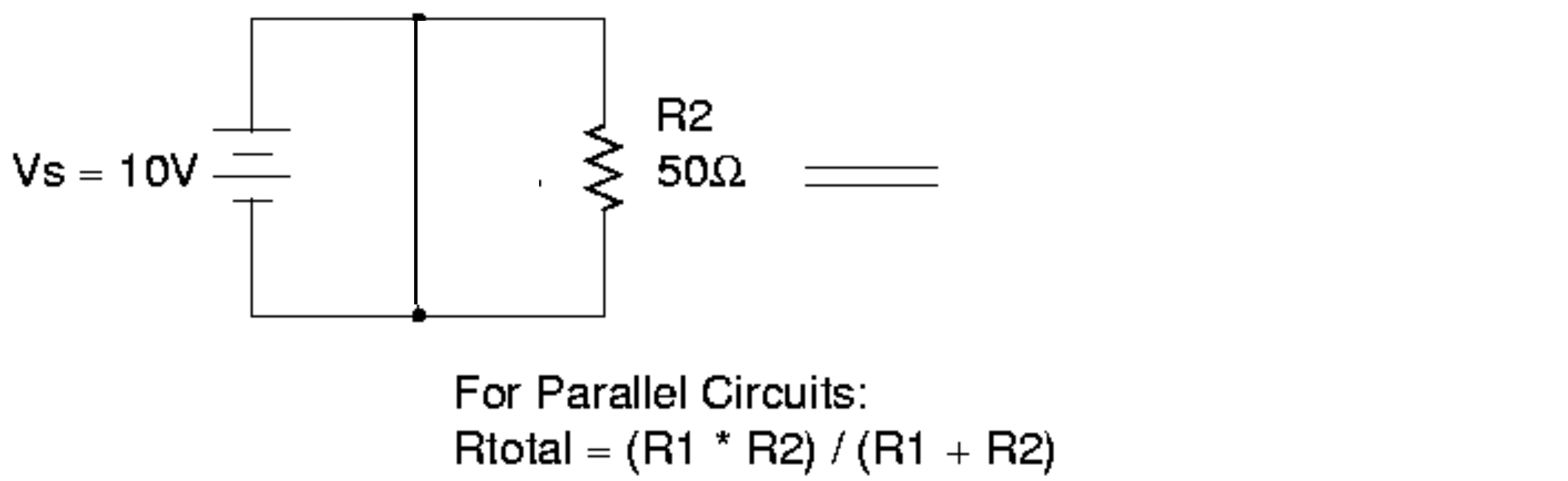
I =?

P=?



What is a SHORT CIRCUIT???

Why is this bad?



For Parallel Circuits:
Rtotal = (R1 * R2) / (R1 + R2)

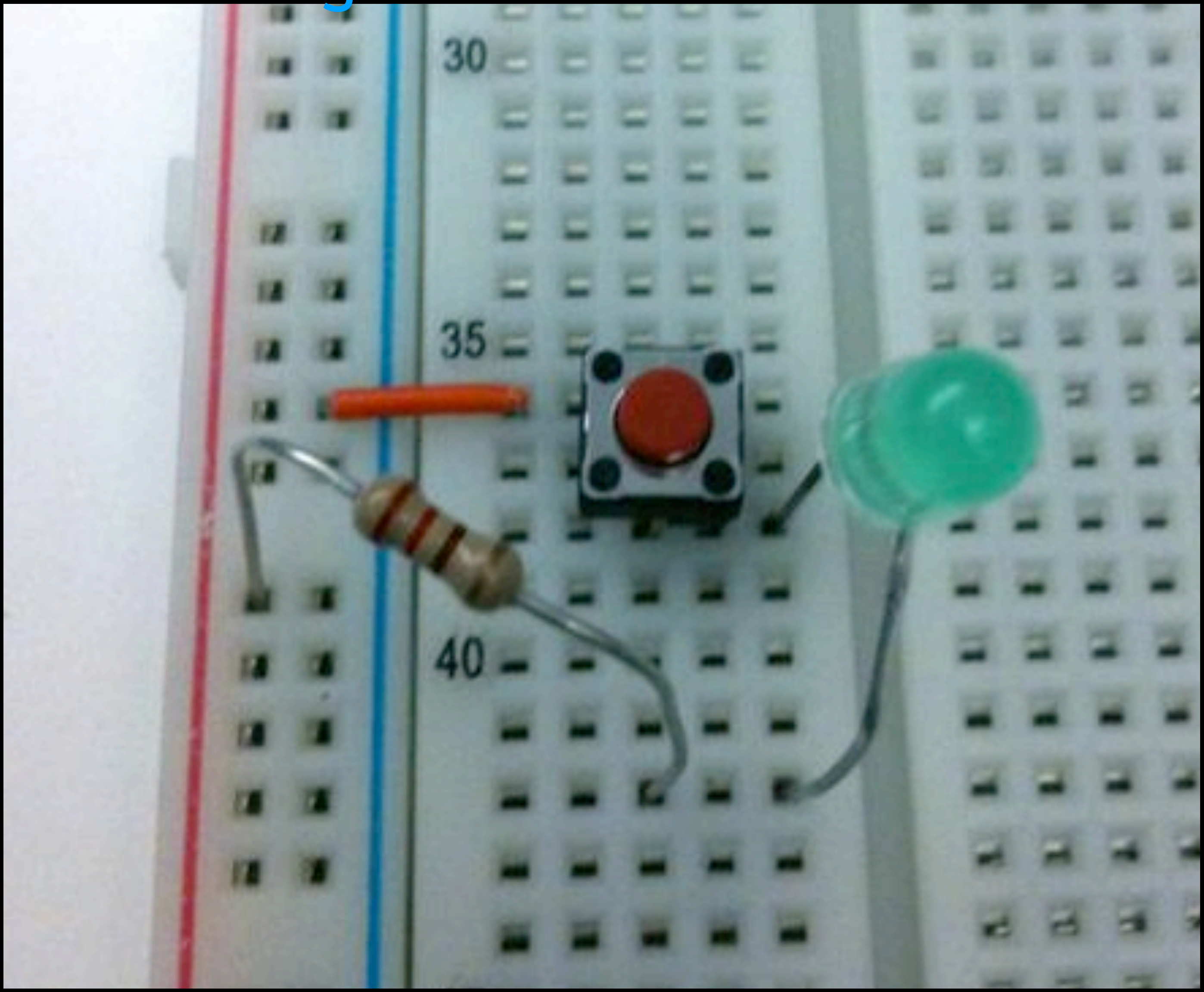
$V=IR$

$I=V/R$

If $R=0$, $I = \infty$

DON’T SHORT POWER TO GROUND

A Tour through a Pushbutton LED circuit



Pushbutton LED circuit breadboard drawing

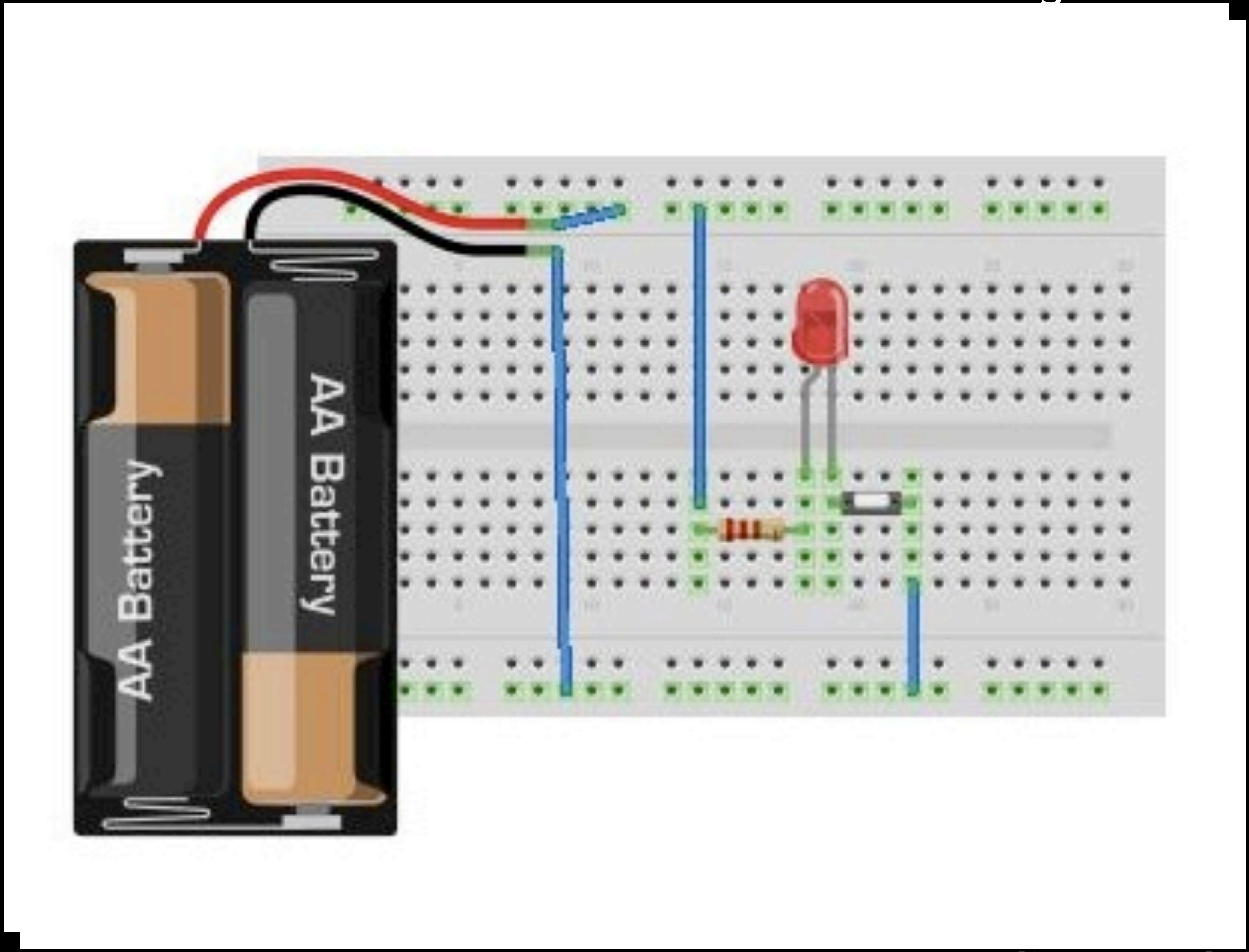
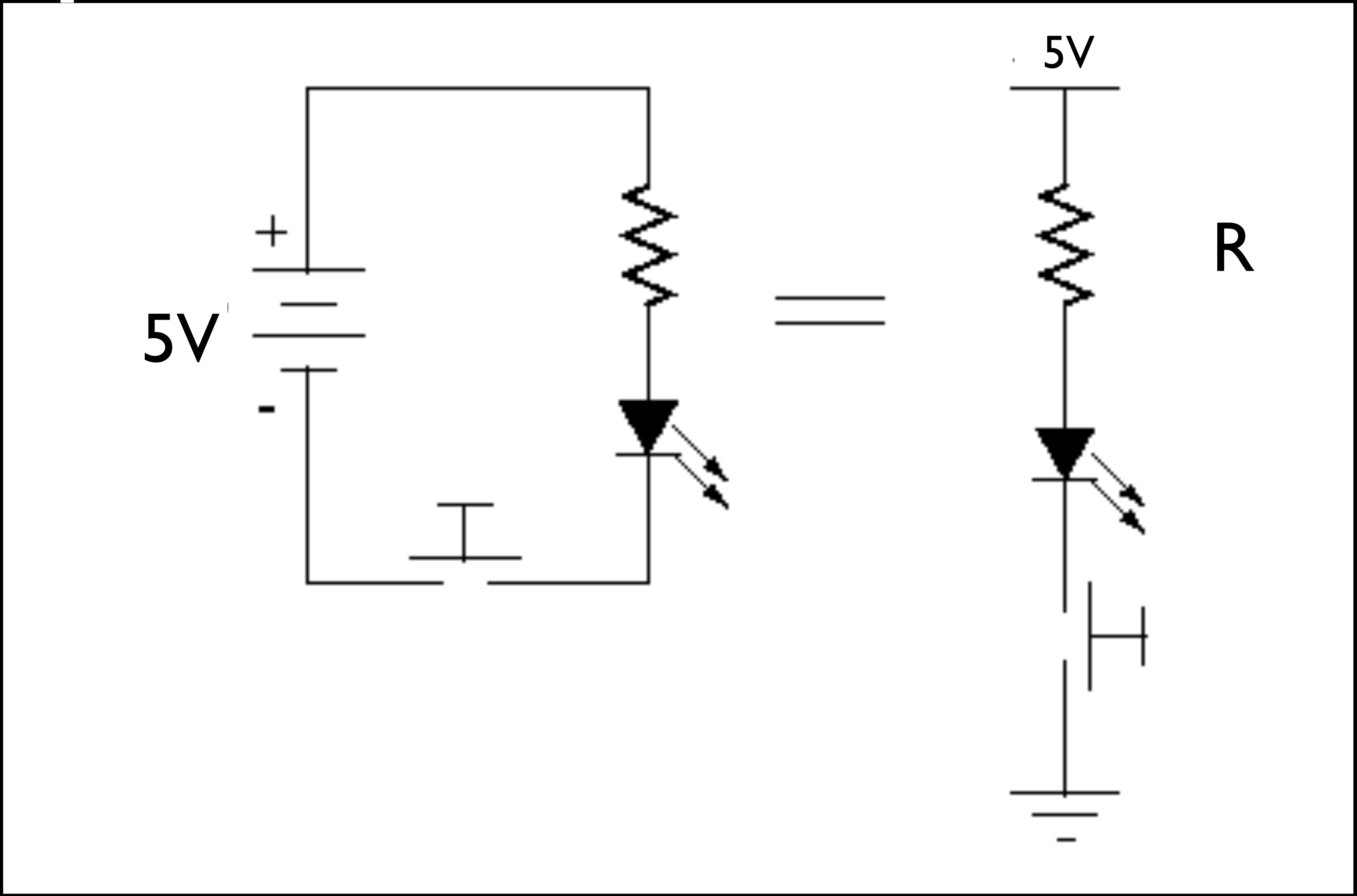


diagram made in Fritzing

Equivalent Pushbutton LED circuit



Sketching in Hardware

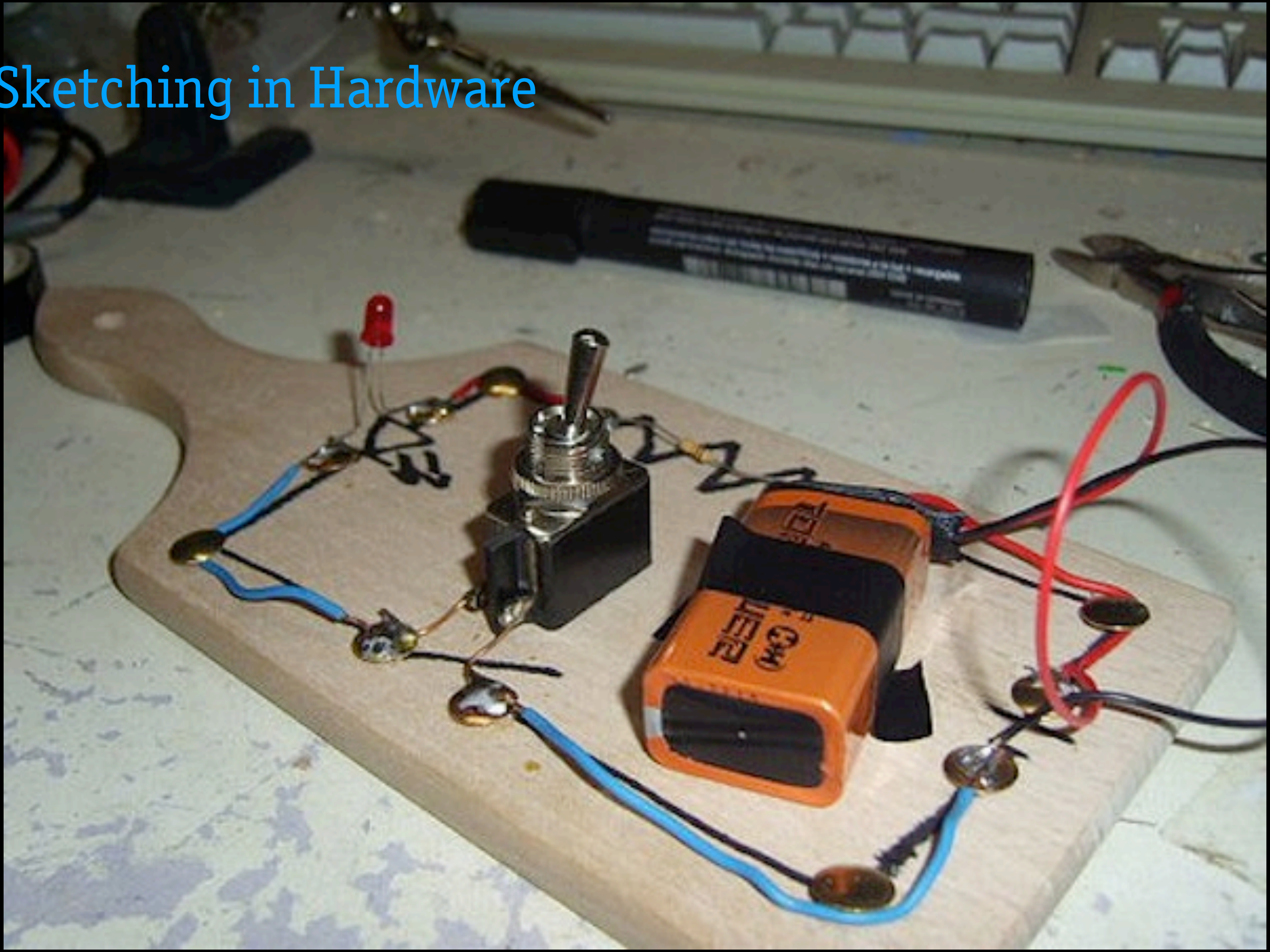
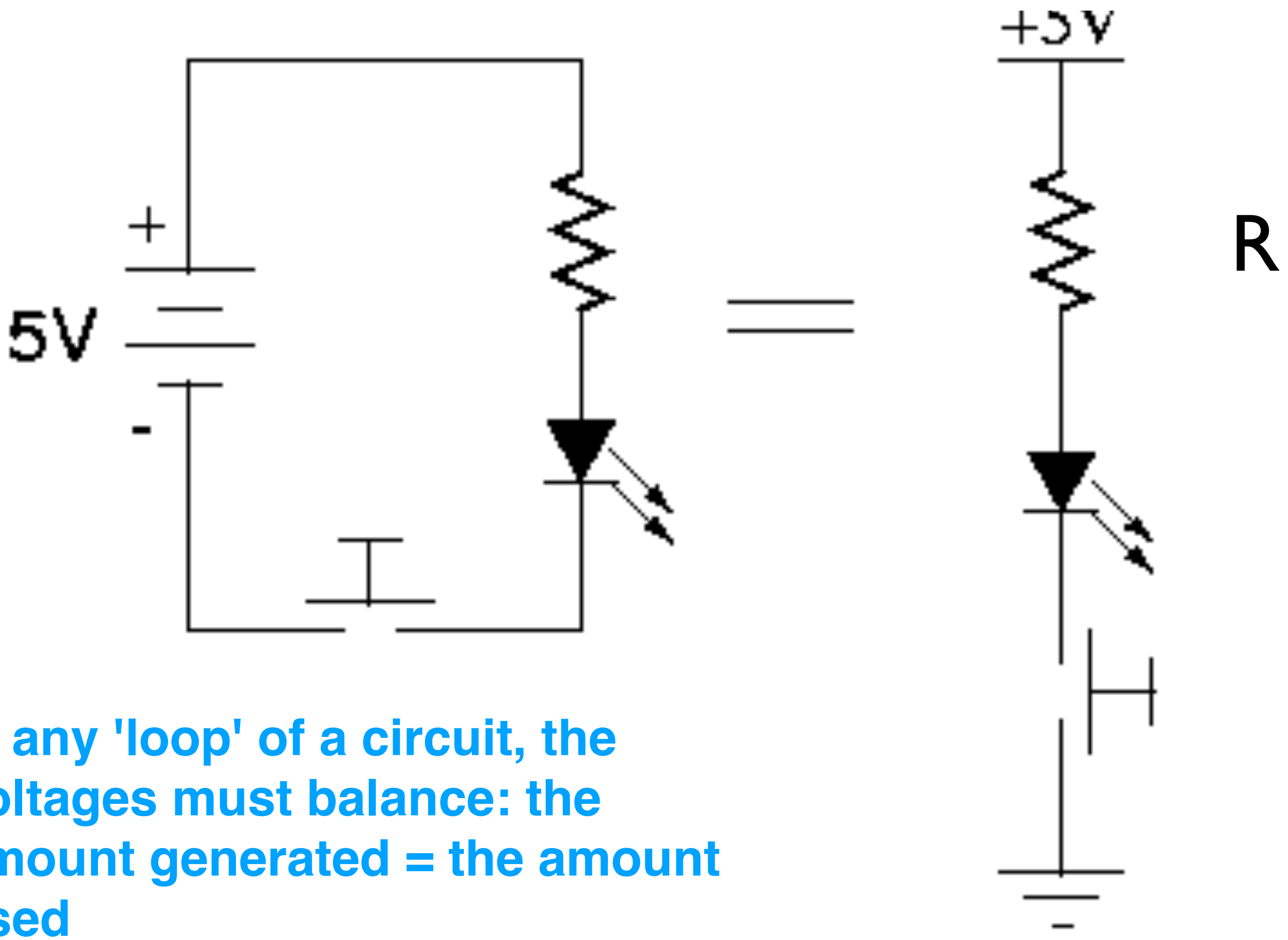


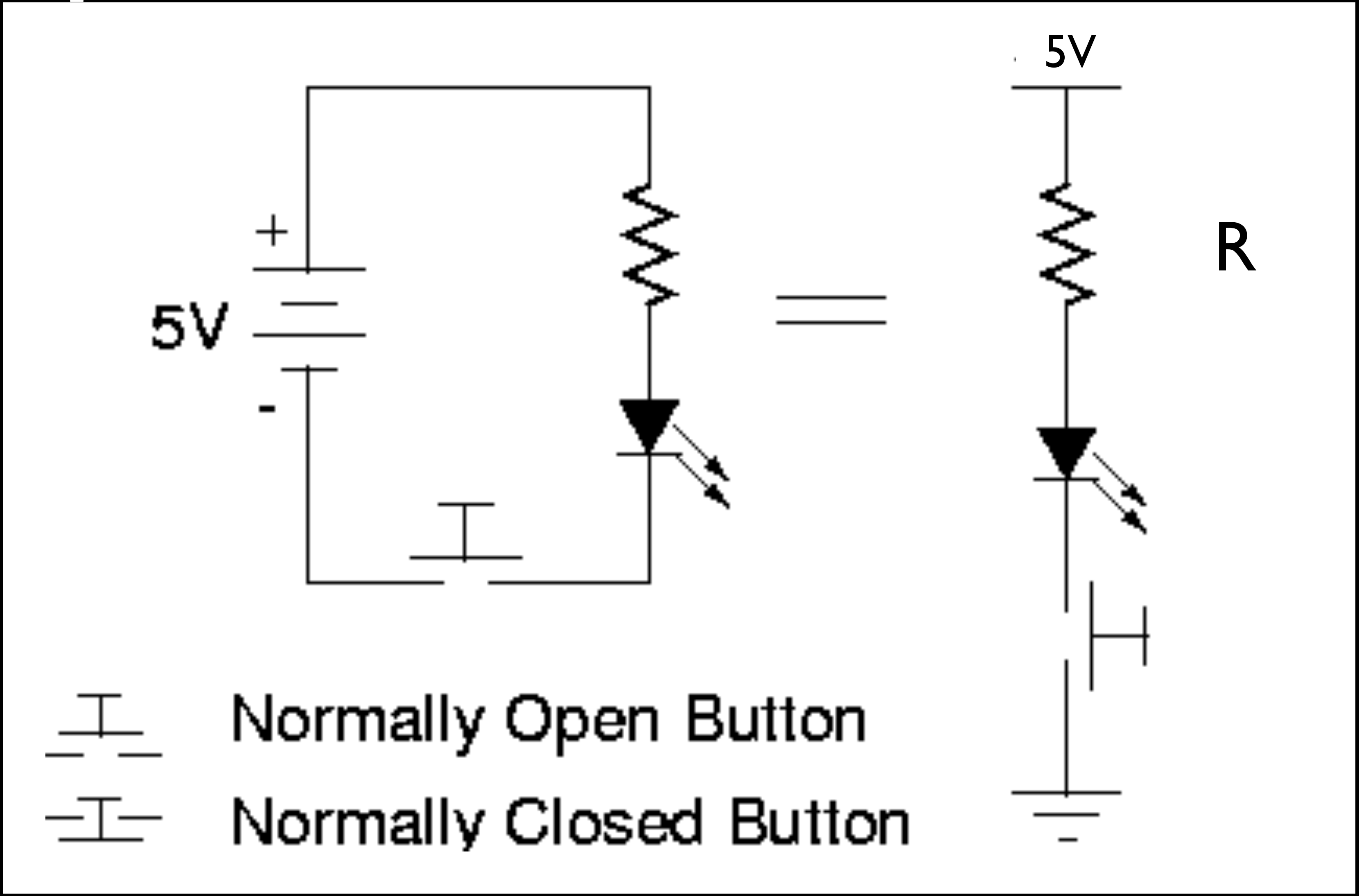
image from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard
originally from http://www.instructables.com/id/Use-a-real-Bread-Board-for-prototyping-your-circui/

KIRCHOFF’S LAW in the Pushbutton LED circuit

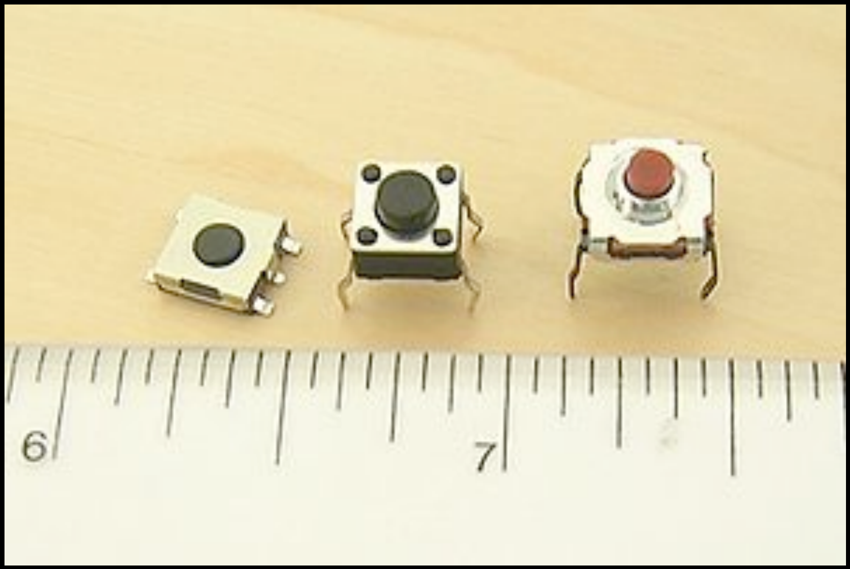


In any 'loop' of a circuit, the voltages must balance: the amount generated = the amount used

Input in the Pushbutton LED circuit

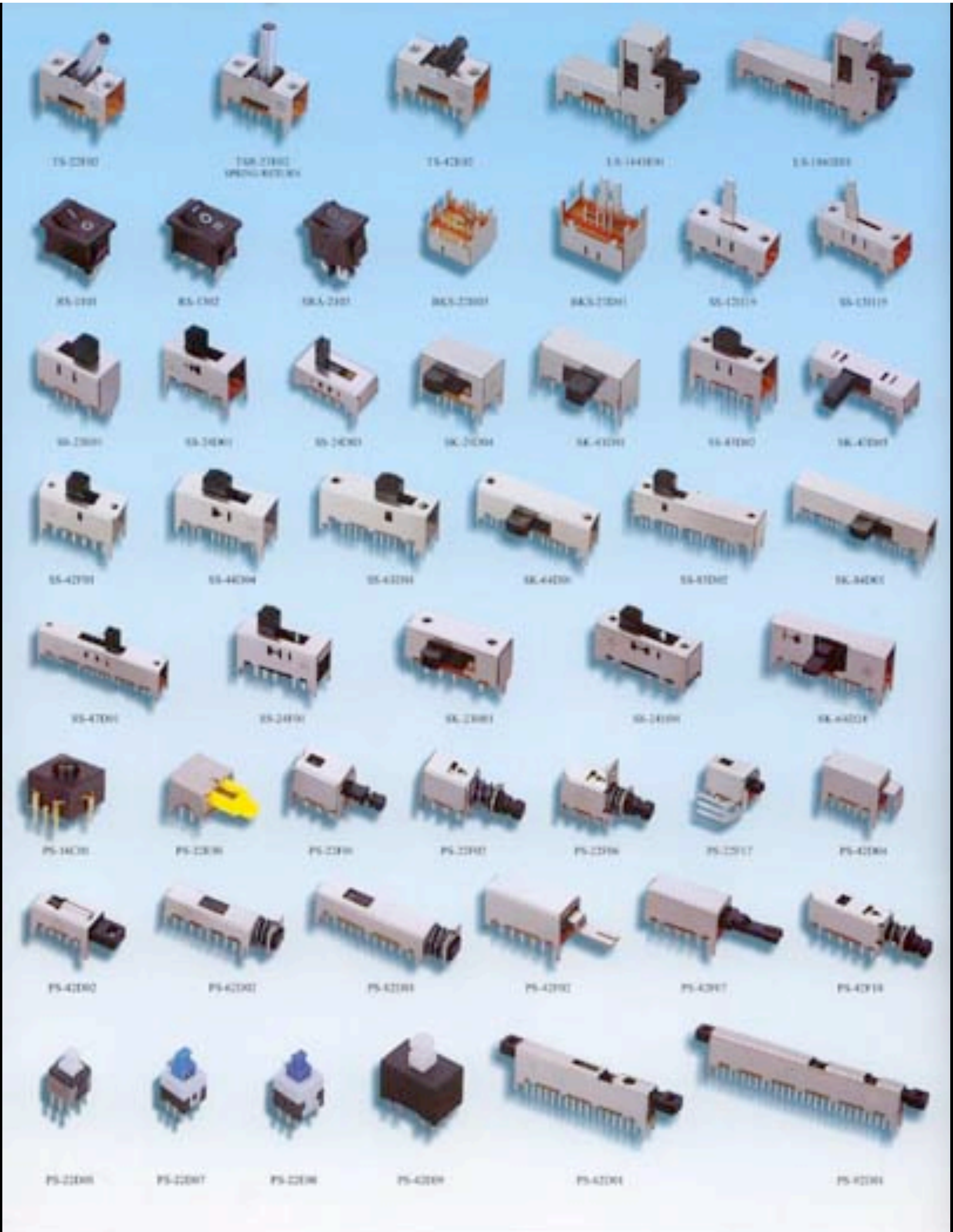


Switches/Buttons

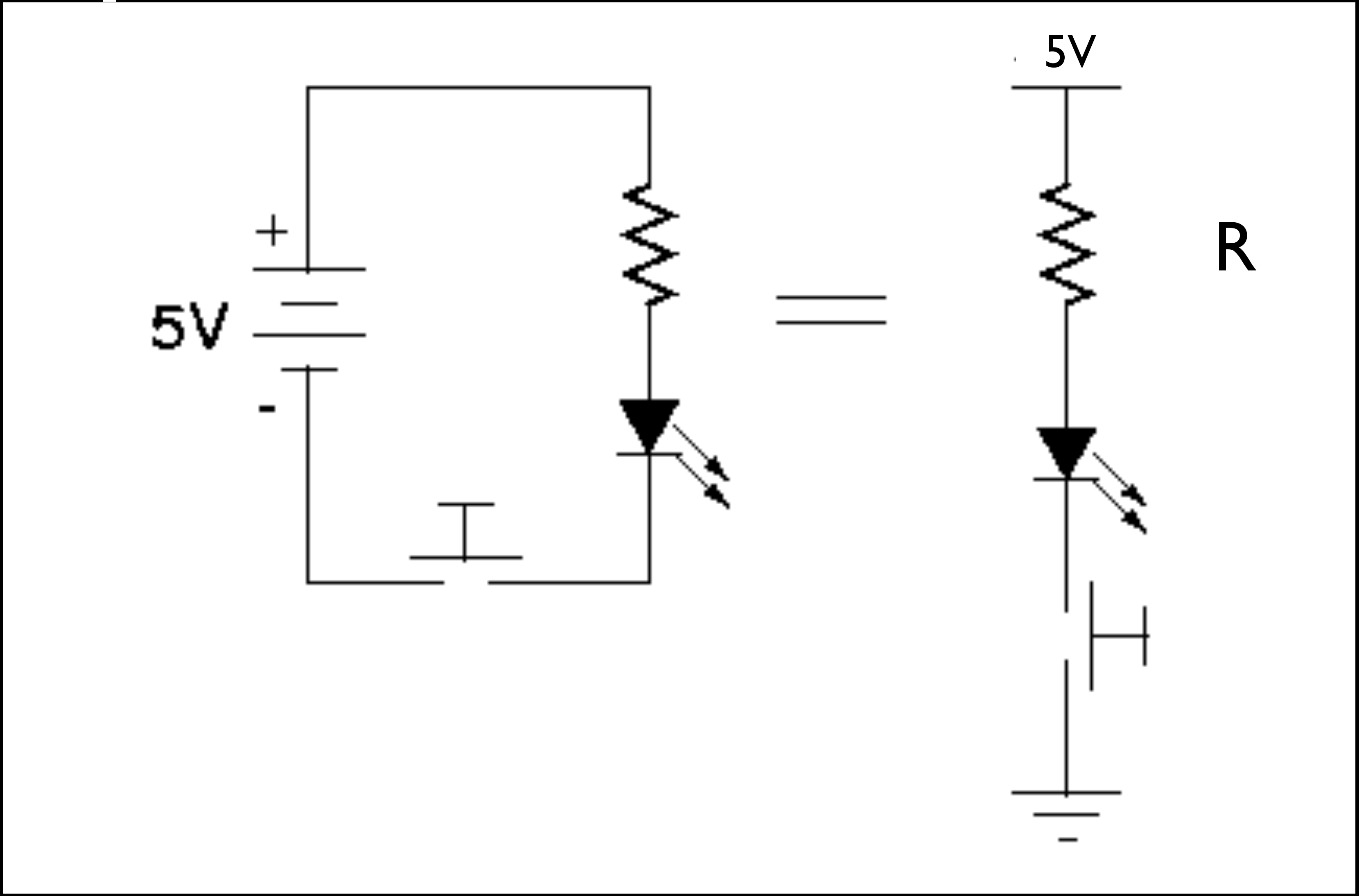


images from Wikipedia

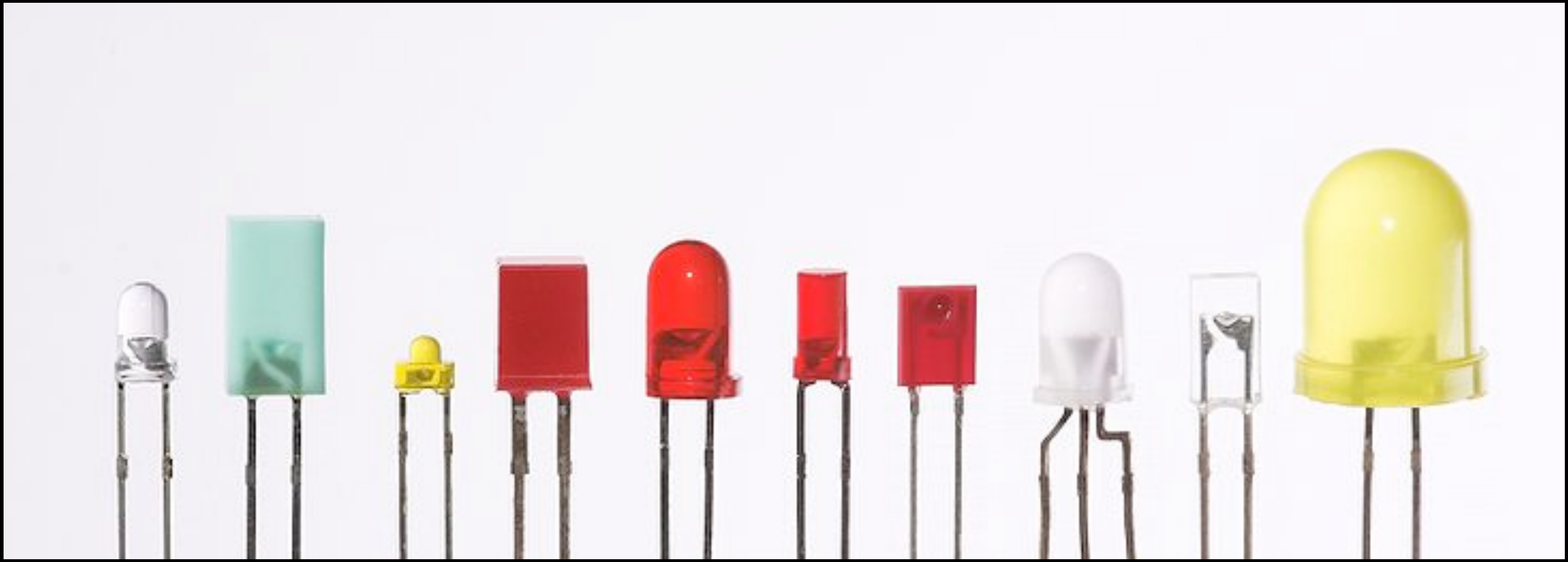
Switches/Buttons



Output in the Pushbutton LED circuit

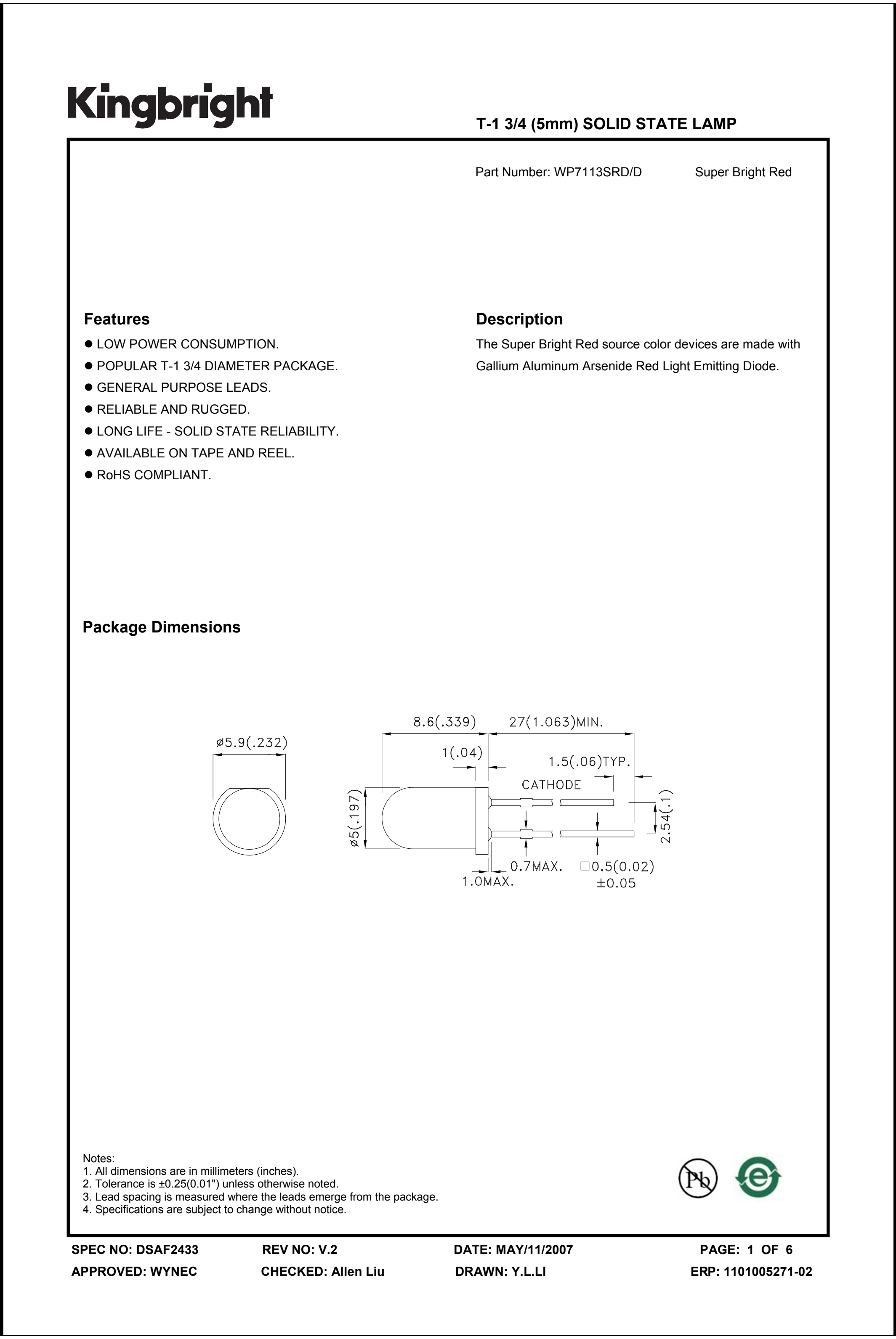


LEDs



images from Wikipedia

LED datasheet



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.

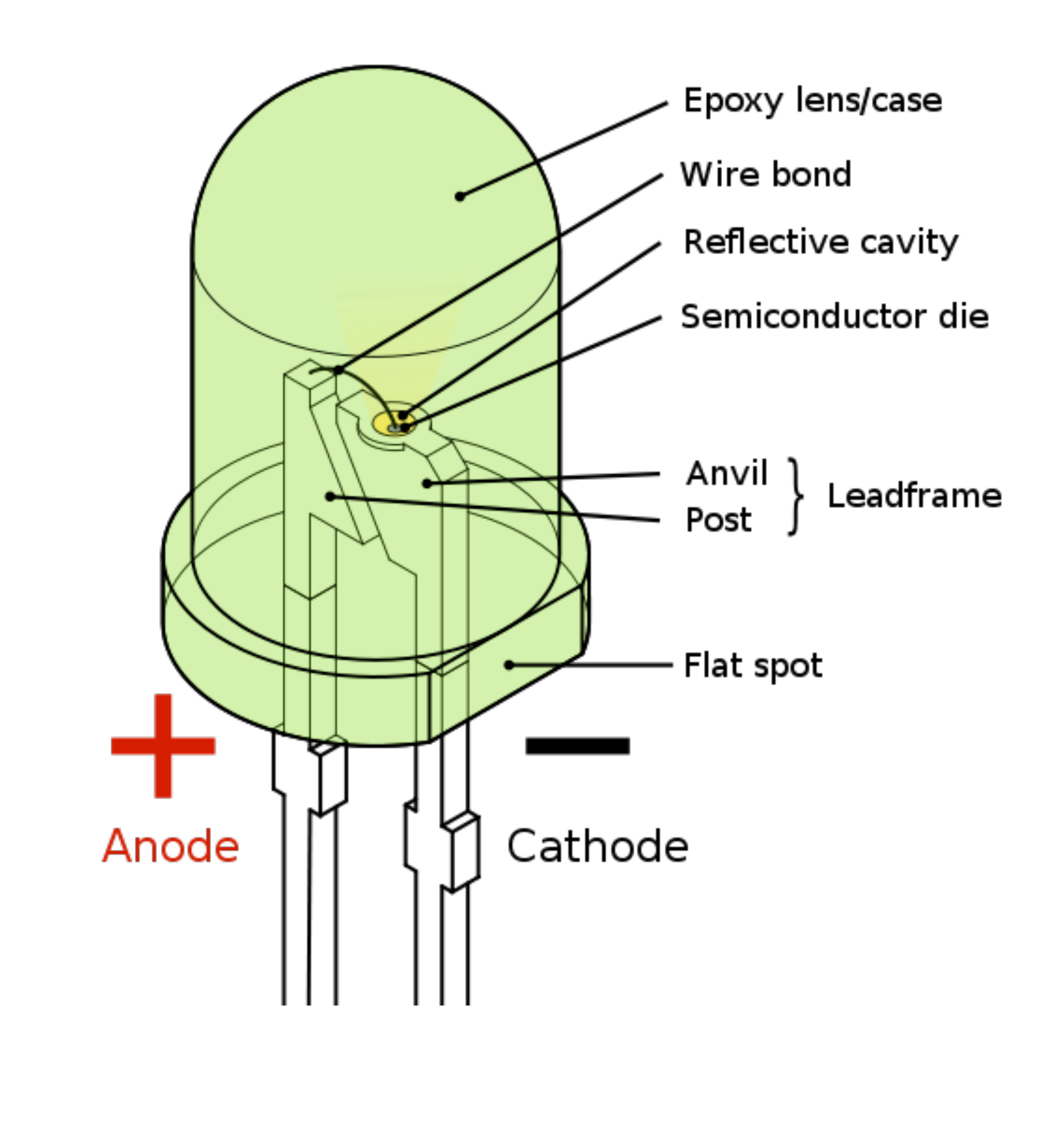
Package Dimensions

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.

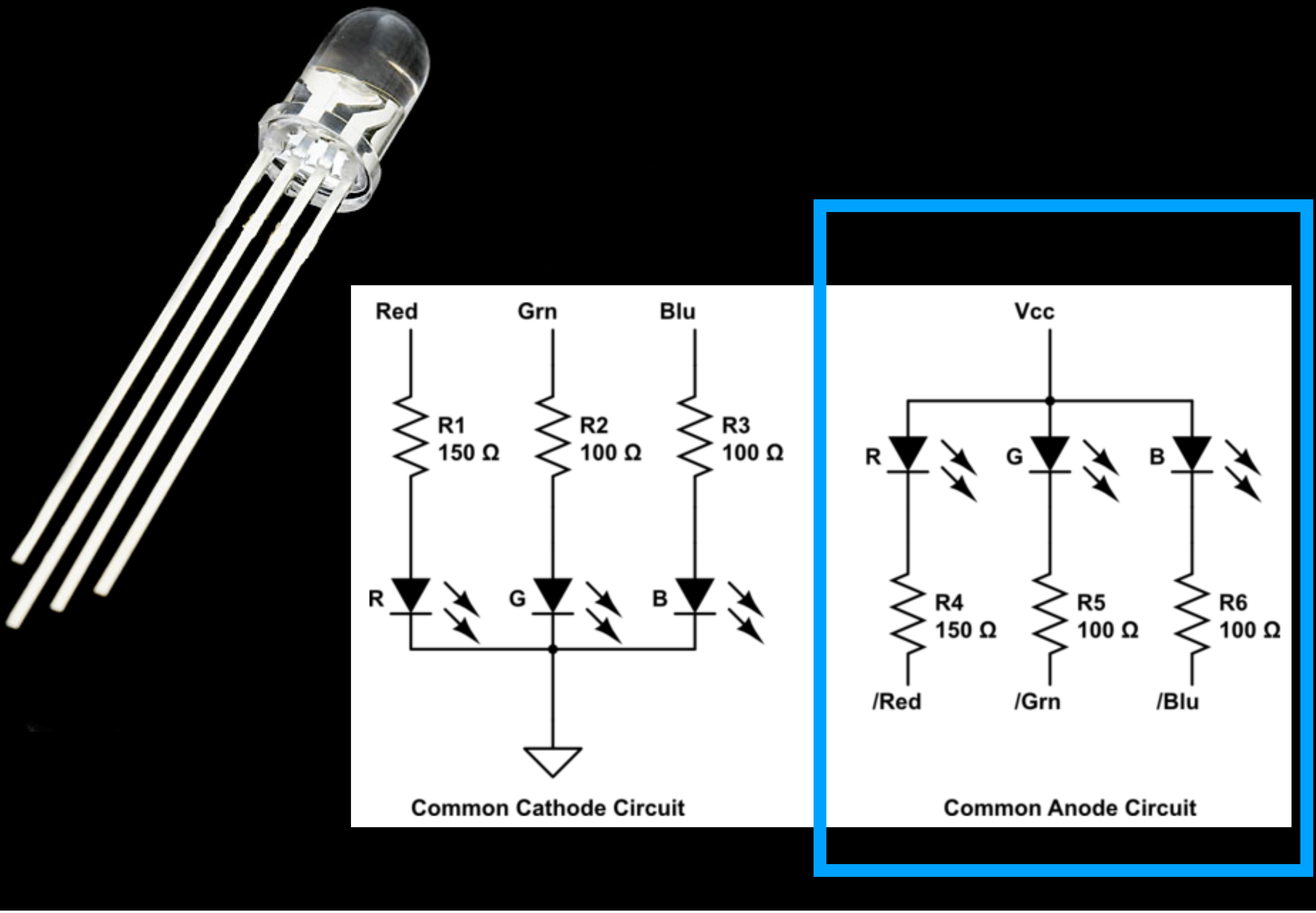
SPEC NO: DSAF2433	**REV NO: V.2**	**DATE: MAY/11/2007**	**PAGE: 1 OF 6**
APPROVED: WYNEC	**CHECKED: Allen Liu**	**DRAWN: Y.L.LI**	**ERP: 1101005271-02**

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

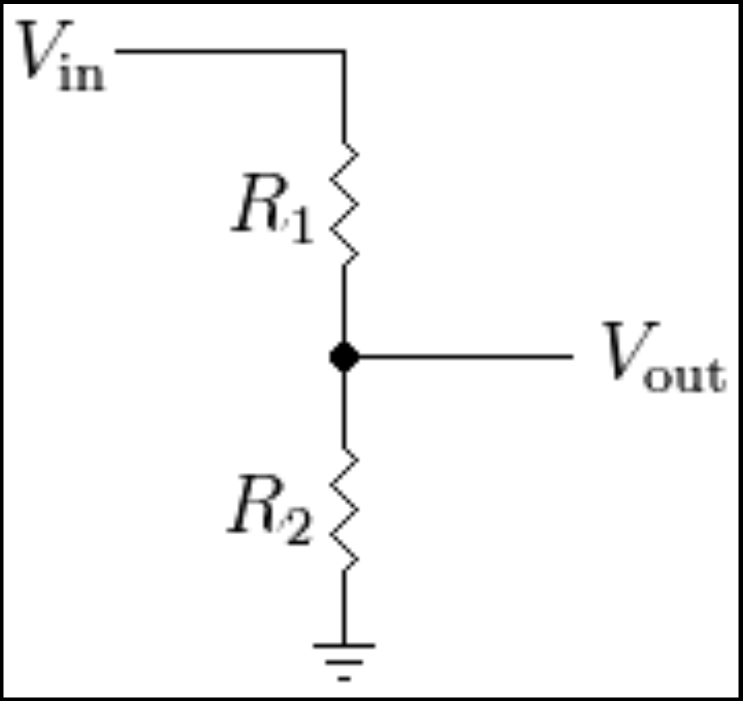
Inside LEDs


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

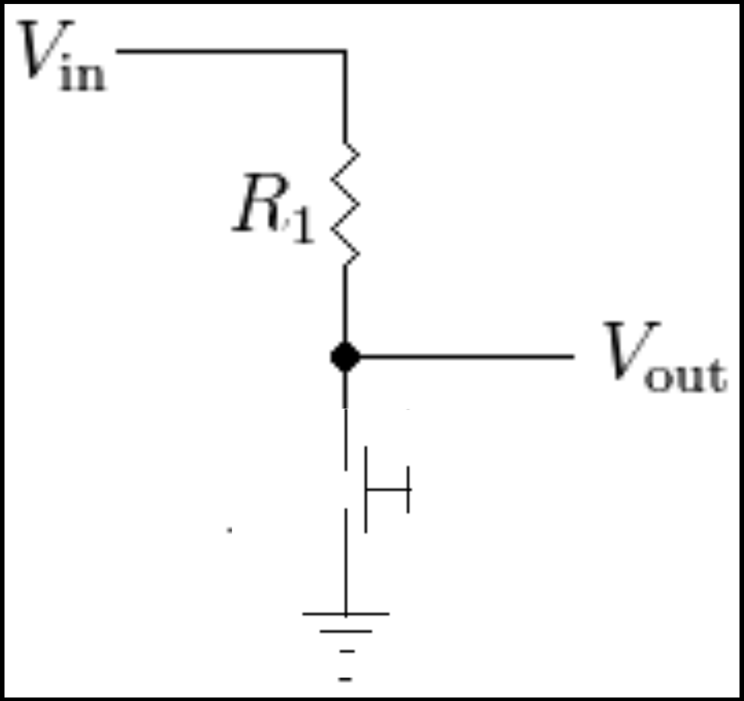
RGB LEDs


Red
Grn
Blu
R1
150 Ω
R2
100 Ω
R3
100 Ω
R
G
B
Common Cathode Circuit
Vcc
R
G
B
R4
150 Ω
R5
100 Ω
R6
100 Ω
/Red
/Grn
/Blu
Common Anode Circuit

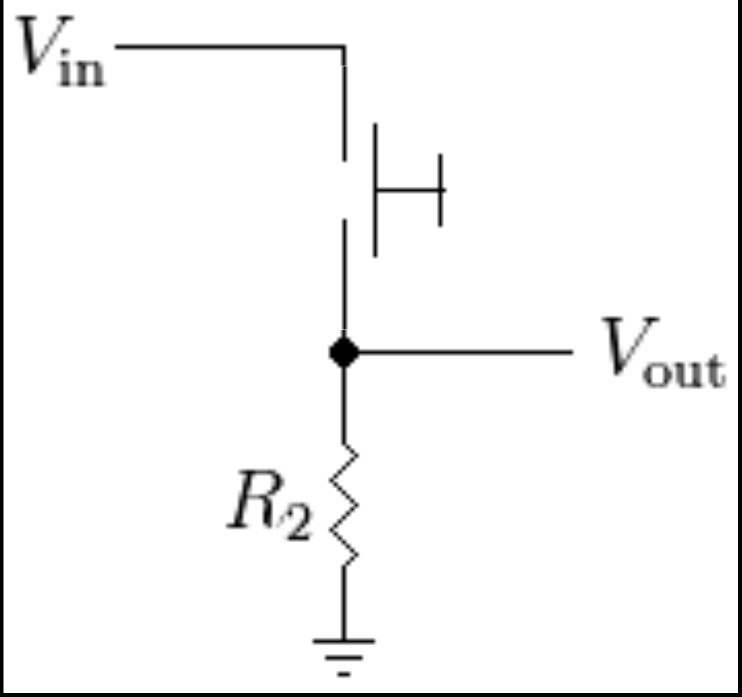
VOLTAGE DIVIDER CIRCUIT



PULL UP RESISTOR



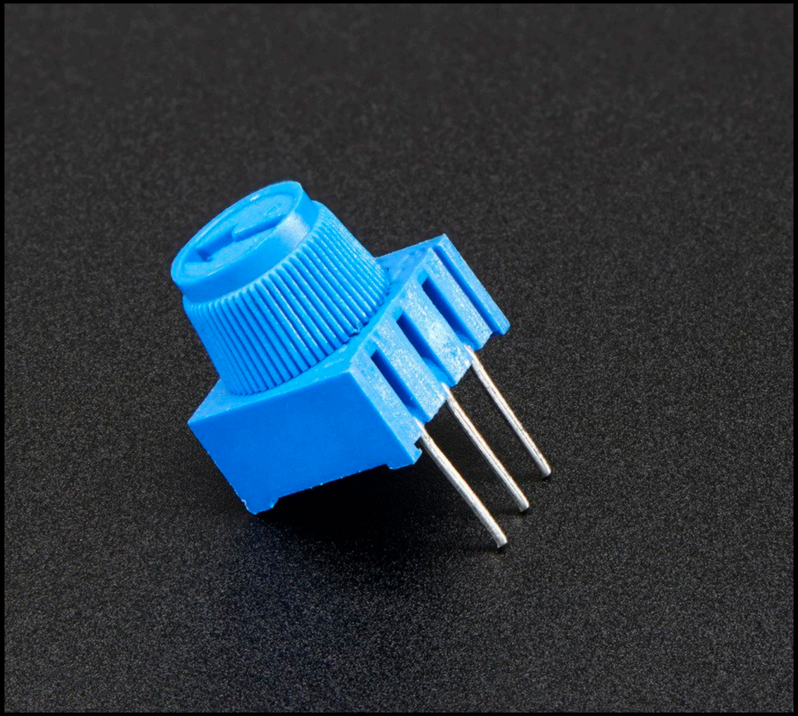
PULL DOWN RESISTOR

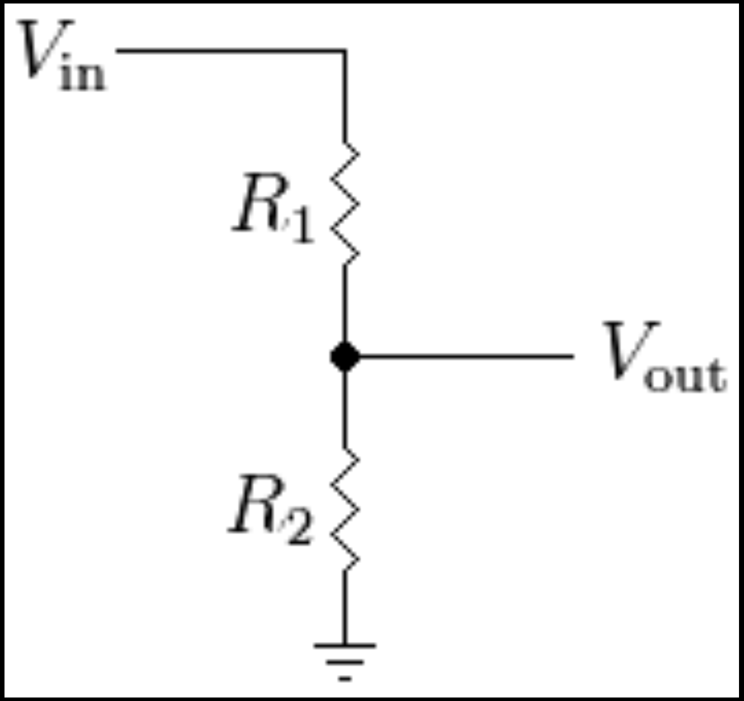


Adjusting the brightness of your LEDs

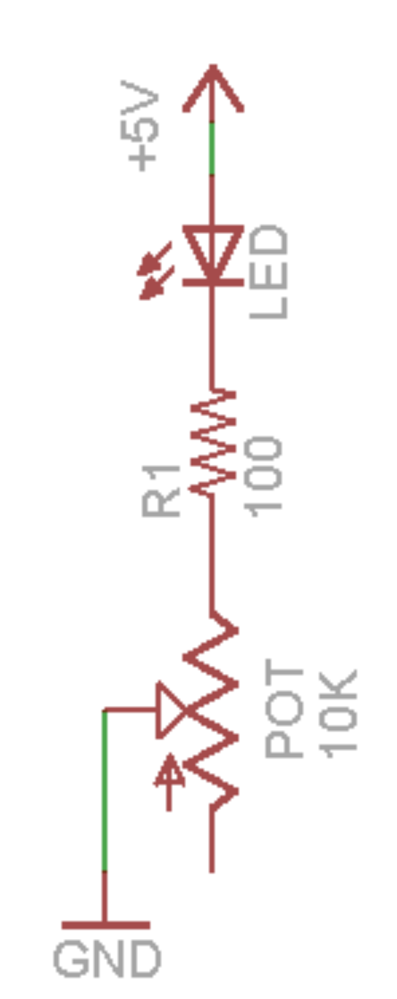
A potentiometer is a variable resistor,

a voltage divider in a package.





Adjusting the brightness of your LEDs



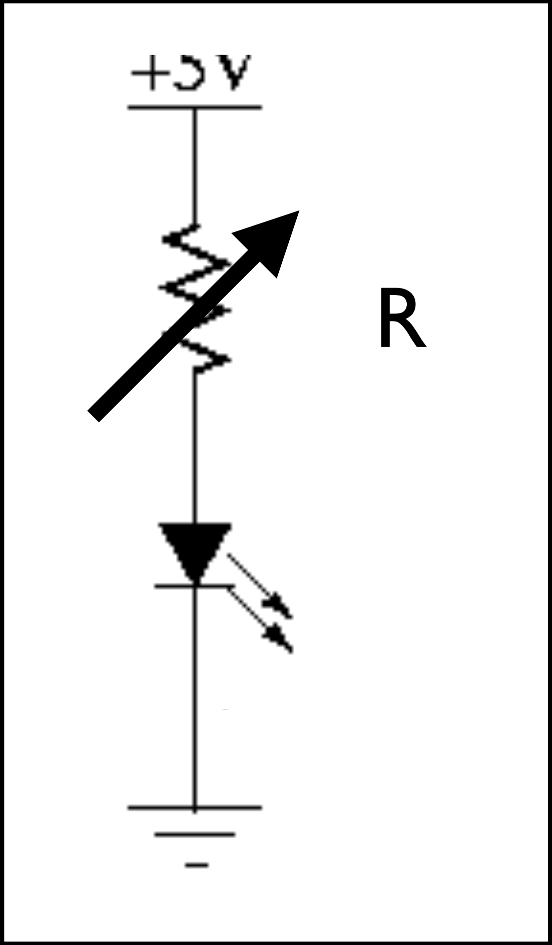
The LED is a diode, with a fixed voltage drop.

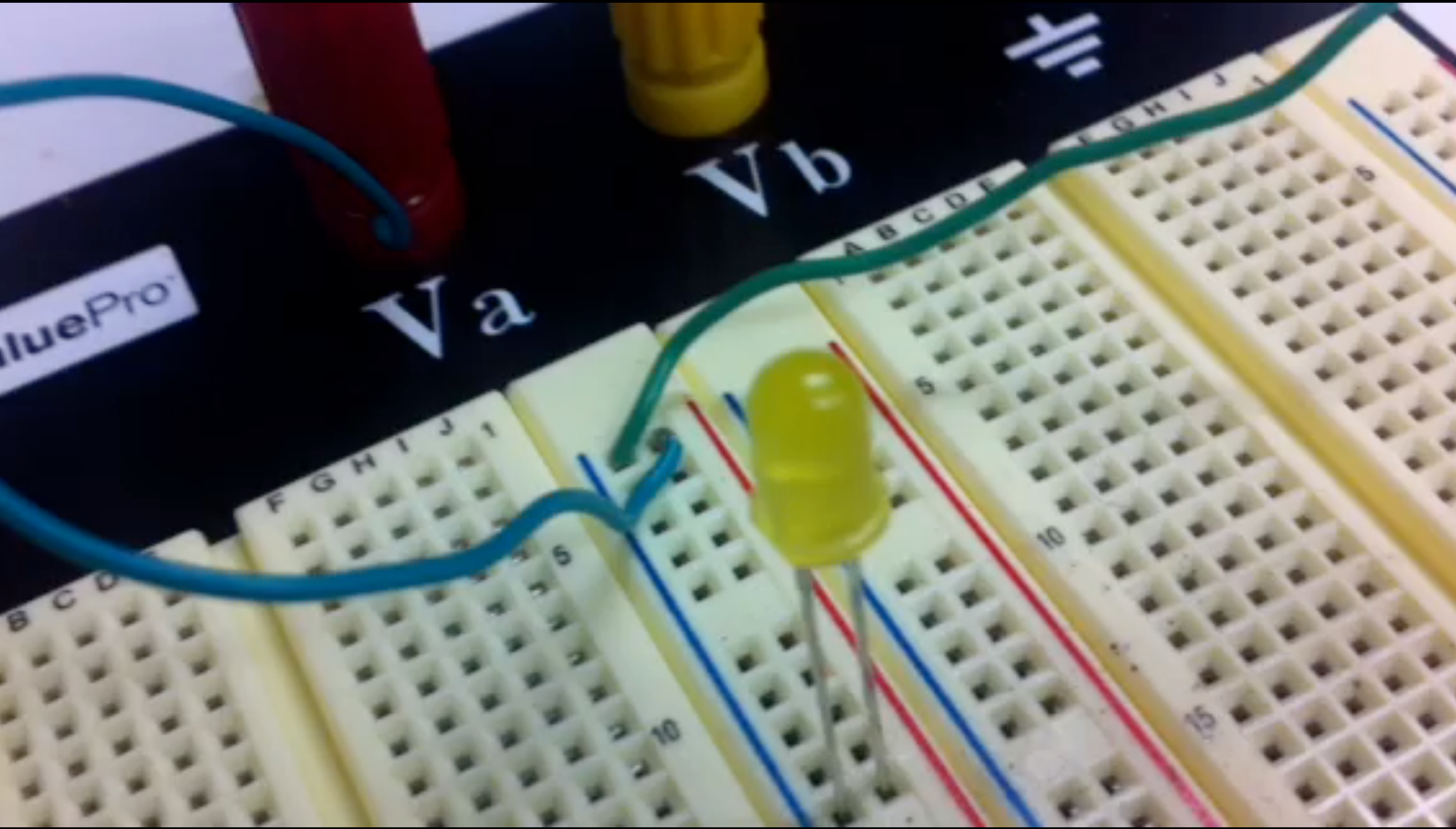
The Current is set by the series resistor

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

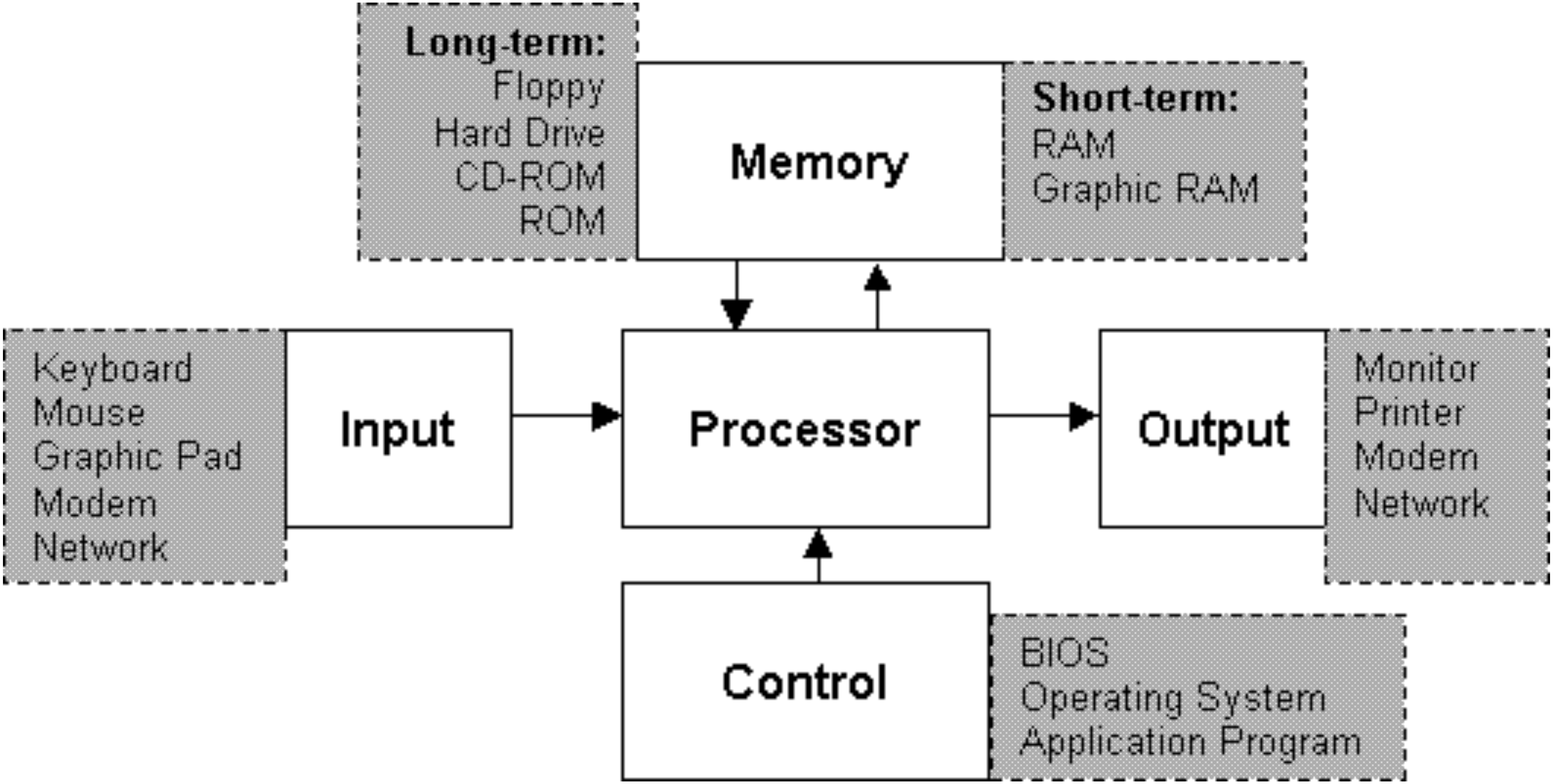
I= V/R

Why is this a BAD circuit?



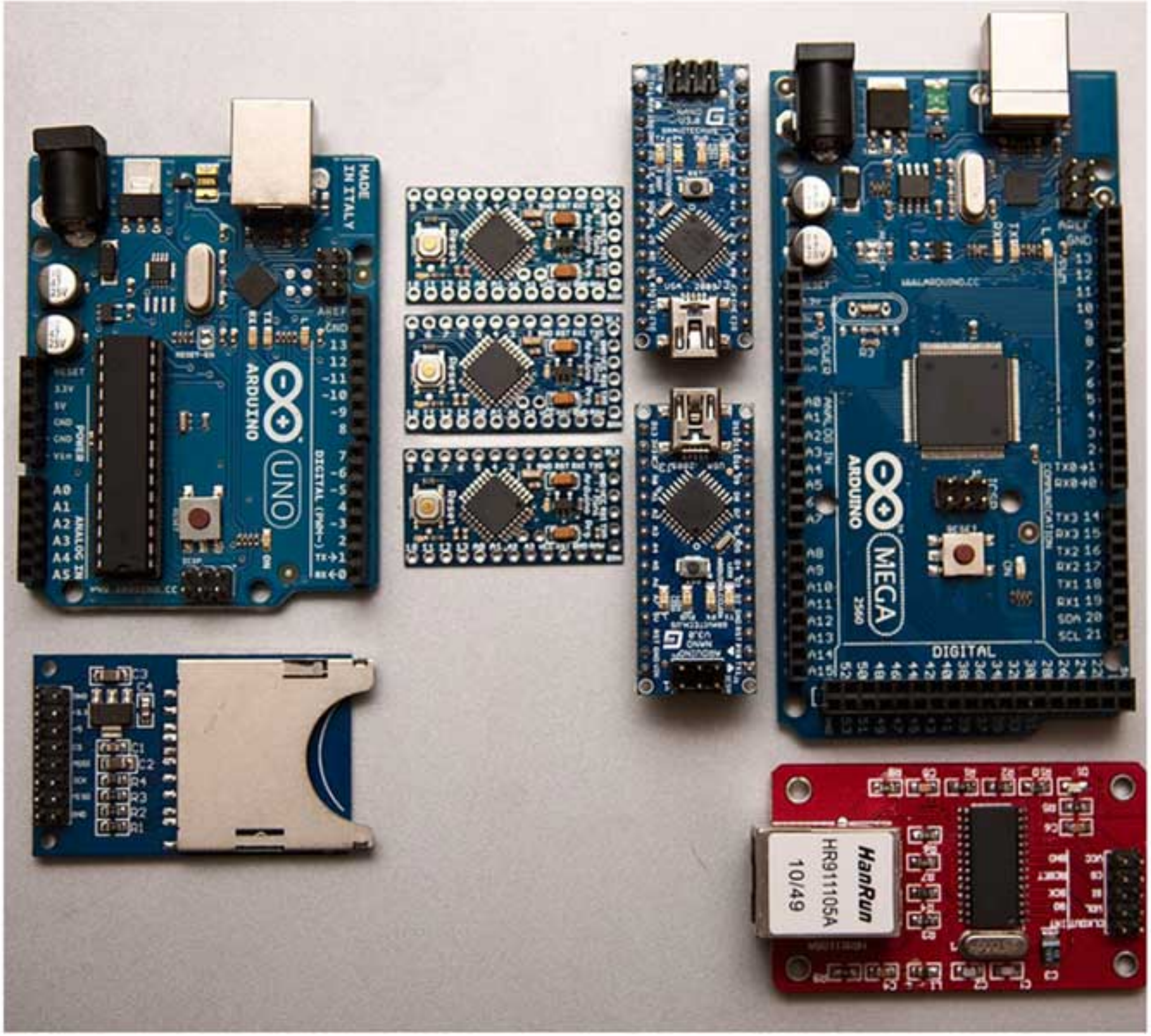

luePro
Va
Vb
A B C D E
F G H I J
1
5
10
15

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)

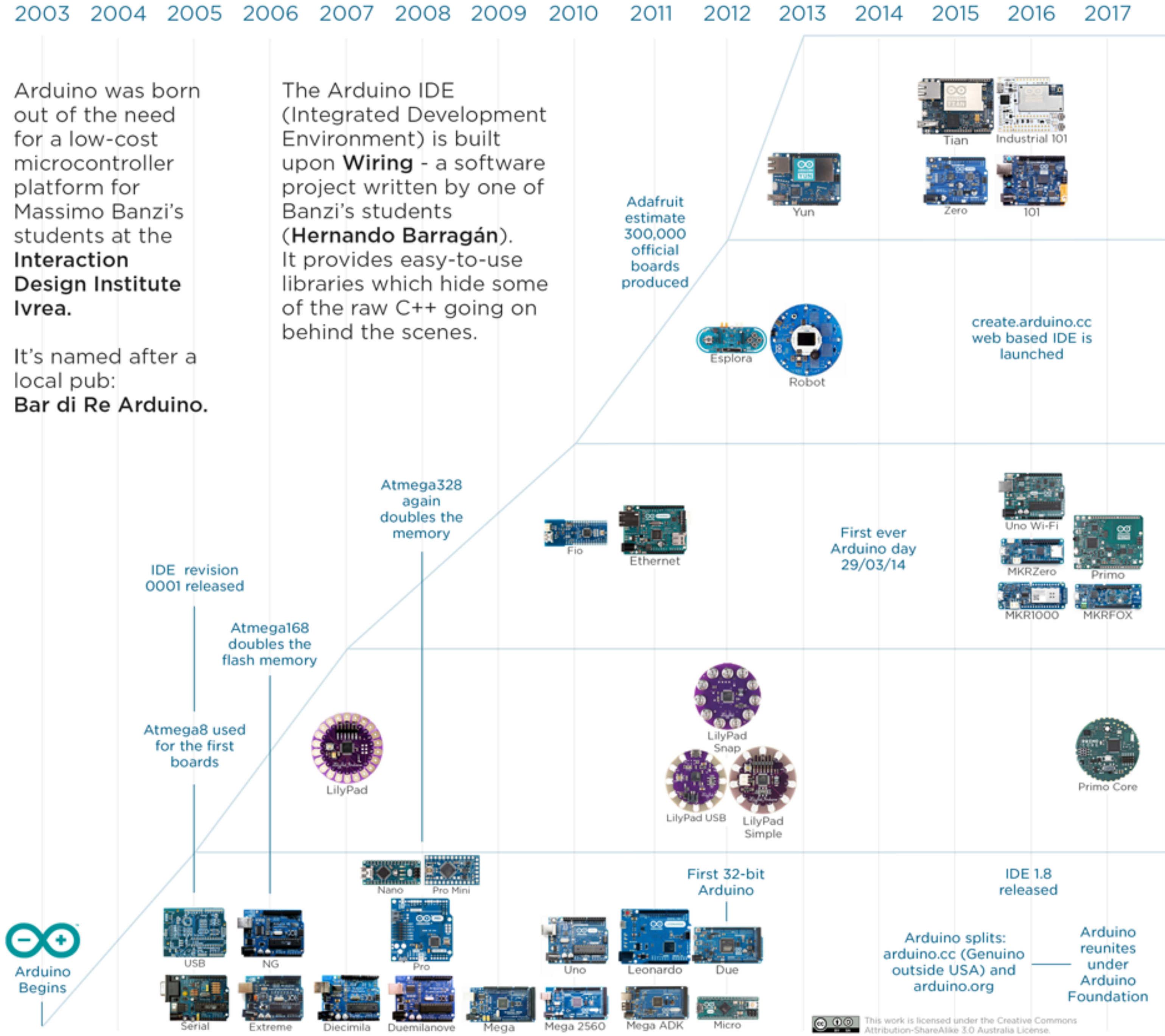

MADE IN ITALY
ARDUINO
UNO
ARDUINO
MEGA
2560
DIGITAL
HanRun
HR911105A
10/49

HISTORY OF ARDUINO

Arduino was born out of the need for a low-cost microcontroller platform for Massimo Banzi's students at the **Interaction Design Institute Ivrea.**

It's named after a local pub: **Bar di Re Arduino.**

The Arduino IDE (Integrated Development Environment) is built upon **Wiring** - a software project written by one of Banzi's students (**Hernando Barragán**). It provides easy-to-use libraries which hide some of the raw C++ going on behind the scenes.



IDE revision 0001 released

Atmega8 used for the first boards

Atmega168 doubles the flash memory

Atmega328 again doubles the memory

Adafruit estimate 300,000 official boards produced

First 32-bit Arduino

First ever Arduino day 29/03/14

create.arduino.cc web based IDE is launched

IDE 1.8 released

Arduino splits: arduino.cc (Genuino outside USA) and arduino.org

Arduino reunites under Arduino Foundation

ARDUINO TODAY

Industrial

- Yun/Yun Mini
- Zero
- M0/M0 Pro
- Tian
- 101/Industrial 101

Powerful, smart technology

Rapid prototyping

Easily integrated with other devices

Educational

- Esplora
- Robot

Classroom friendly

Modern, STEM learning

Hands-on and intuitive

IoT

- MKR1000
- MKRZero
- MKRFOX1200
- Uno Wi-Fi
- Ethernet
- Primo

Connectivity and communication

Low power consumption

Easy to prototype with

Wearables

- LilyPad
- LilyPad Simple
- LilyPad Snap
- LilyPad USB
- Primo Core

Thin, compact form factor

Battery powered

Easy to use with condutive material

Maker

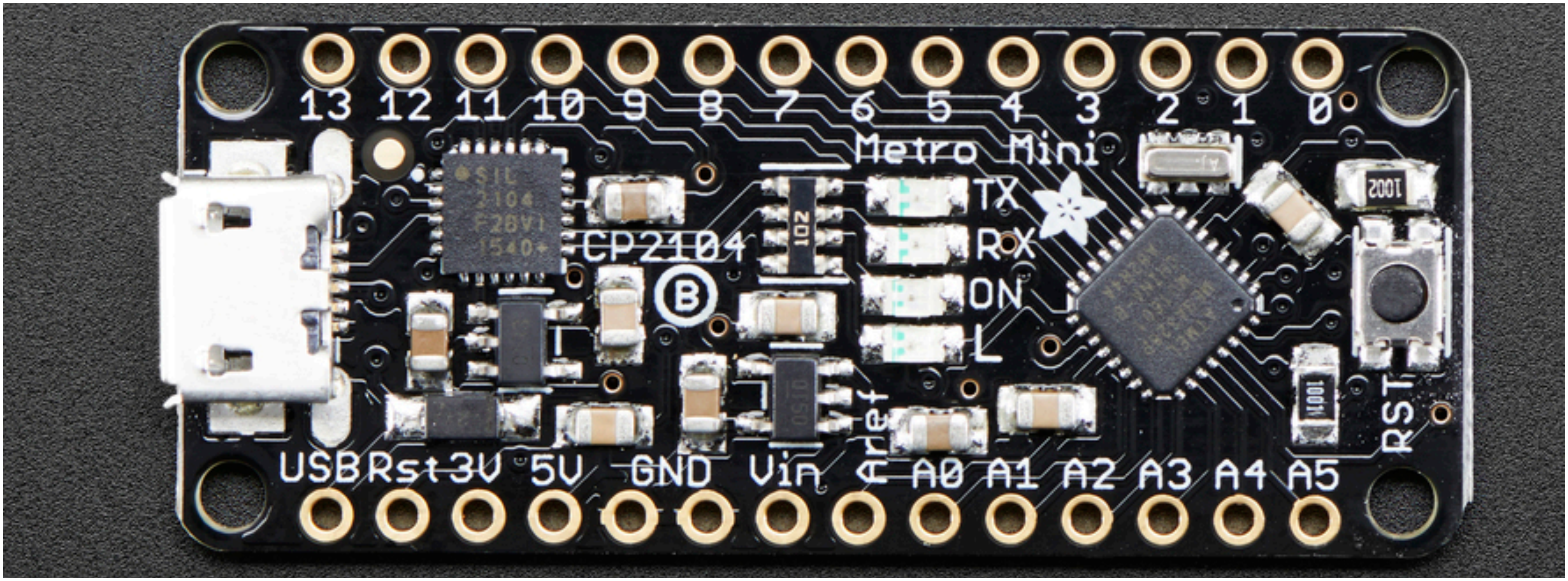
- Uno
- Leonardo
- Mini/Pro Mini
- Nano/Micro
- Mega2560/ADK
- Primo
- Due

Affordable

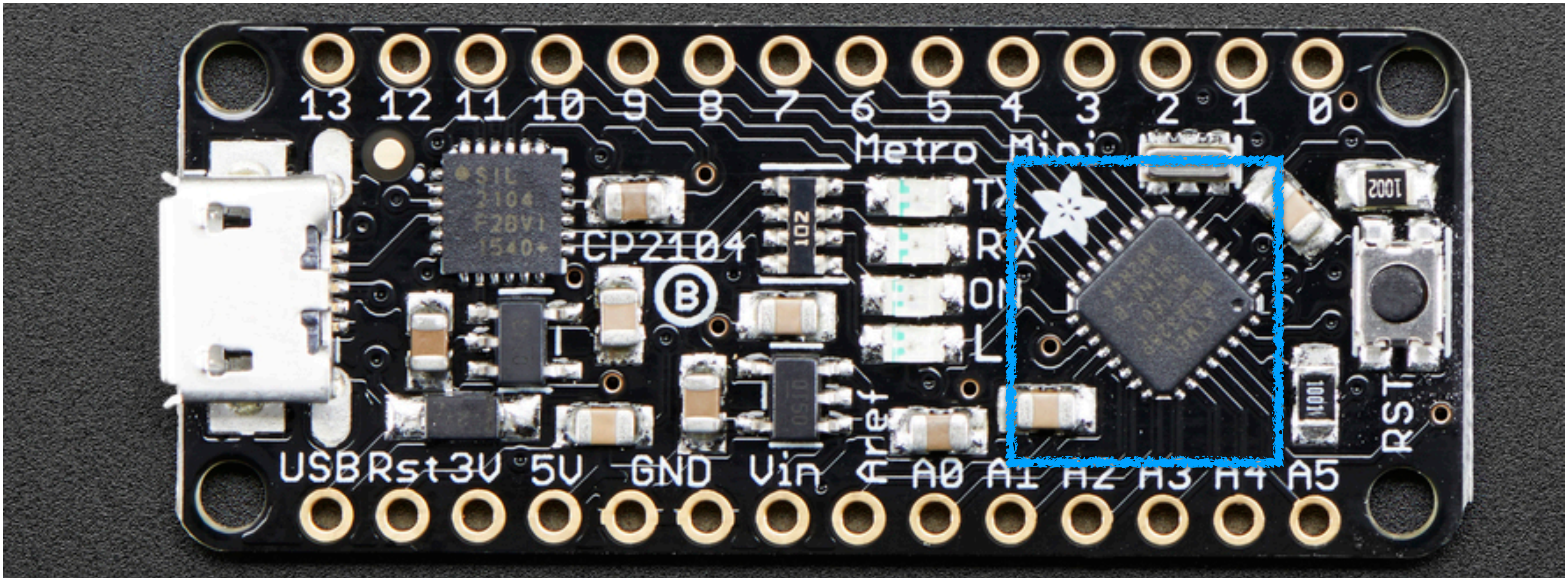
Community driven

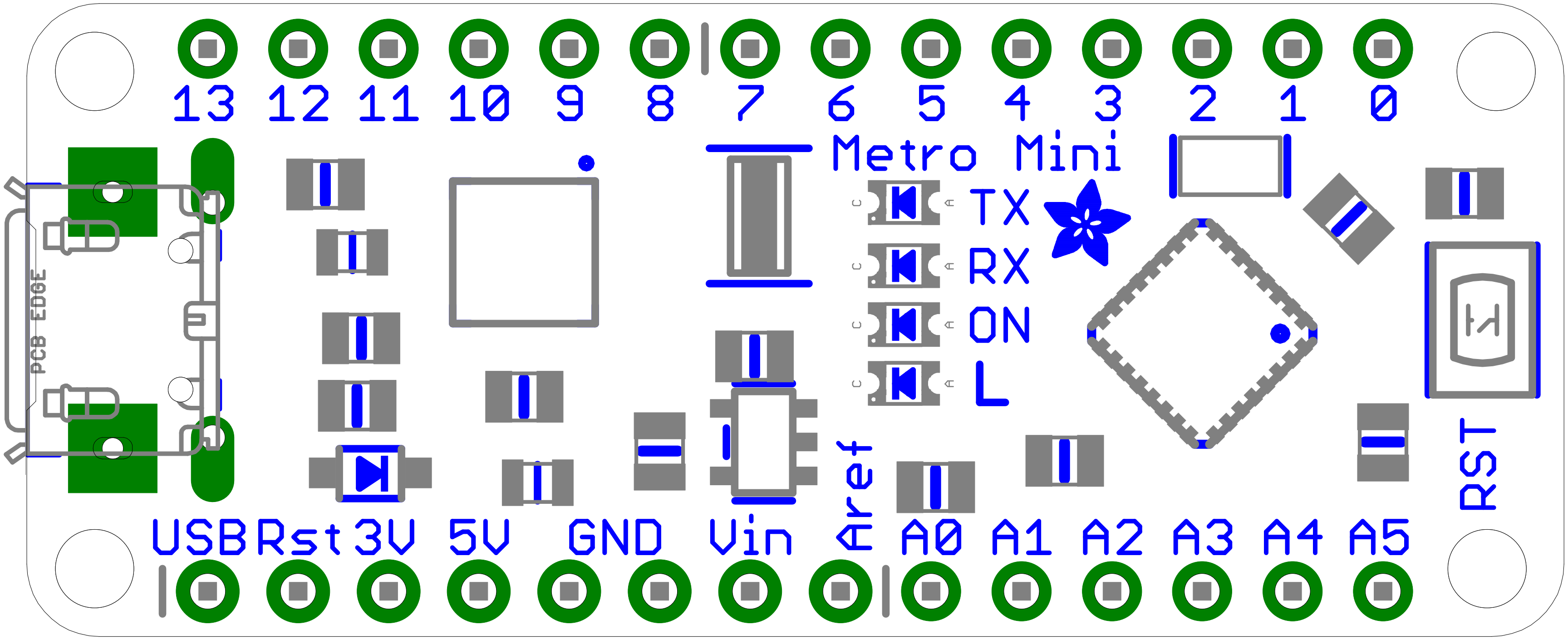
Modular and adaptable

Physical Hardware



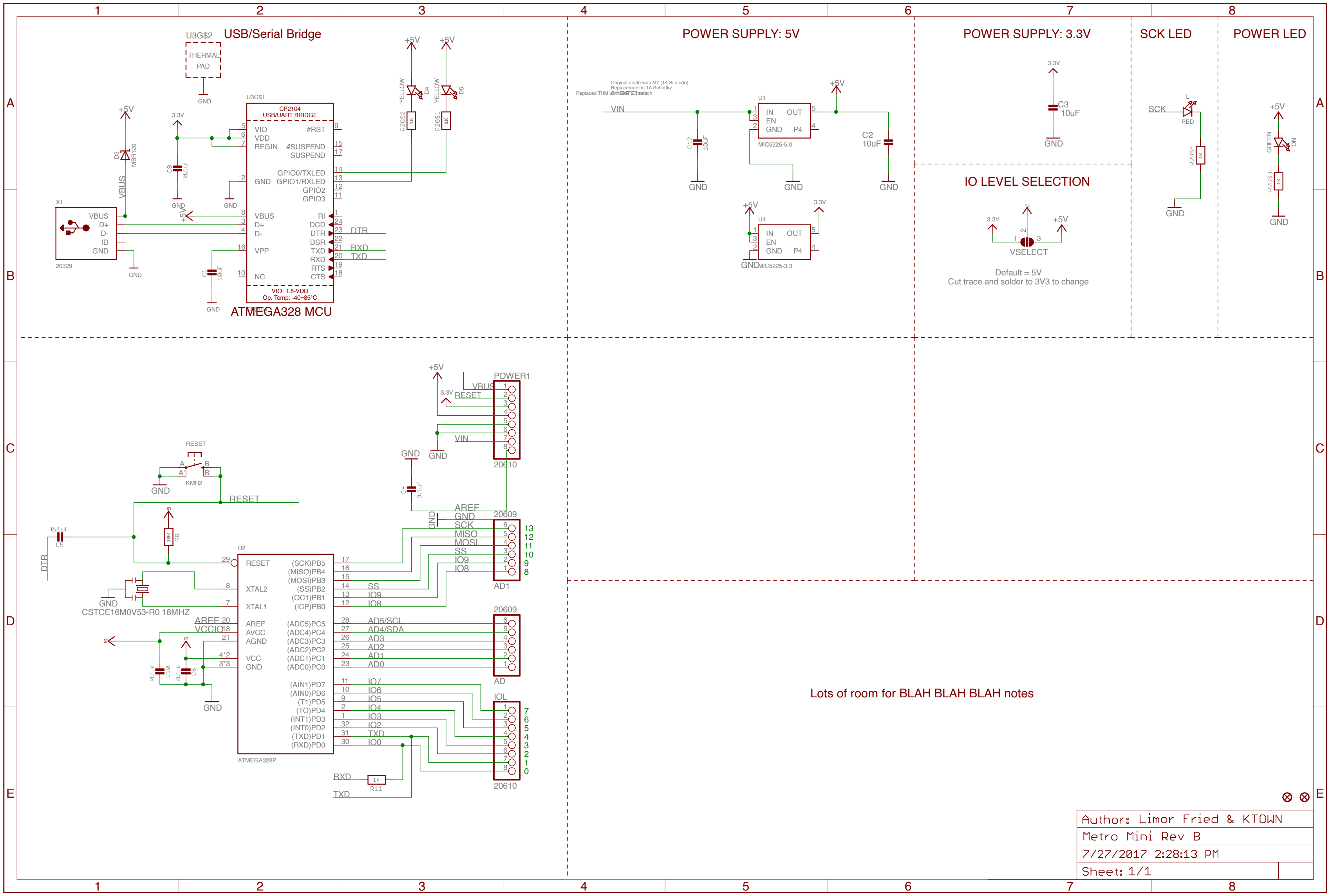
Microcontroller




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

Schematic

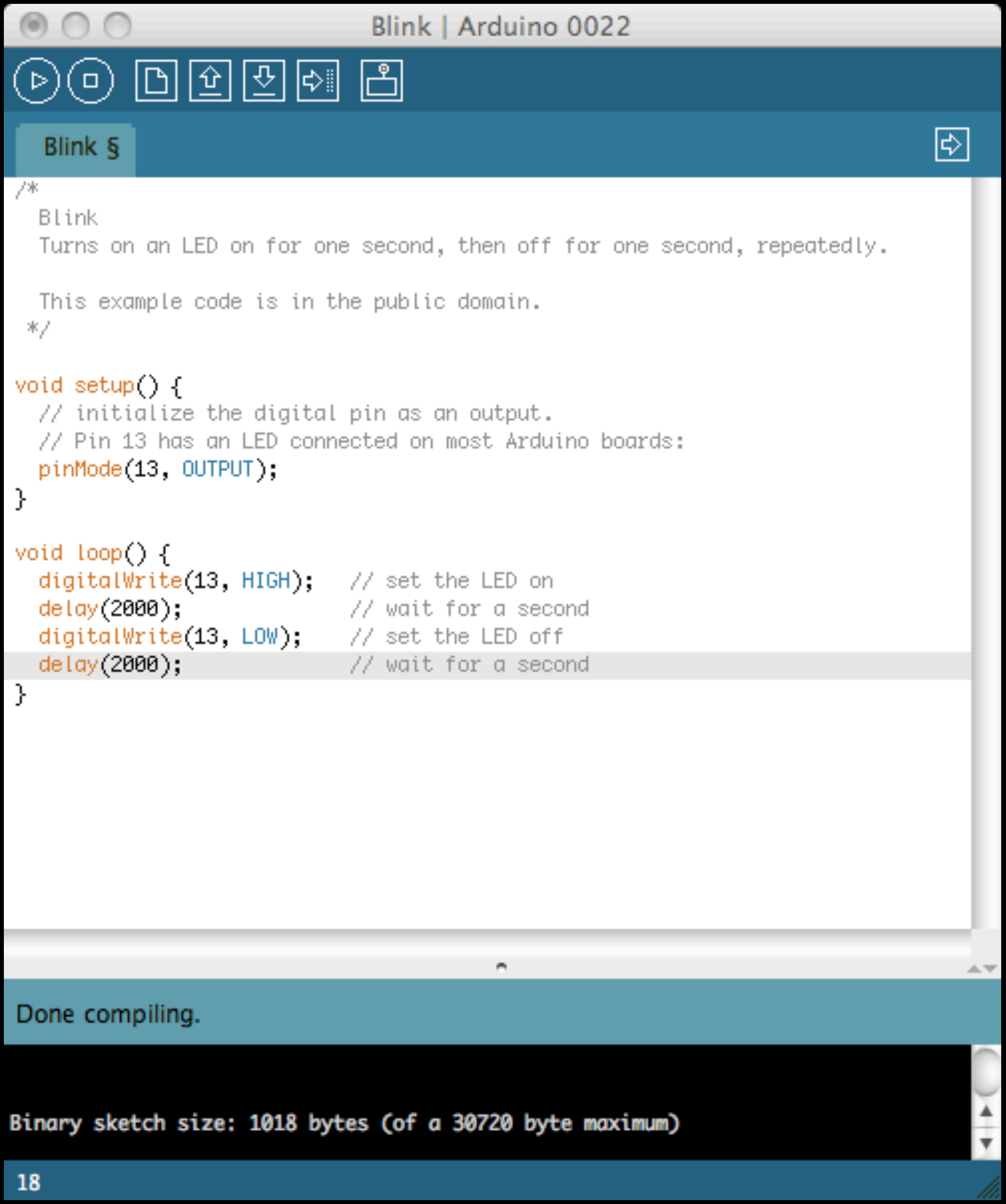
7/27/2017 2:28:31 PM f=0.75 C:\Users\ladyada\Dropbox (Personal)\breakouts\DevBoards\Adafruit-METRO-328-PCB\Metro Mini Re


USB/Serial Bridge
U3G$2
THERMAL PAD
U3G$1
CP2104 USB/UART BRIDGE
VIO VDD REGIN #RST #SUSPEND SUSPEND GPIO0/TXLED GPIO1/RXLED GPIO2 GPIO3
VBUS D+ D- RI DCD DTR DSR TXD RXD RTS CTS VPP NC GND
VIO: 1.8-VDD
Op. Temp: -40~85°C
X1
VBUS D+ D- ID GND
20329
D3 MBR120
YELLOW D4
YELLOW D5
DTR
RXD
TXD
ATMEGA328 MCU
POWER SUPPLY: 5V
Original diode was M7 (1A Si diode)
Replacement is 1A Schottky
Replaced THM with MOSFET switch
VIN
U1
IN OUT EN GND P4
MIC5225-5.0
C12 10uF
C2 10uF
U4
MIC5225-3.3
POWER SUPPLY: 3.3V
C3 10uF
IO LEVEL SELECTION
VSELECT
Default = 5V
Cut trace and solder to 3V3 to change
SCK LED
SCK
RED
POWER LED
GREEN
ON
+5V
3.3V
GND
POWER1
VBUS
RESET
VIN
20610
AREF GND SCK MISO MOSI SS IO9 IO8
20609
AD1
13 12 11 10 9 8
RESET
KMR2
U2
RESET XTAL2 XTAL1 AREF AVCC AGND VCC GND
(SCK)PB5 (MISO)PB4 (MOSI)PB3 (SS)PB2 (OC1)PB1 (ICP)PB0
(ADC5)PC5 (ADC4)PC4 (ADC3)PC3 (ADC2)PC2 (ADC1)PC1 (ADC0)PC0
(AIN1)PD7 (AIN0)PD6 (T1)PD5 (T0)PD4 (INT1)PD3 (INT0)PD2 (TXD)PD1 (RXD)PD0
ATMEGA328P
CSTCE16M0V53-R0 16MHZ
AD5/SCL AD4/SDA AD3 AD2 AD1 AD0
AD
IO7 IO6 IO5 IO4 IO3 IO2 TXD IO0
IOL
7 6 5 4 3 2 1 0
R11 1K
Lots of room for BLAH BLAH BLAH notes
Author: Limor Fried & KTOWN
Metro Mini Rev B
7/27/2017 2:28:13 PM
Sheet: 1/1

Arduino Software Environment

IDE | Structure of Arduino programs | Flashing programs

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
}
```

Done compiling.

```
Binary sketch size: 1018 bytes (of a 30720 byte maximum)
```

Sketch

```
/*
  Blink
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}
```

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

Multimeter demonstration

Voltage

Resistance

Connections