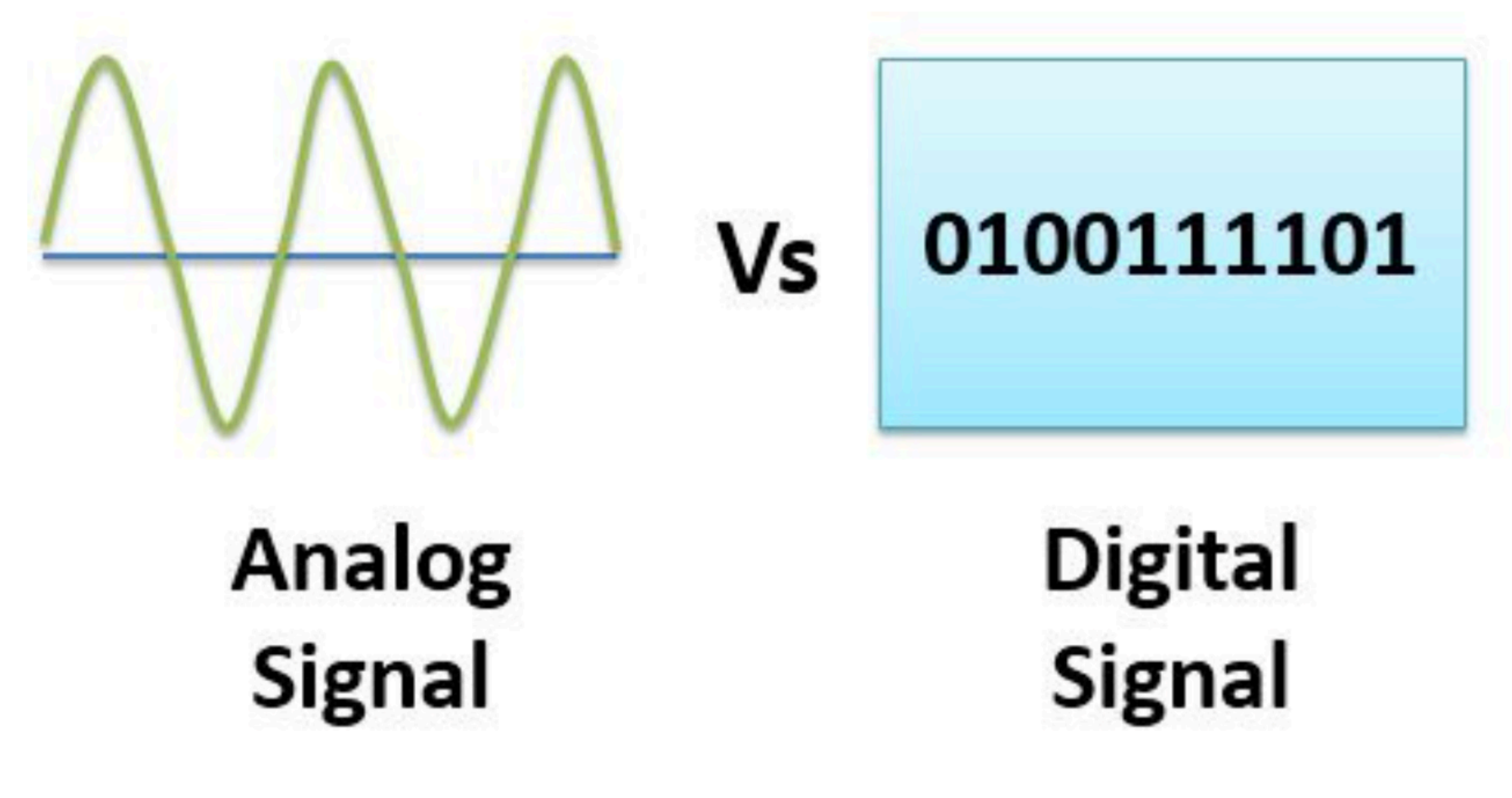
Lecture #2
Basic Electronics
Developer Platform

Spring 2024

Signals



Vs

0100111101

Analog Signal

Digital Signal

Analog and Digital

- We can store only digital signal.
  - We will convert everything that is analog to digital.
- When reading or writing digital signals we need to establish values for:
  - Bits per sample.
  - Sampling rate.

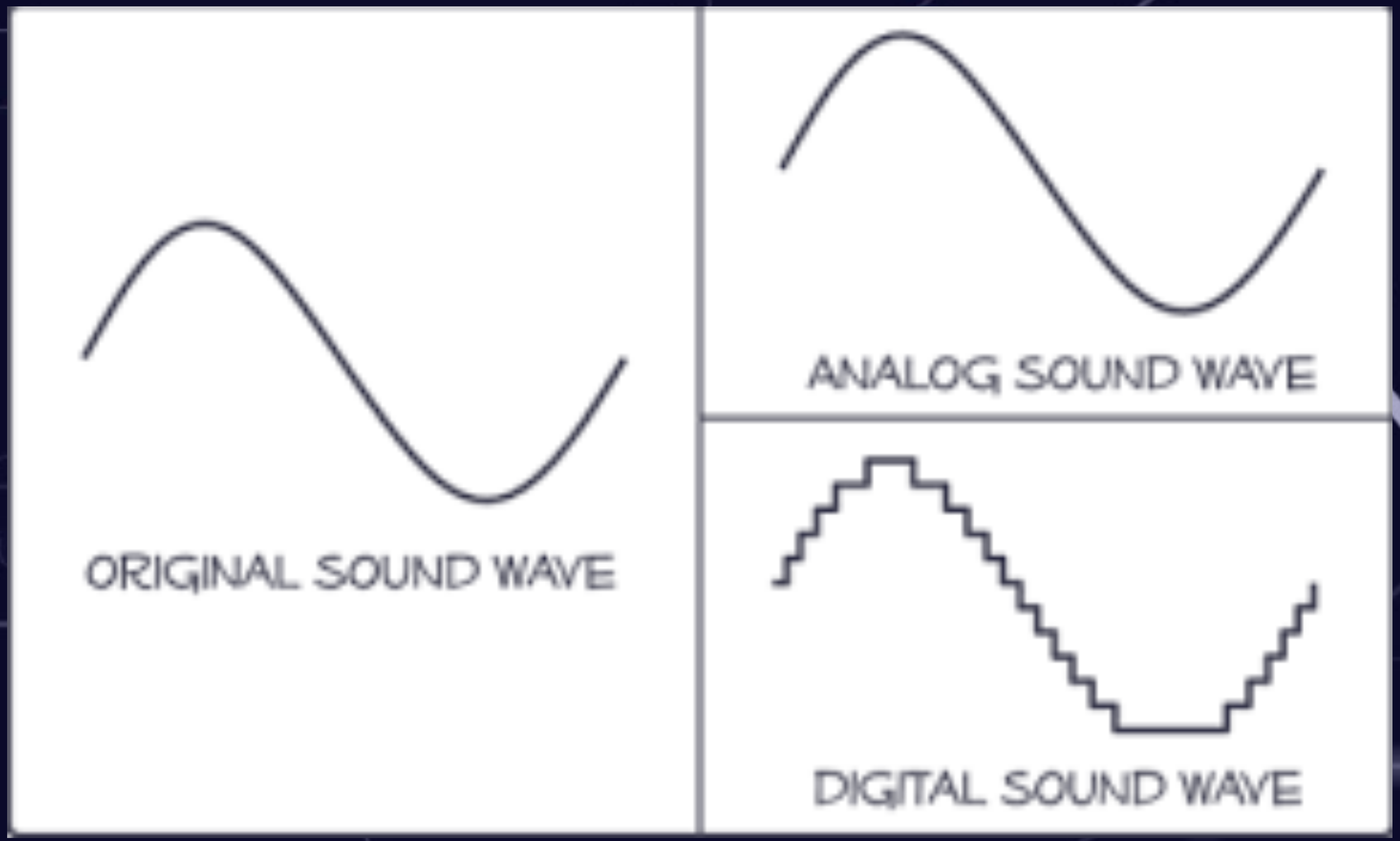
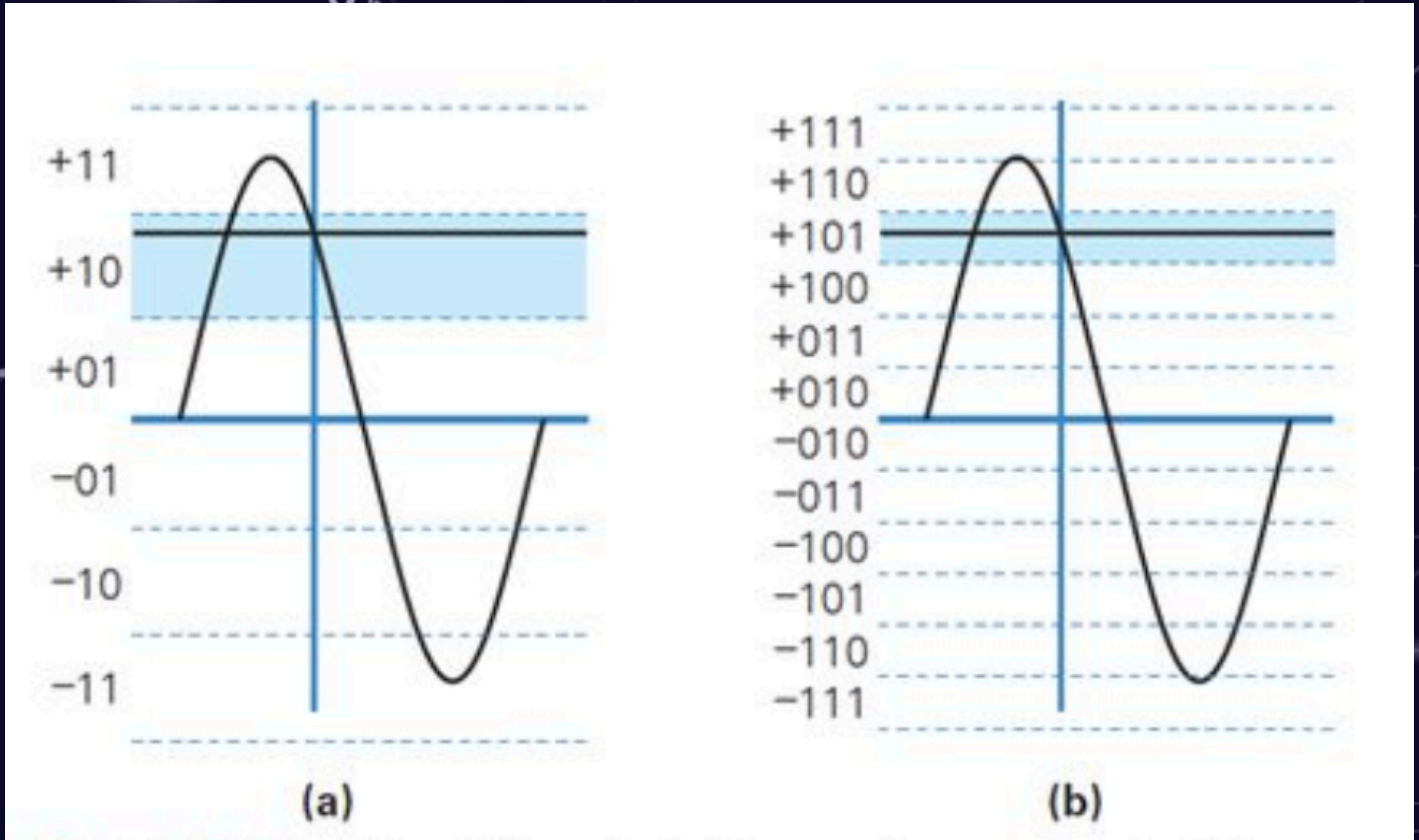


Image source: www.electronioproducts.com

Bits per sample

- How many bits are used to represent a value.

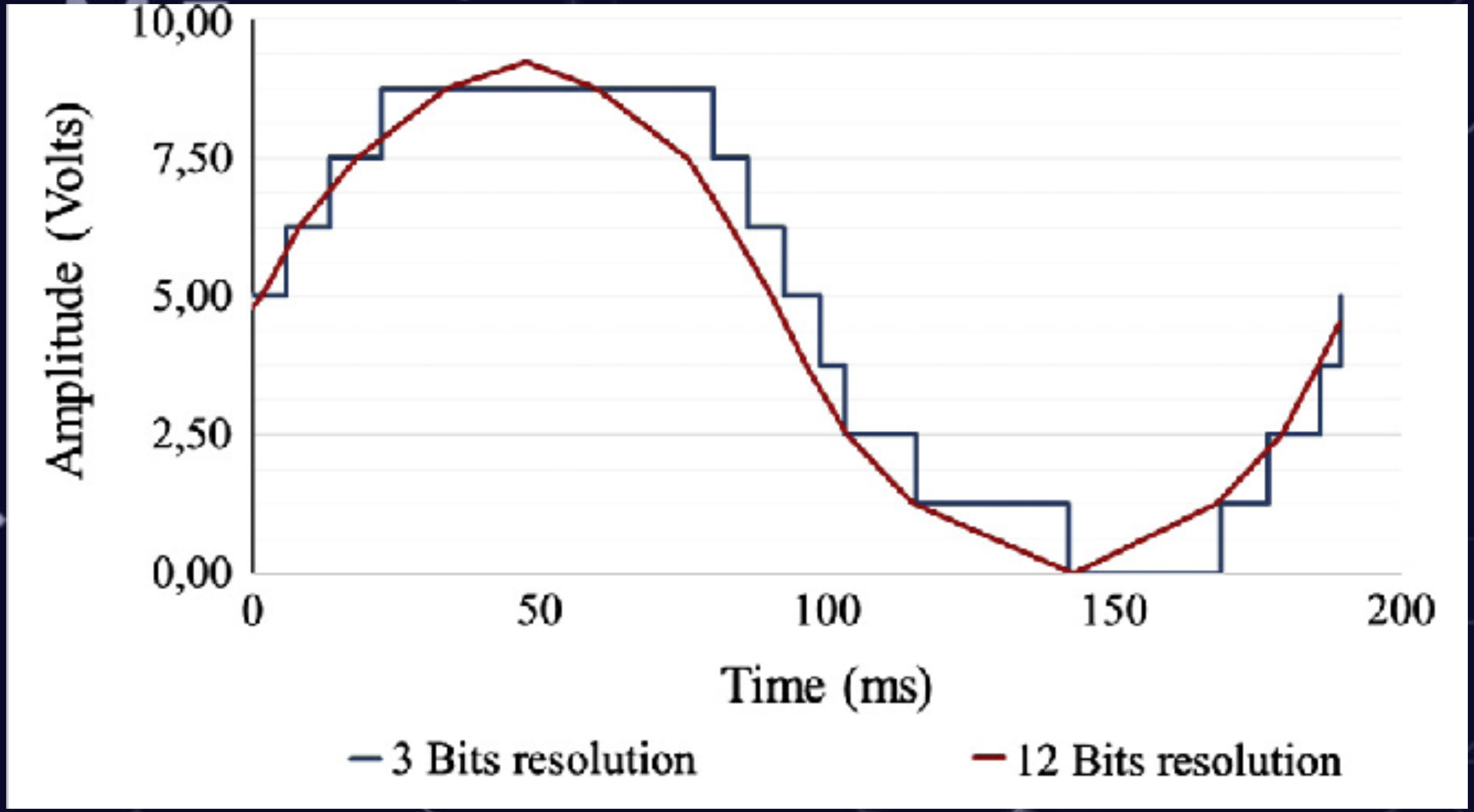


Bits per sample

- For **n** bits:
  - Values will range between 0 and 2^n - 1.
  - Eg. for 3 bits we will have:
    - 000 - 0
    - 001 - 1
    - 010 - 2
    - 011 - 3
    - 100 - 4
    - 101 - 5
    - 110 - 6
    - 111 - 7

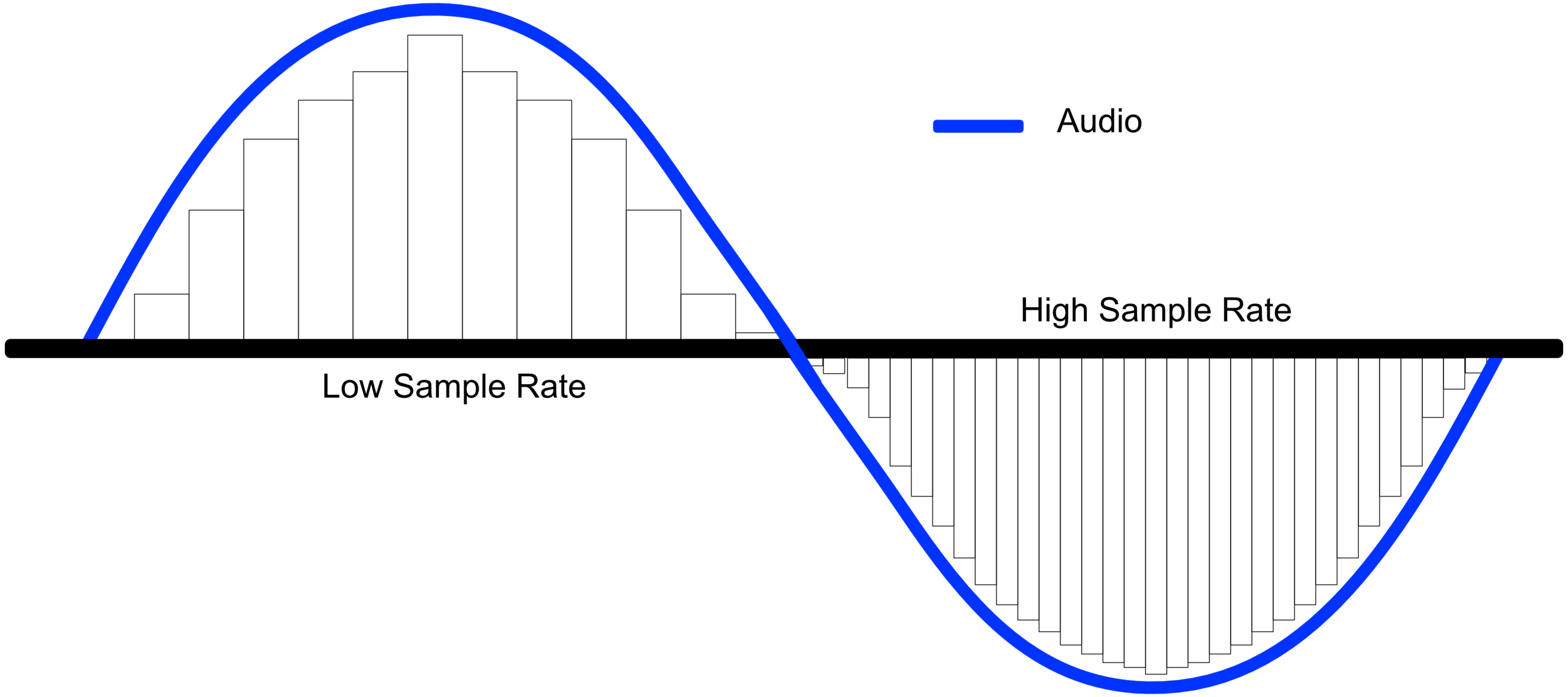
Source: etowns

Bits per sample

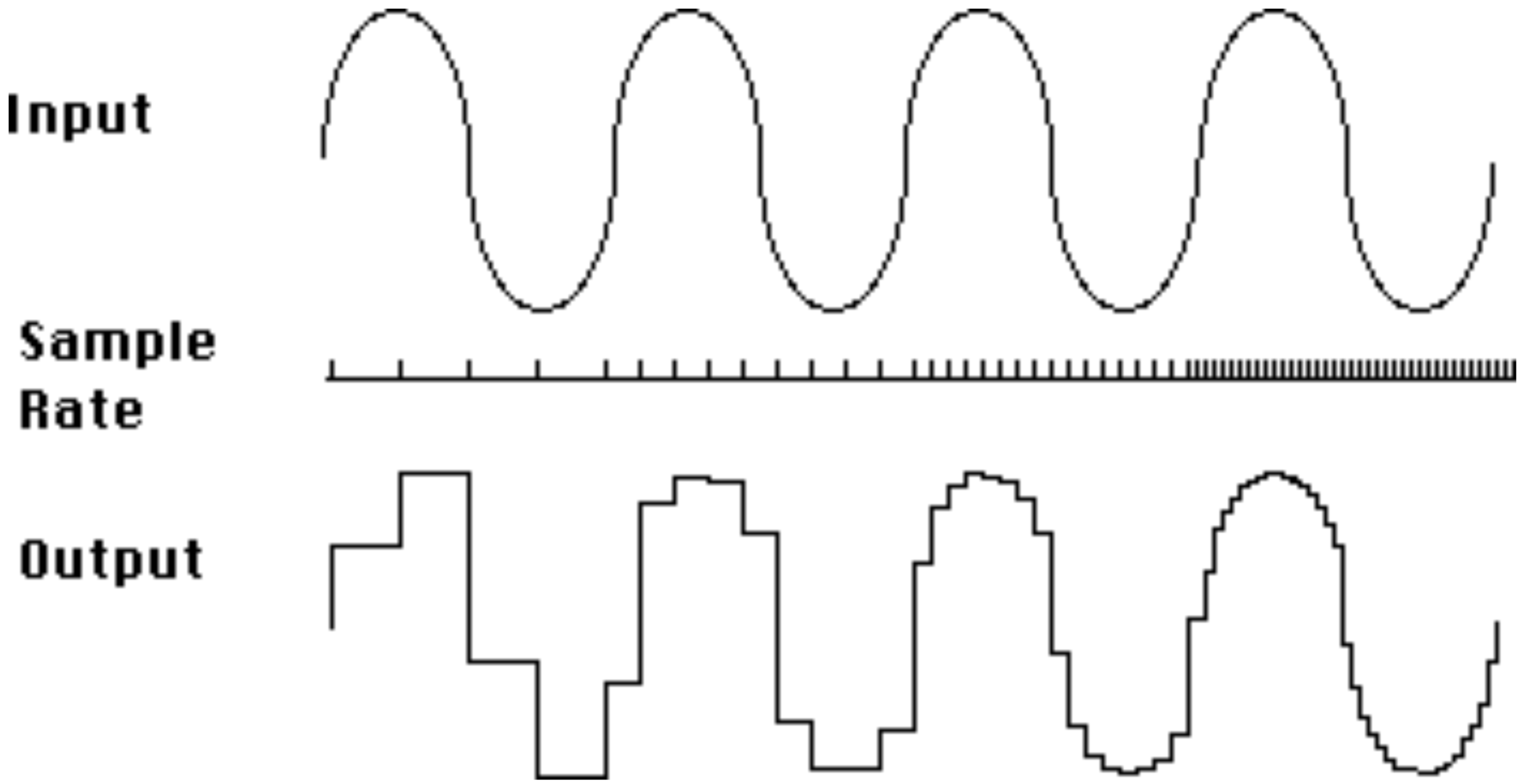


Sampling

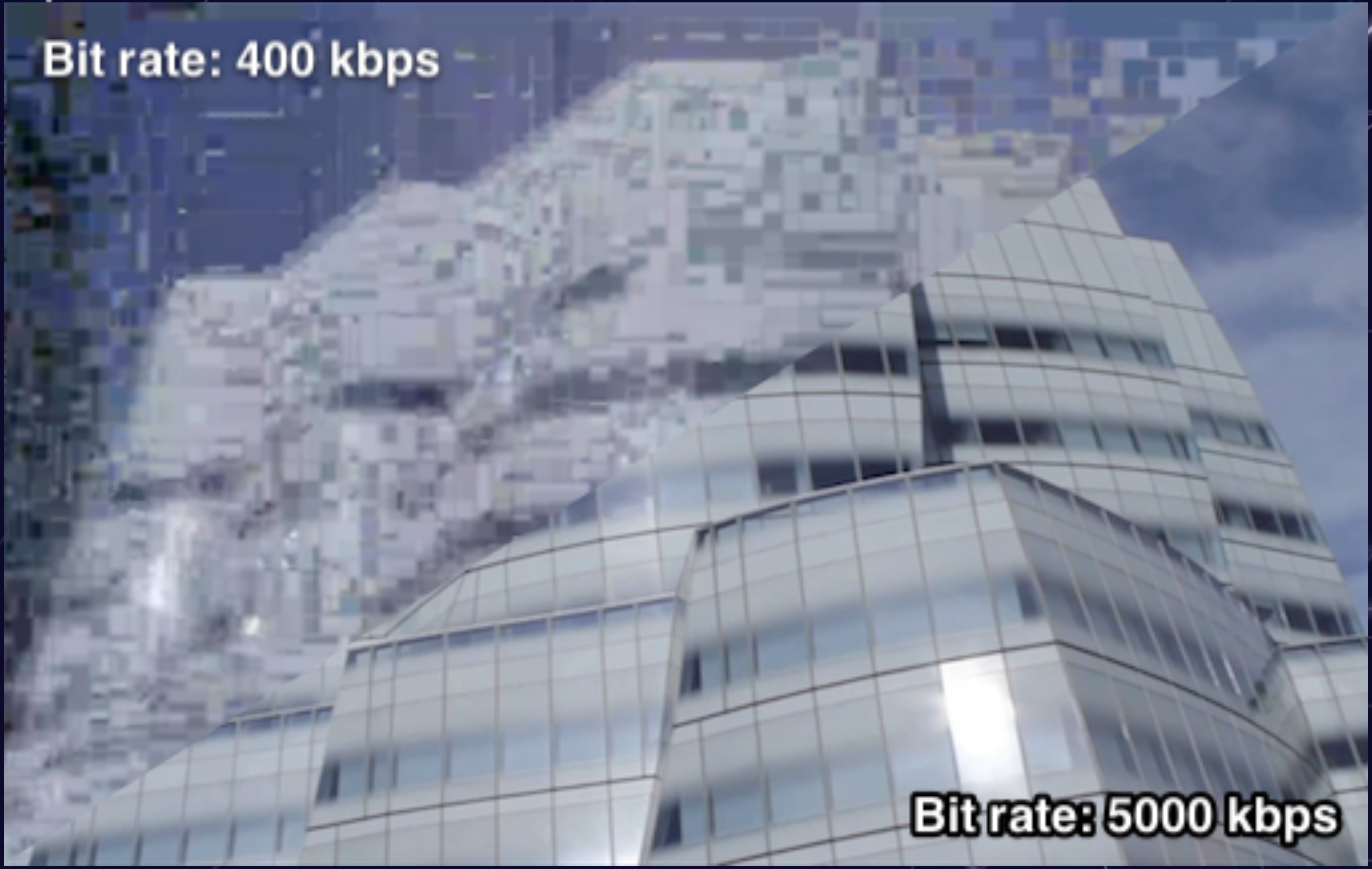
- Make measurements



Sampling



Sampling



Frequency

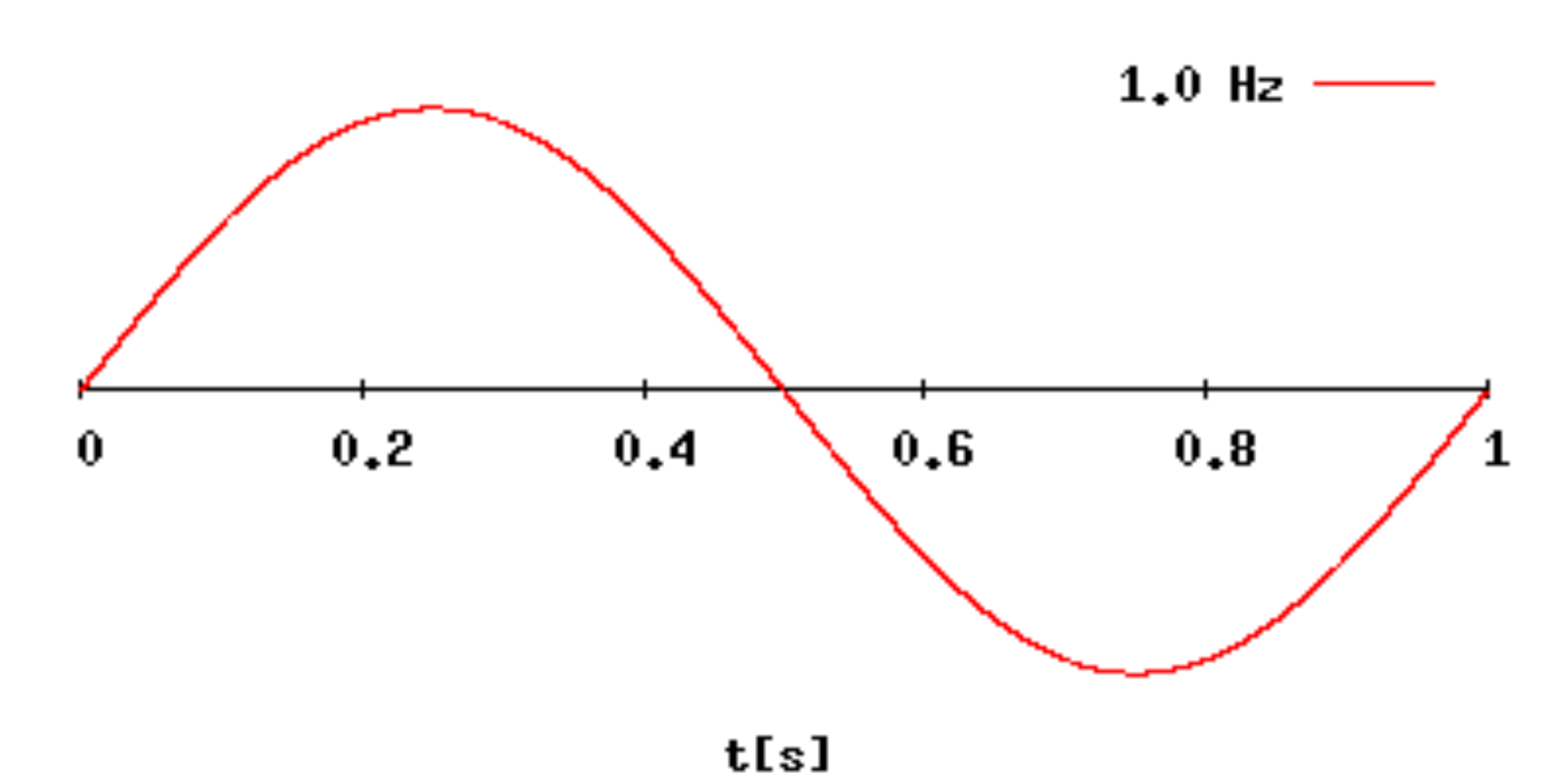
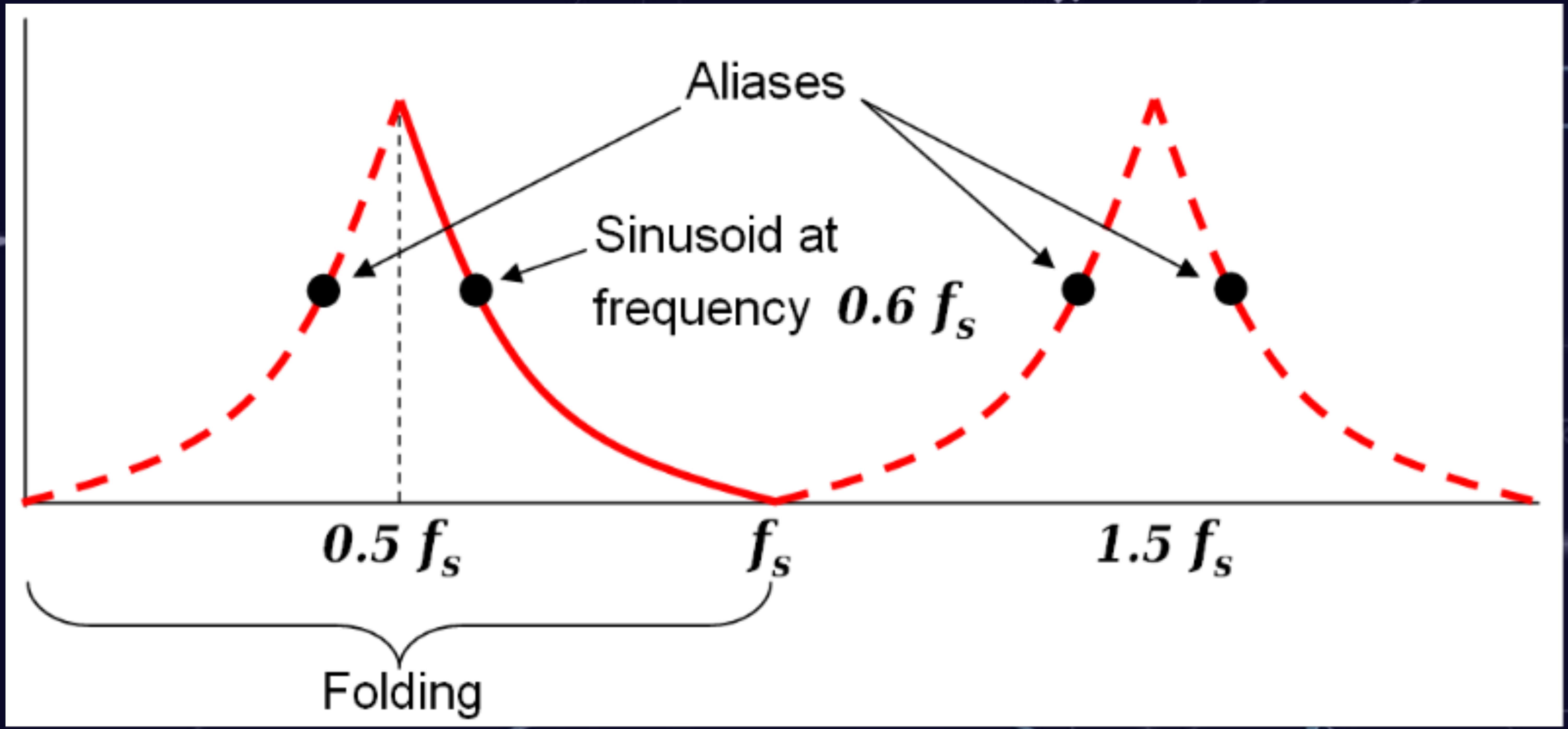


Image source: https://commons.wikimedia.org/wiki/File:Wave_frequency.gif

Sampling Rate

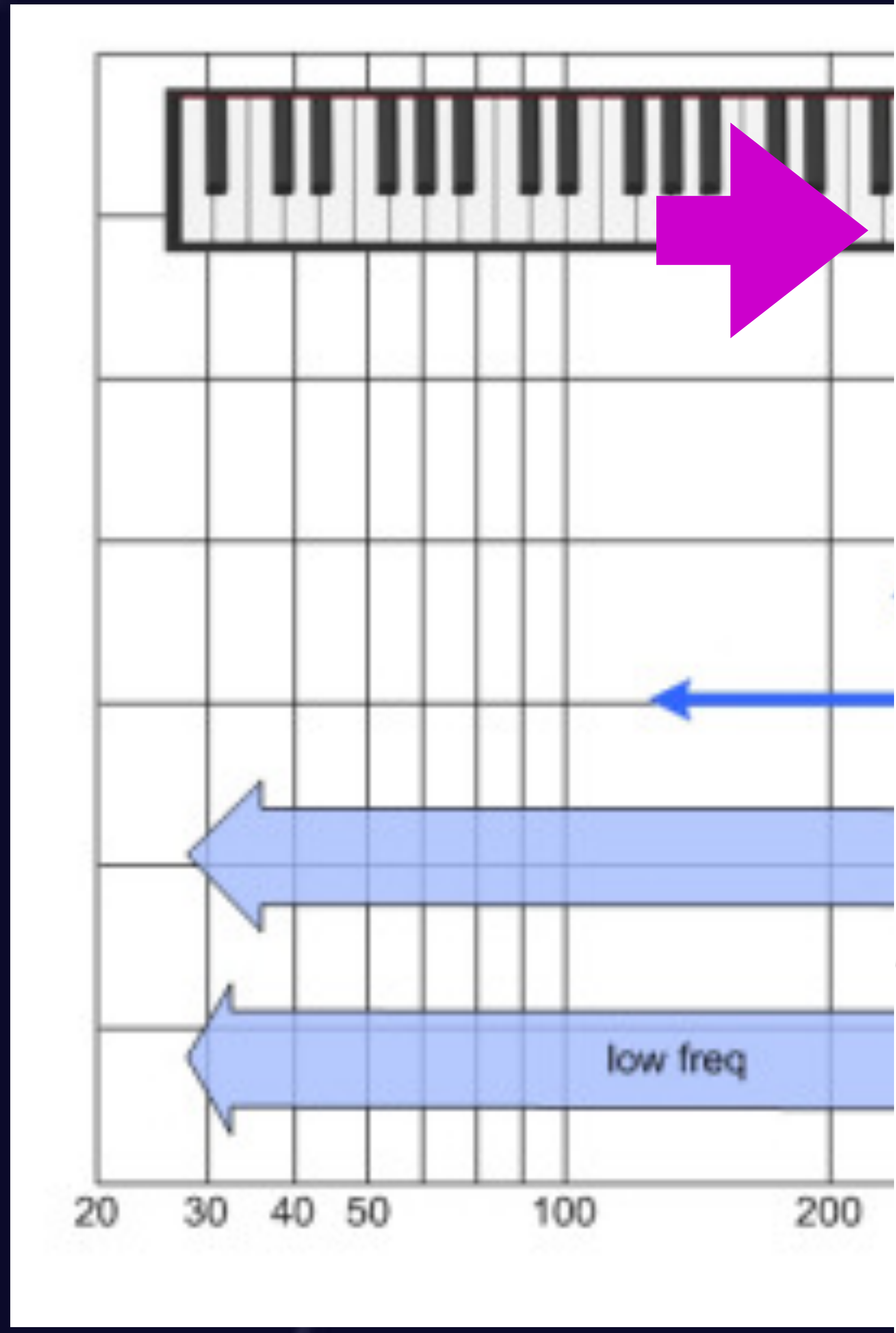
- Nyquist Theorem: Sampling rate >= 2*max frequency

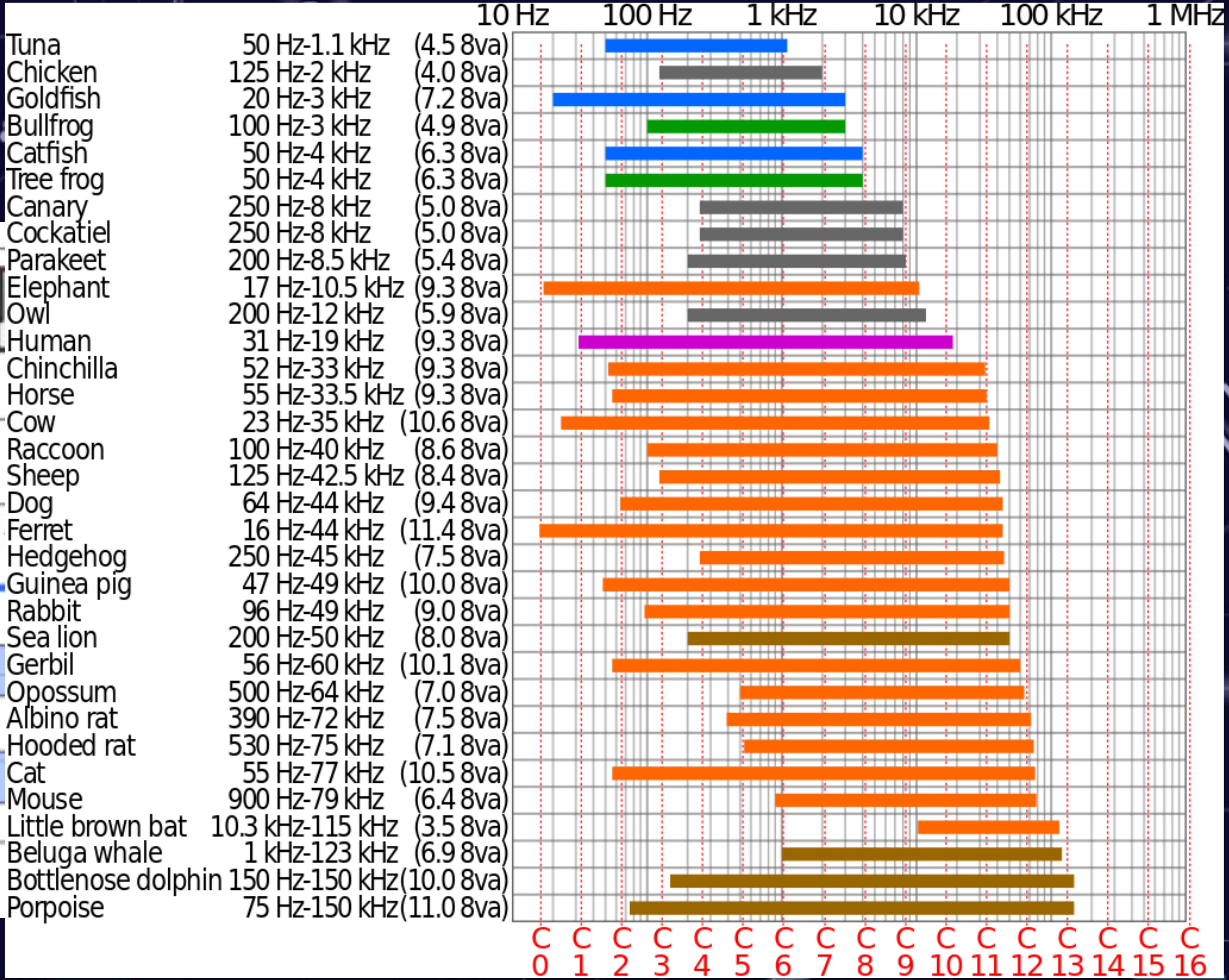


https://whatis.techtarget.com/definition/Nyquist-Theorem

Voice Frequency

- Human audible range:
  - 20 Hz to 20KHz.





Tuna	50 Hz-1.1 kHz	(4.5 8va)
Chicken	125 Hz-2 kHz	(4.0 8va)
Goldfish	20 Hz-3 kHz	(7.2 8va)
Bullfrog	100 Hz-3 kHz	(4.9 8va)
Catfish	50 Hz-4 kHz	(6.3 8va)
Tree frog	50 Hz-4 kHz	(6.3 8va)
Canary	250 Hz-8 kHz	(5.0 8va)
Cockatiel	250 Hz-8 kHz	(5.0 8va)
Parakeet	200 Hz-8.5 kHz	(5.4 8va)
Elephant	17 Hz-10.5 kHz	(9.3 8va)
Owl	200 Hz-12 kHz	(5.9 8va)
Human	31 Hz-19 kHz	(9.3 8va)
Chinchilla	52 Hz-33 kHz	(9.3 8va)
Horse	55 Hz-33.5 kHz	(9.3 8va)
Cow	23 Hz-35 kHz	(10.6 8va)
Raccoon	100 Hz-40 kHz	(8.6 8va)
Sheep	125 Hz-42.5 kHz	(8.4 8va)
Dog	64 Hz-44 kHz	(9.4 8va)
Ferret	16 Hz-44 kHz	(11.4 8va)
Hedgehog	250 Hz-45 kHz	(7.5 8va)
Guinea pig	47 Hz-49 kHz	(10.0 8va)
Rabbit	96 Hz-49 kHz	(9.0 8va)
Sea lion	200 Hz-50 kHz	(8.0 8va)
Gerbil	56 Hz-60 kHz	(10.1 8va)
Opossum	500 Hz-64 kHz	(7.0 8va)
Albino rat	390 Hz-72 kHz	(7.5 8va)
Hooded rat	530 Hz-75 kHz	(7.1 8va)
Cat	55 Hz-77 kHz	(10.5 8va)
Mouse	900 Hz-79 kHz	(6.4 8va)
Little brown bat	10.3 kHz-115 kHz	(3.5 8va)
Beluga whale	1 kHz-123 kHz	(6.9 8va)
Bottlenose dolphin	150 Hz-150 kHz	(10.0 8va)
Porpoise	75 Hz-150 kHz	(11.0 8va)

Titze, I.R. (1994). Principles of Voice Production, Prentice Hall (pp. 188), ISBN 978-0-13-717893-3.

Voice Frequency

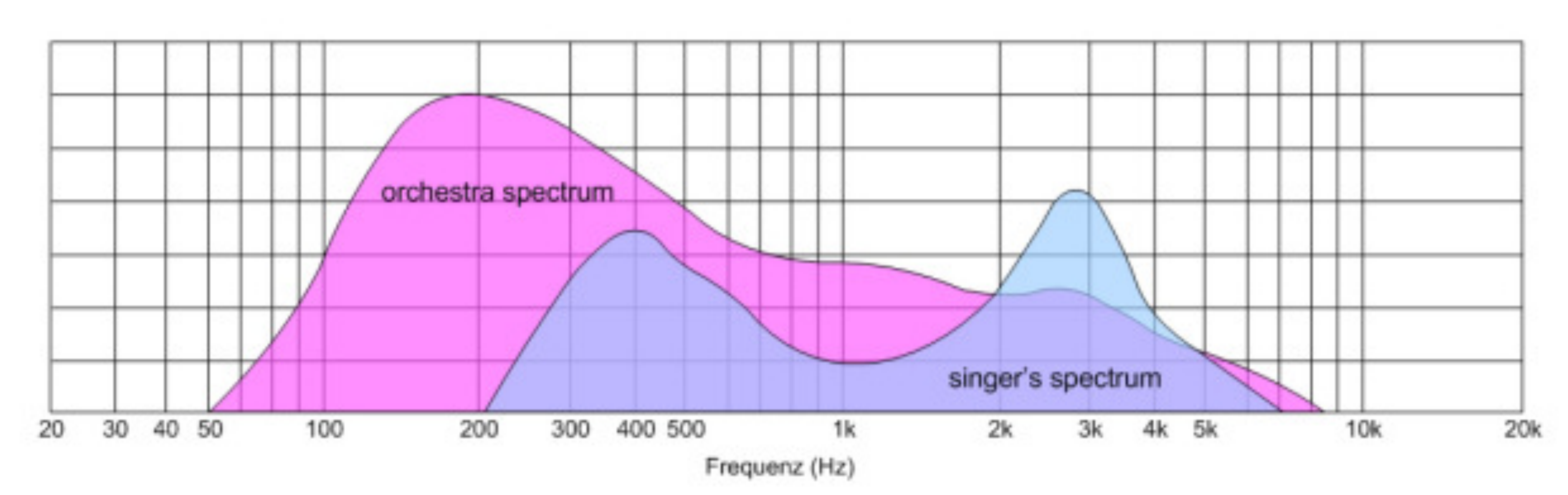
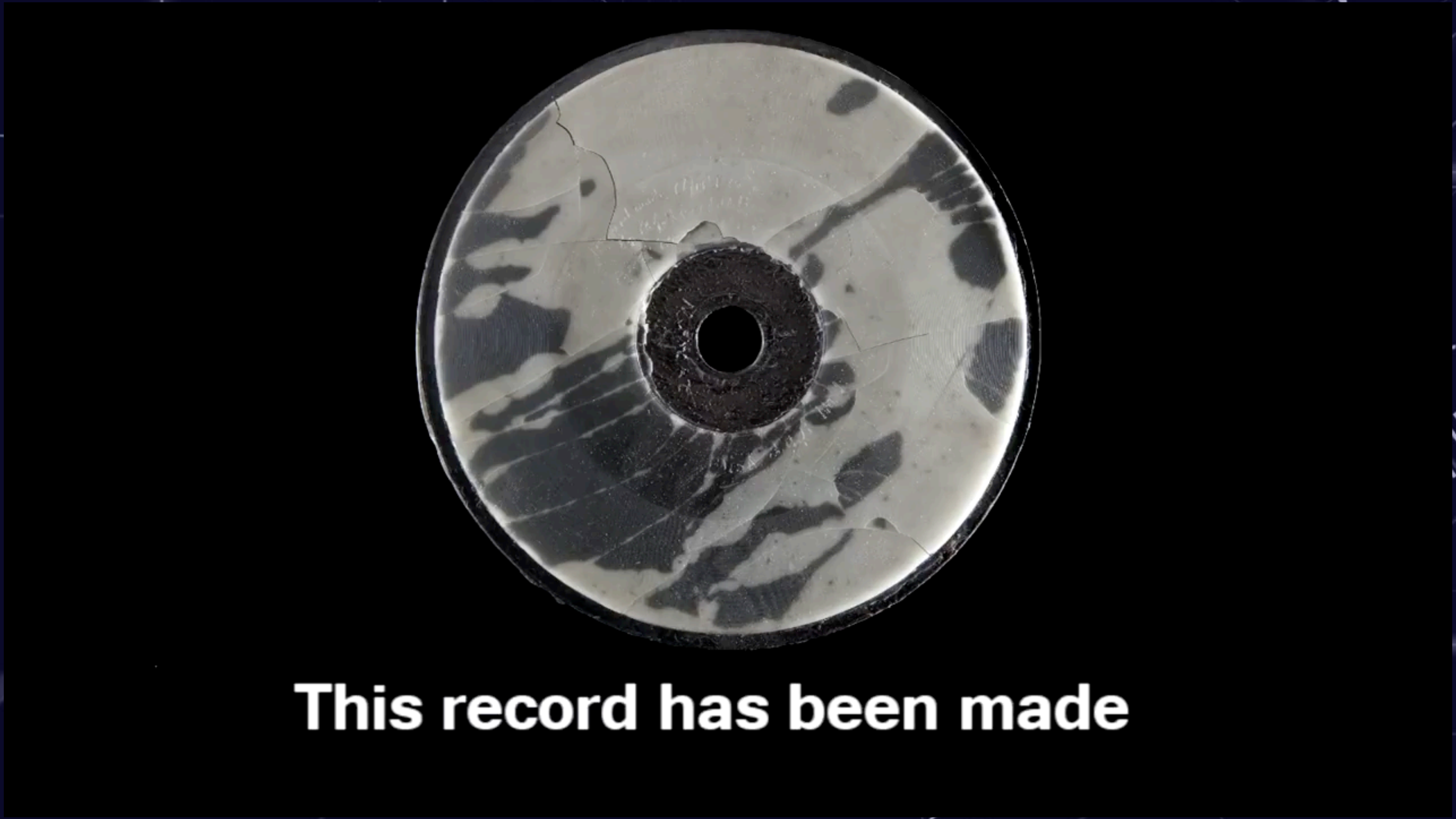


Image source: www.proav.de/audio/speech-level.html



This record has been made

Source: https://www.youtube.com/watch?v=qf97H6cV5QQ

Voice Frequency

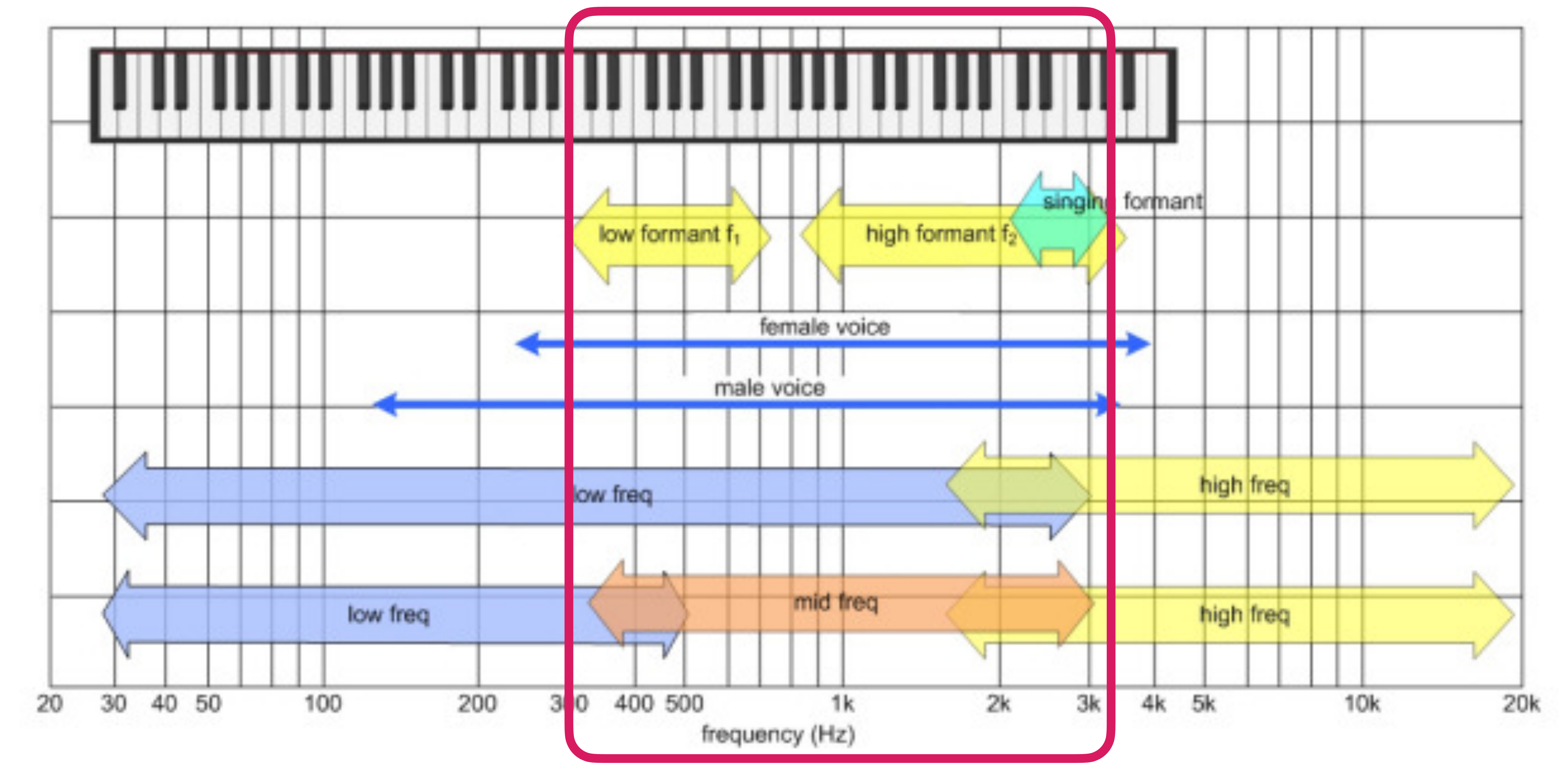


Image source: www.proav.de/audio/speech-level.html

Telephony, voice frequency range: 300Hz to 3400Hz.

Ohm Law

$$I = \frac{V}{R}$$

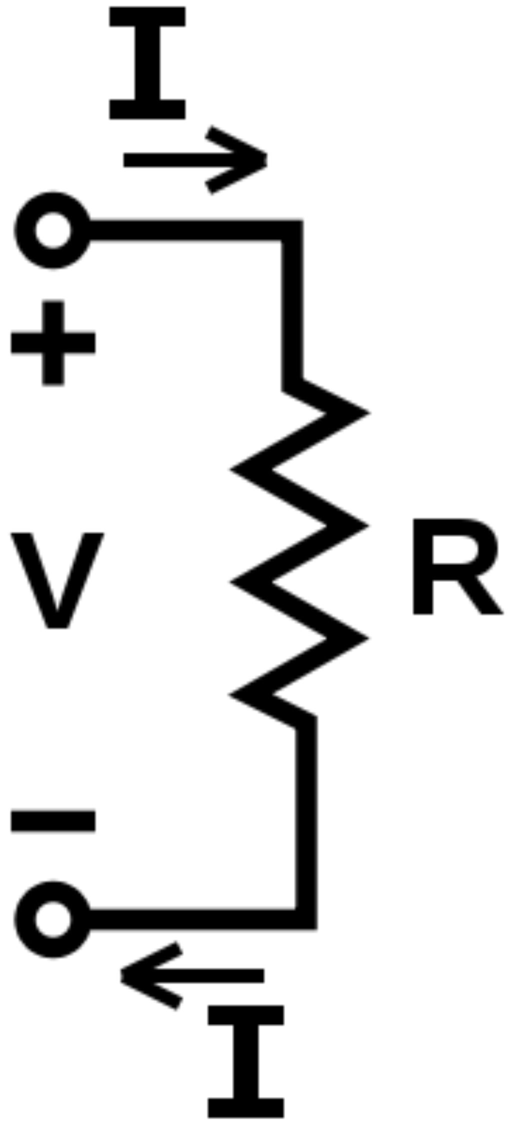
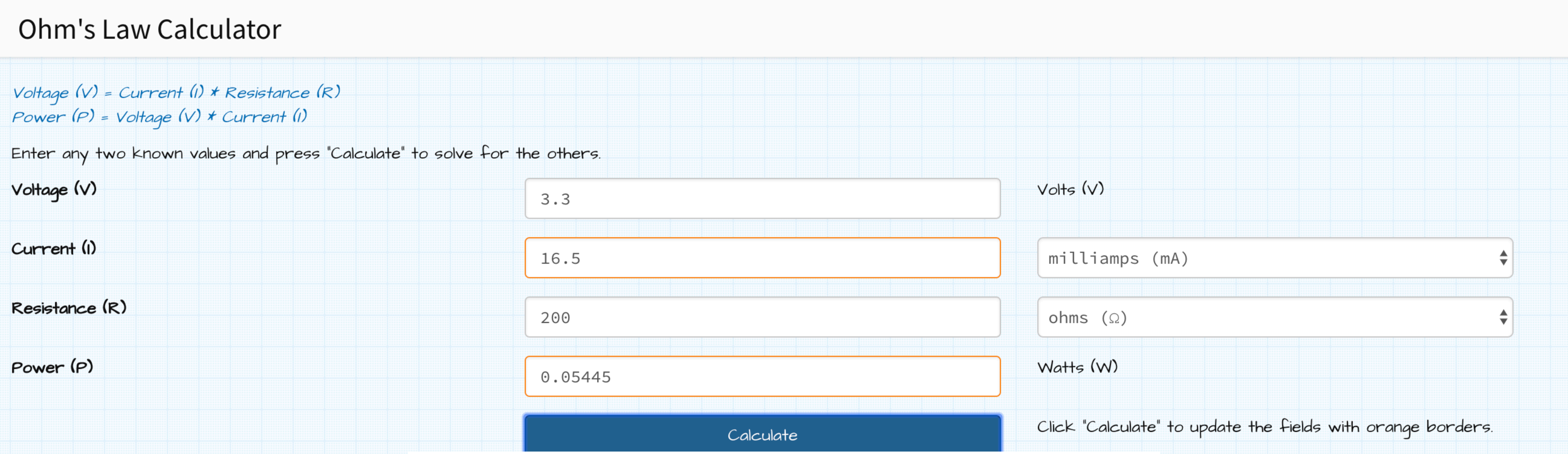


Image source: http://stat.case.edu/~pillar/genealogy/ohm.gif

Ohm Law



Ohm's Law Calculator

*Voltage (V) = Current (I) * Resistance (R)*
*Power (P) = Voltage (V) * Current (I)*

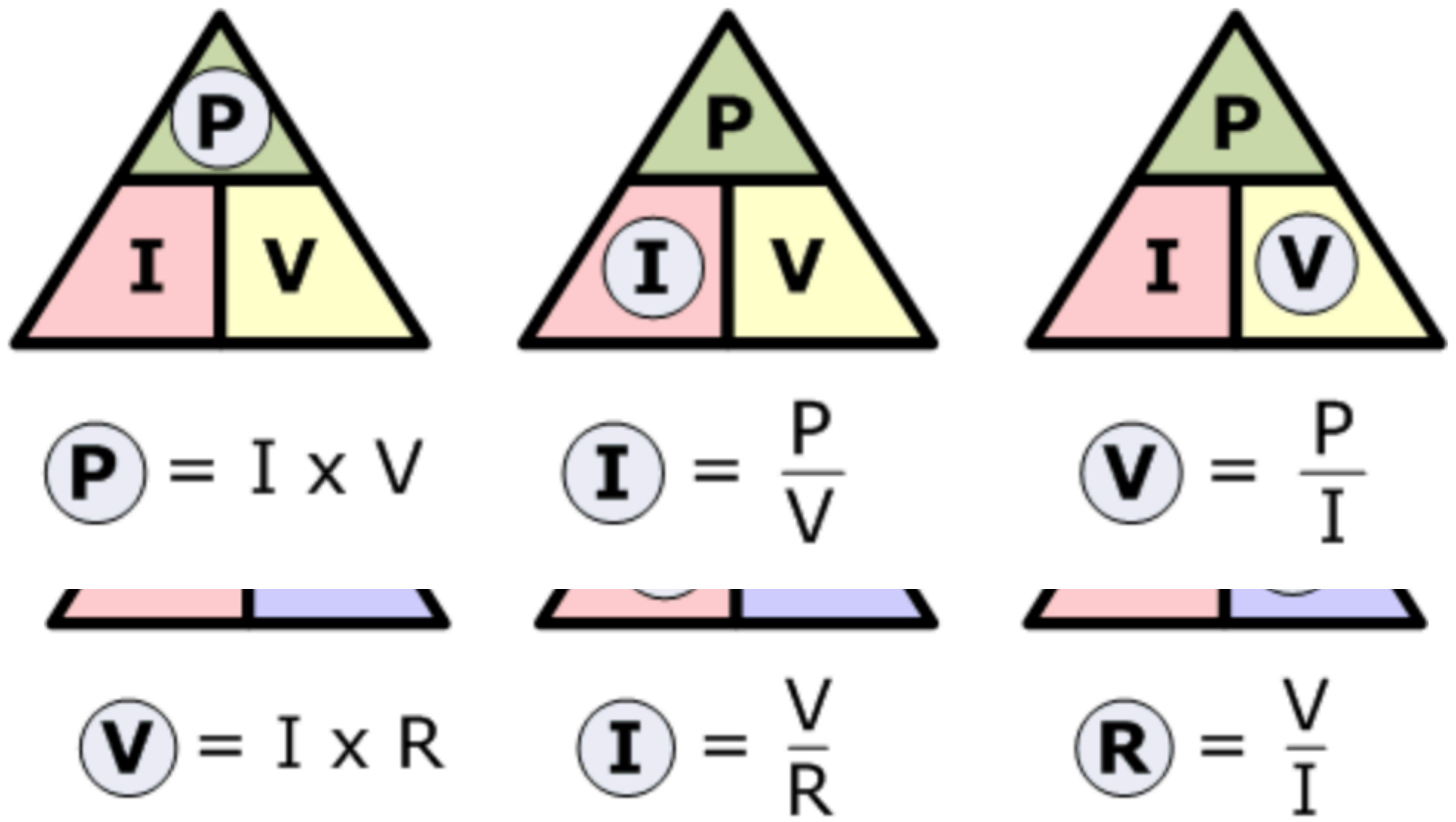
Enter any two known values and press "Calculate" to solve for the others.

Voltage (V)	3.3	Volts (V)
Current (I)	16.5	milliamps (mA)
Resistance (R)	200	ohms (Ω)
Power (P)	0.05445	Watts (W)

Calculate

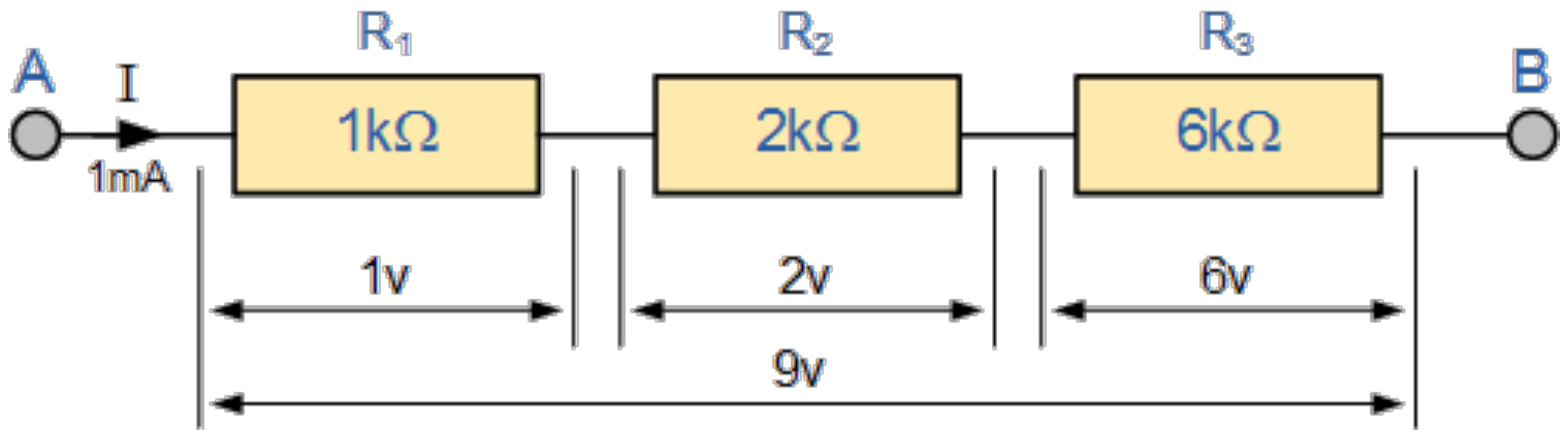
Click "Calculate" to update the fields with orange borders.

http://



ulator

Resistors in Series

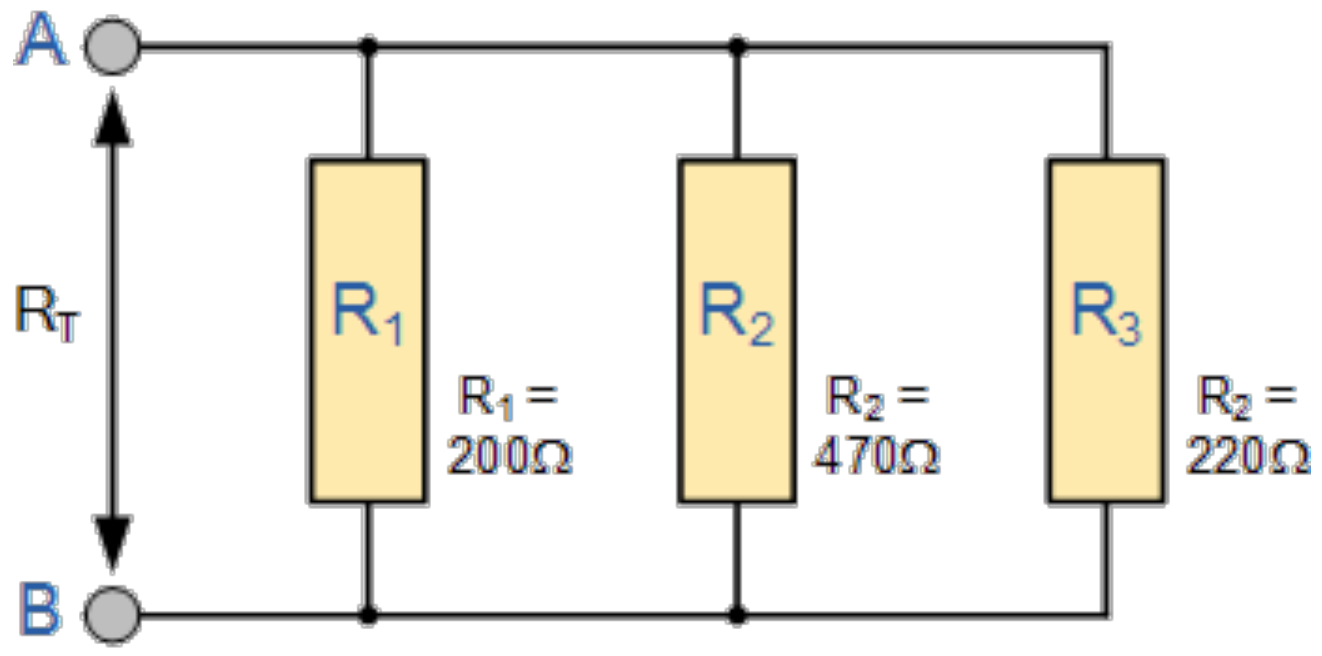


$$R_T = R_1 + R_2 + R_3$$

$R_{EQ} = R_1 + R_2 + R_3 = 1k\Omega + 2k\Omega + 6k\Omega = 9k\Omega$

https://www.electronics-tutorials.ws/resistor/res_3.html

Resistors in Parallel



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots + \frac{1}{R_n} \text{ etc}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{200} + \frac{1}{470} + \frac{1}{220} = 0.0117$$

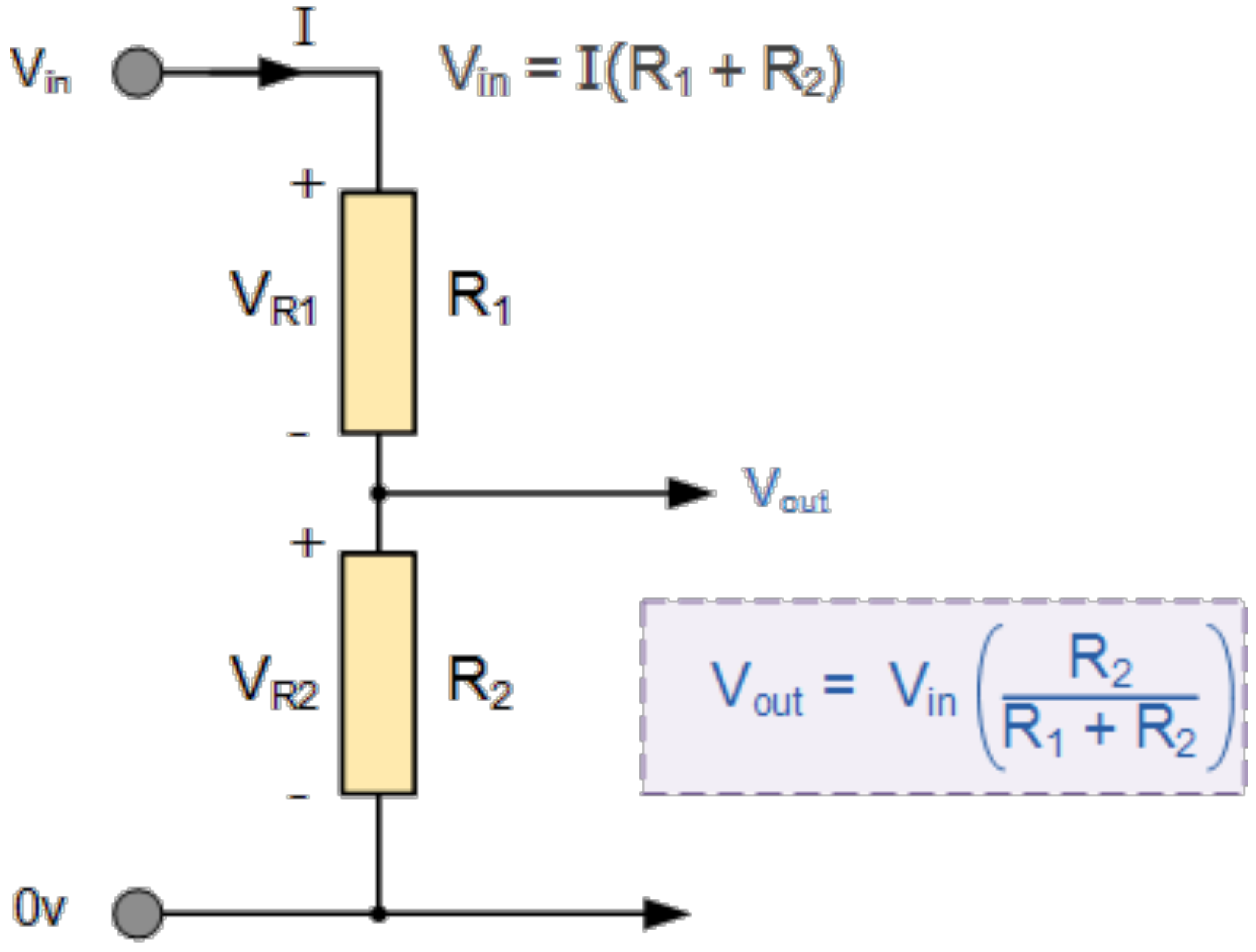
$$\text{therefore: } R_T = \frac{1}{0.0117} = 85.67\Omega$$

https://www.electronics-tutorials.ws/resistor/res_4.html

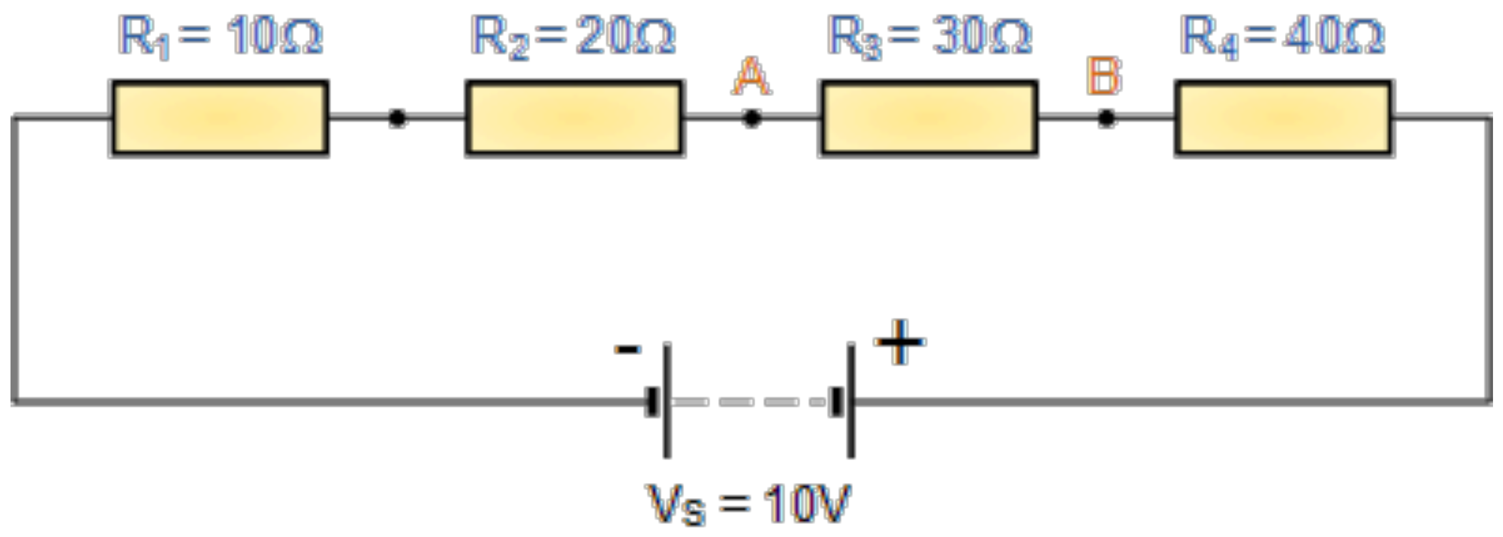
Voltage Divider Network

Kirchhoff's Voltage Law:

"the supply voltage in a closed circuit is equal to the sum of all the voltage drops (I*R) around the circuit"



Voltage Divider Network

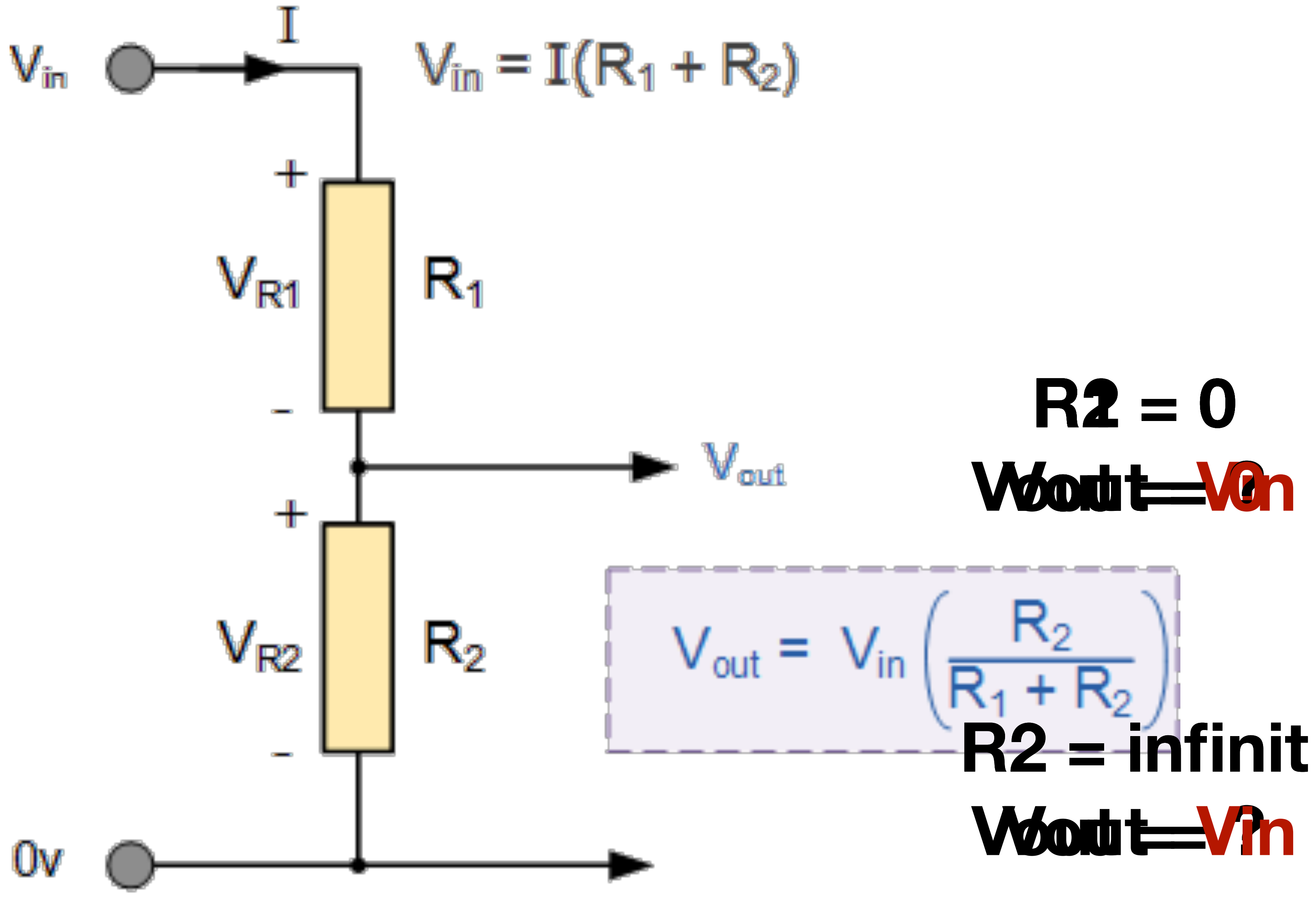


$$V_{AB} = V_{R3} = V_S \times \frac{R3}{R1 + R2 + R3 + R4}$$

$$V_{AB} = 10 \times \frac{30}{10+20+30+40} = 10 \times 0.3 = 3V$$

https://www.electronics-tutorials.ws/resistor/res_3.html

Voltage Divider Network



$$V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$$

R1 = 0

R2 = 0

Vout = ?

Vout = 0

Vout = Vin

R2 = infinit

Vout = ?

Vout = Vin

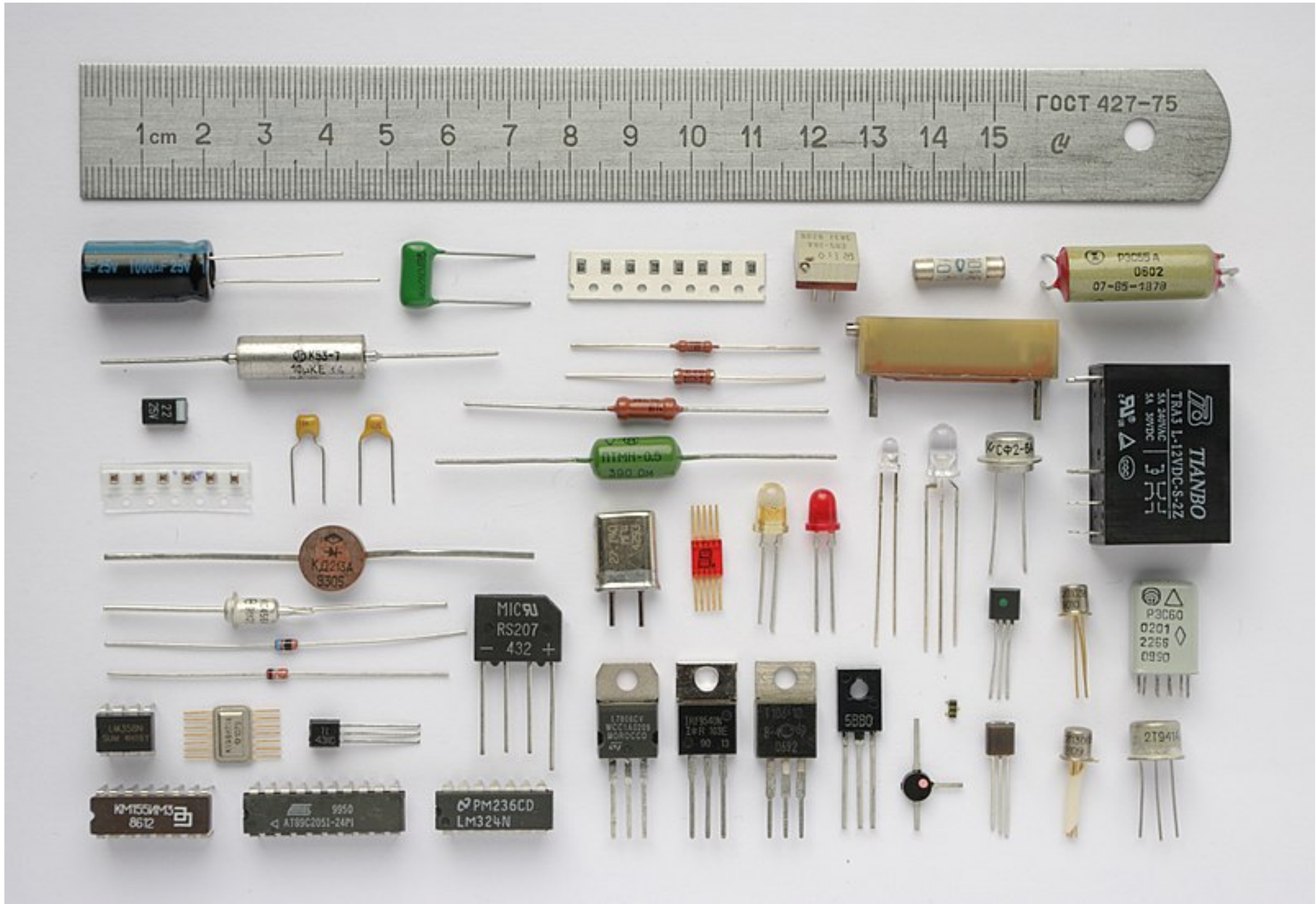
R1 = 0

R2 = 0

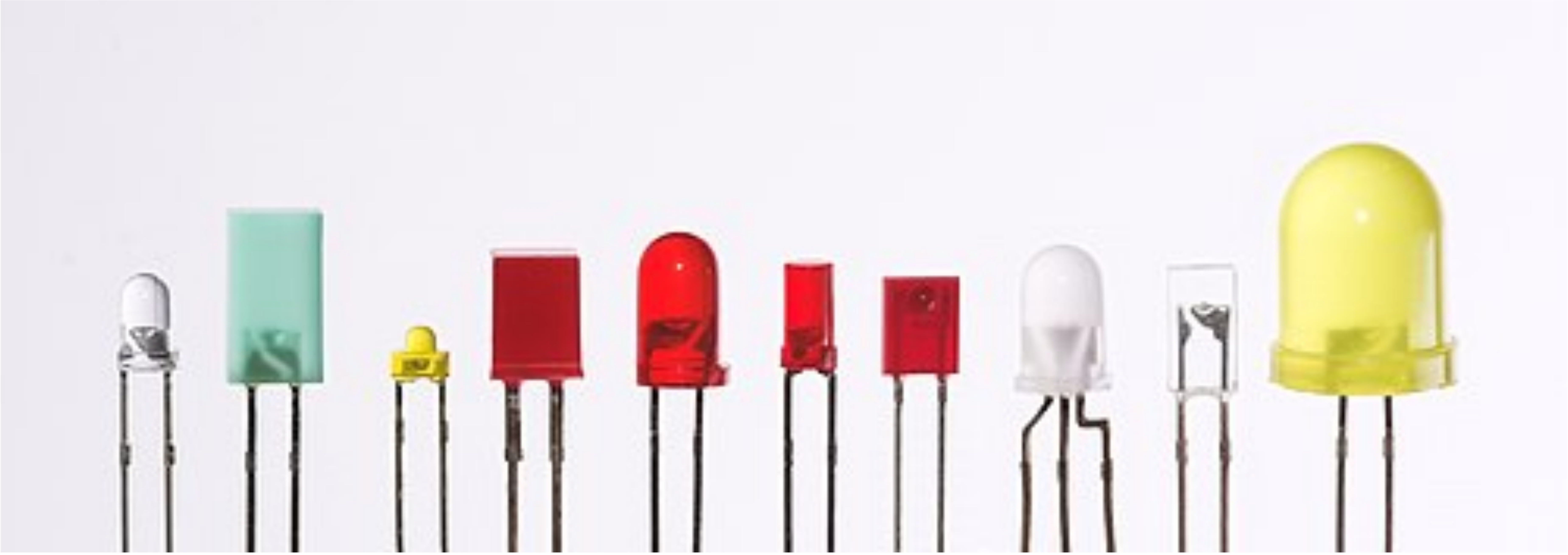
Vout = ?

Short circuit

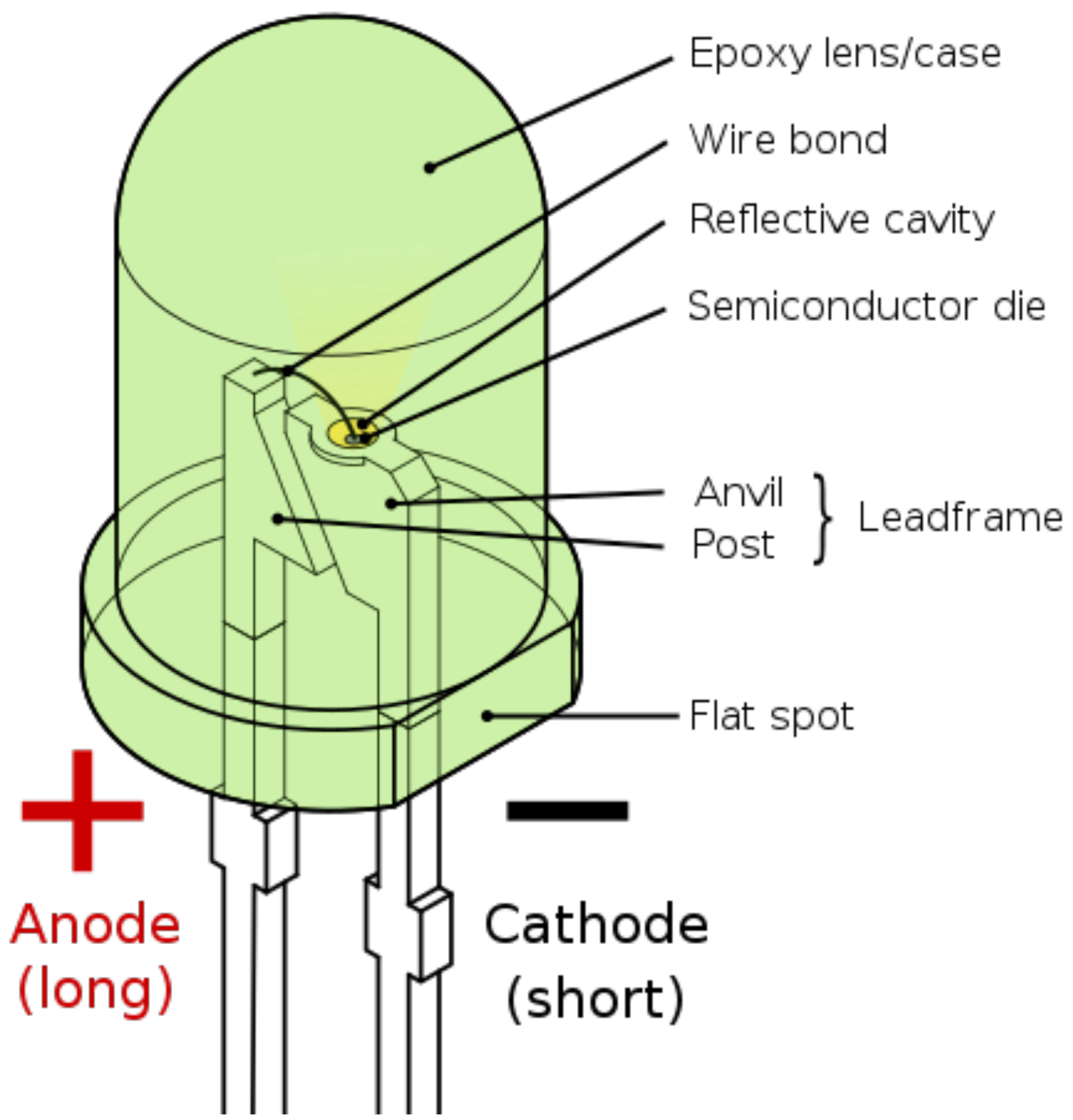
Electronic Components

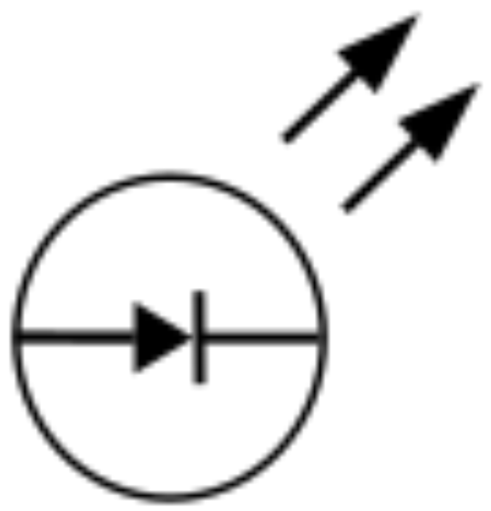


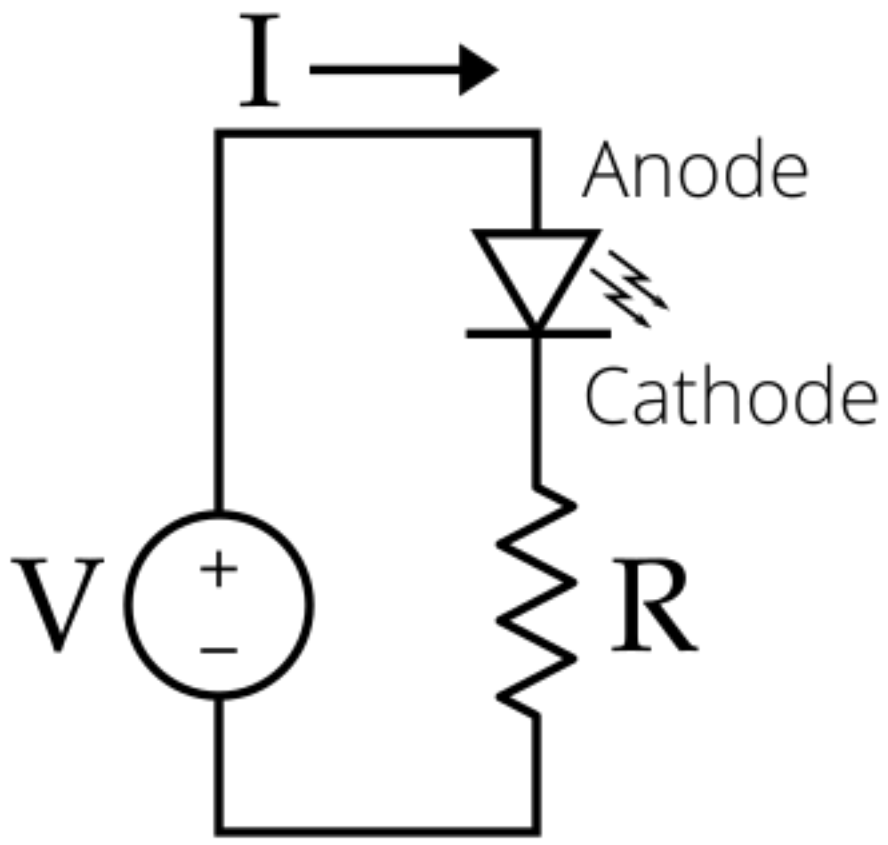
LEDs



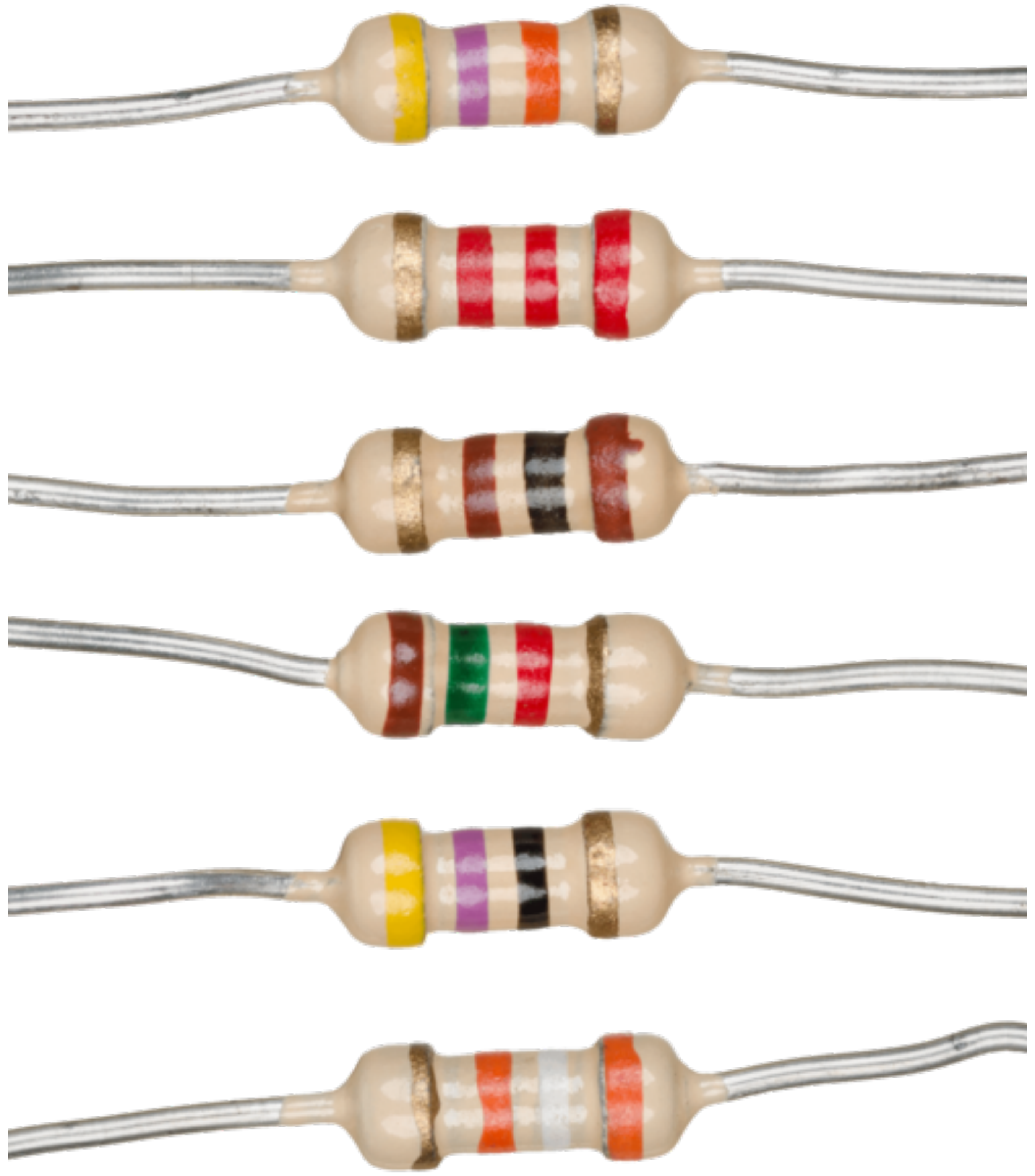
Light-emitting Diode

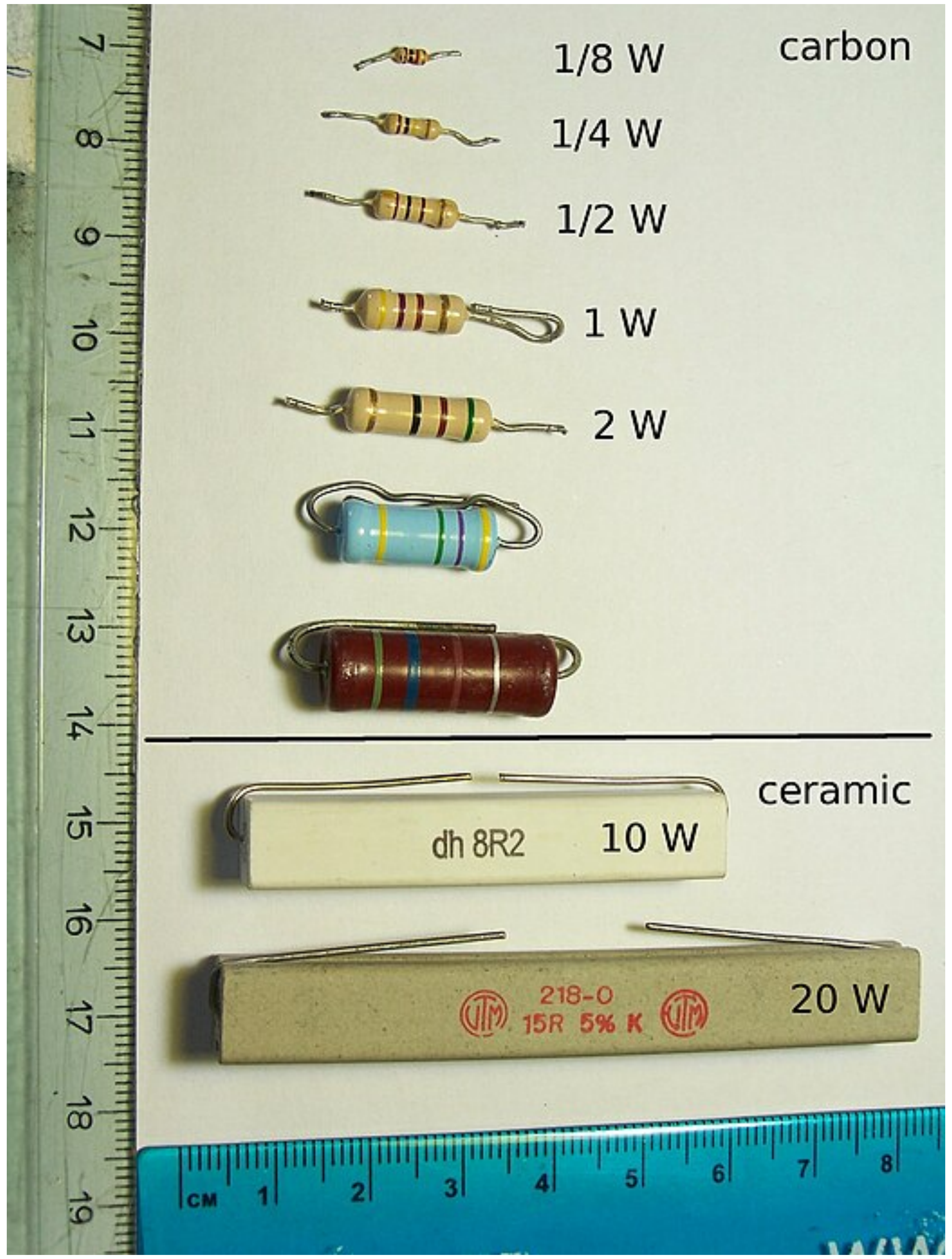


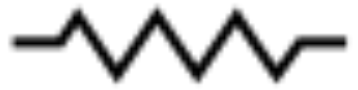


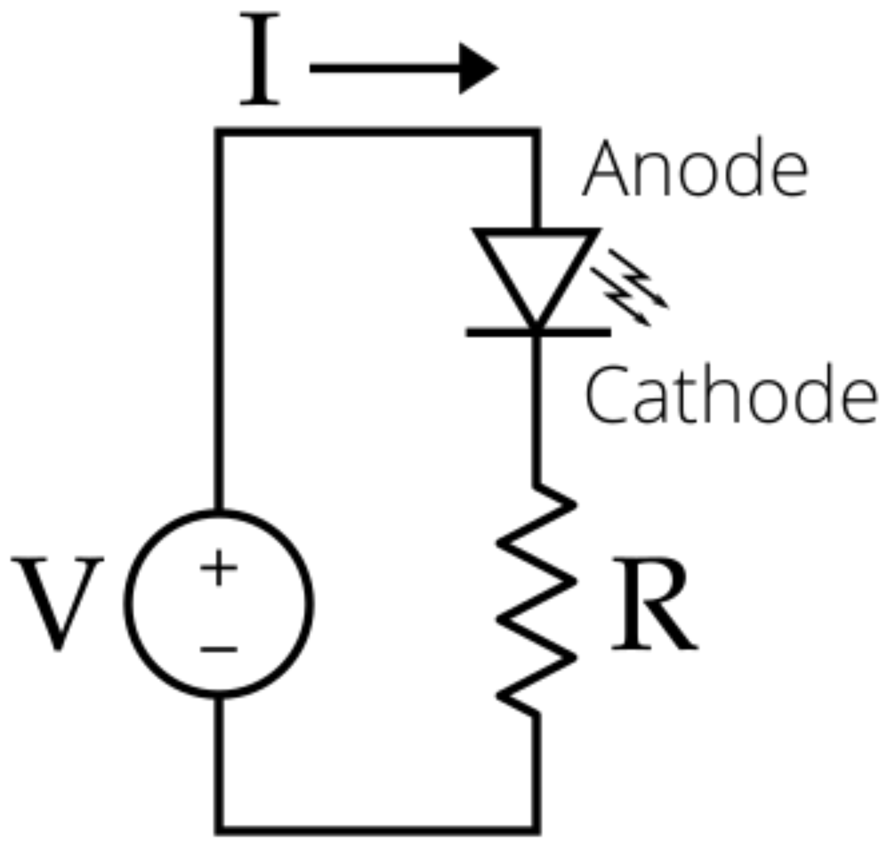


Resistors



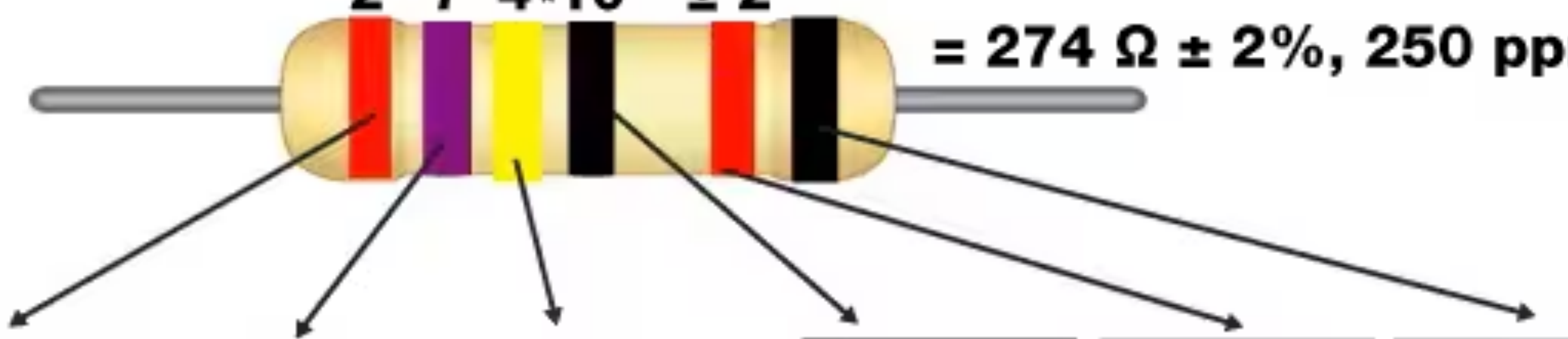

carbon
1/8 W
1/4 W
1/2 W
1 W
2 W
ceramic
dh 8R2
10 W
218-0
15R 5% K
20 W




I
Anode
Cathode
V
+
−
R

6-Band

2 7 4×10^0 ± 2

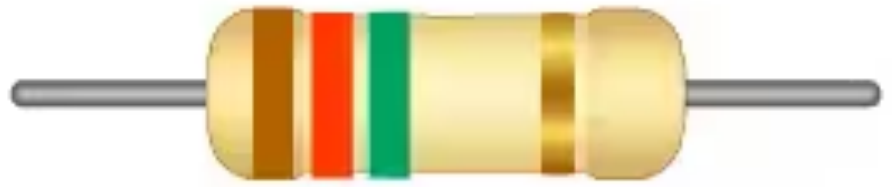


= 274 Ω ± 2%, 250 ppm/K

Color	1st Digit	2nd Digit	3rd Digit		Multiplier	Tolerance	Temperature Coefficient
Black	0	0	0		1 Ω		250 ppm/K
Brown	1	1	1		10 Ω	± 1%	100 ppm/K
Red	2	2	2		100 Ω	± 2%	50 ppm/K
Orange	3	3	3	×	1k Ω		15 ppm/K
Yellow	4	4	4		10k Ω		25 ppm/K
Green	5	5	5		100k Ω	± 0.5%	20 ppm/K
Blue	6	6	6		1M Ω	± 0.25%	10 ppm/K
Violet	7	7	7			± 0.1%	5 ppm/K
Grey	8	8	8				1 ppm/K
White	9	9	9				
Gold					0.1 Ω	± 5%	
Silver					0.01 Ω	± 10%	

12 × 10^5 ±5%

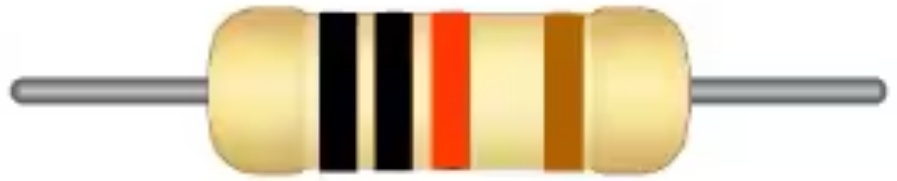
4-Band



= 1,200 kΩ ± 5%

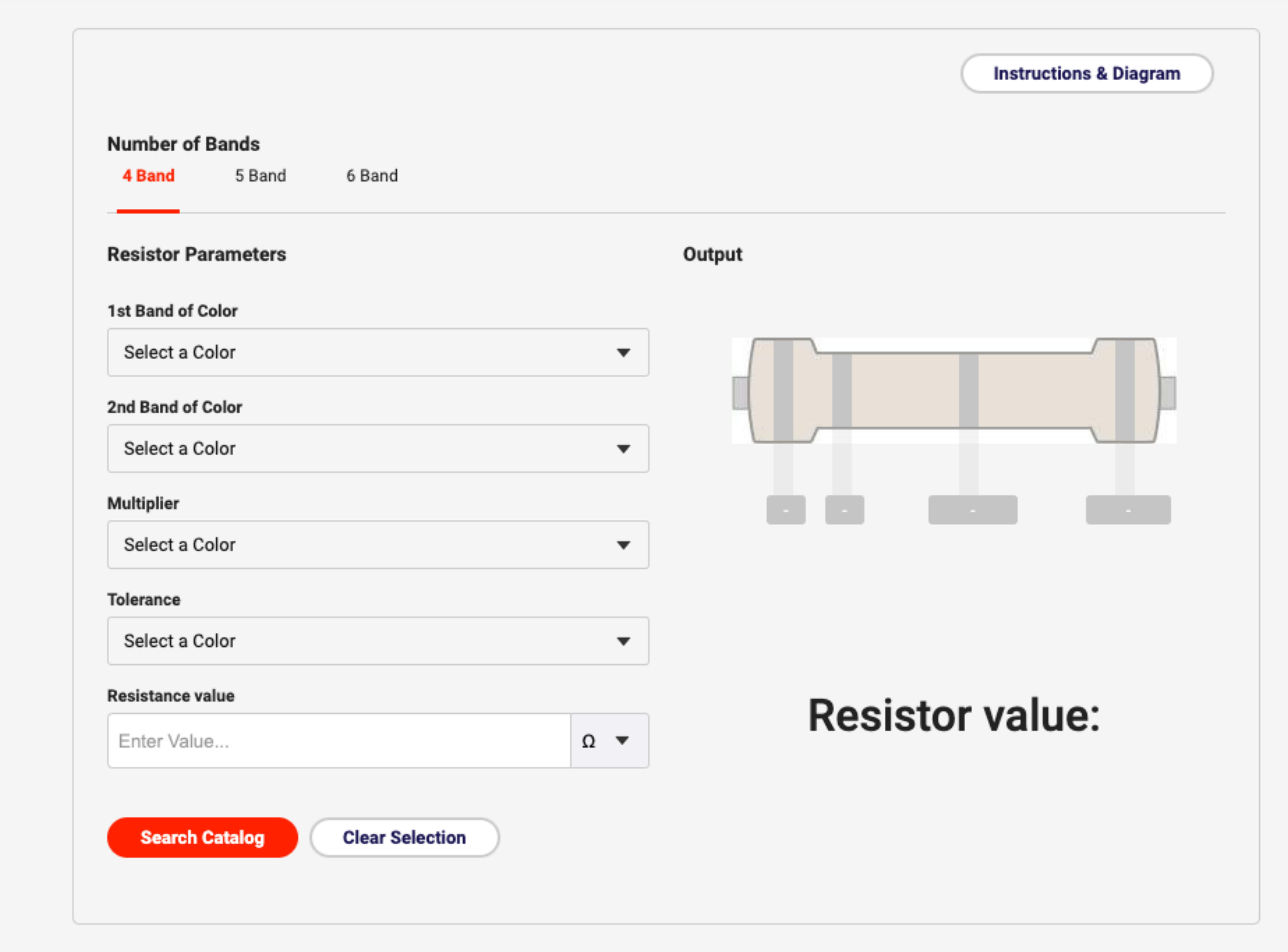
100 ×10^2 ±1%

5-Band



= 10,000 Ω ± 1%

https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code



Number of Bands

4 Band | 5 Band | 6 Band

Resistor Parameters

1st Band of Color: Select a Color

2nd Band of Color: Select a Color

Multiplier: Select a Color

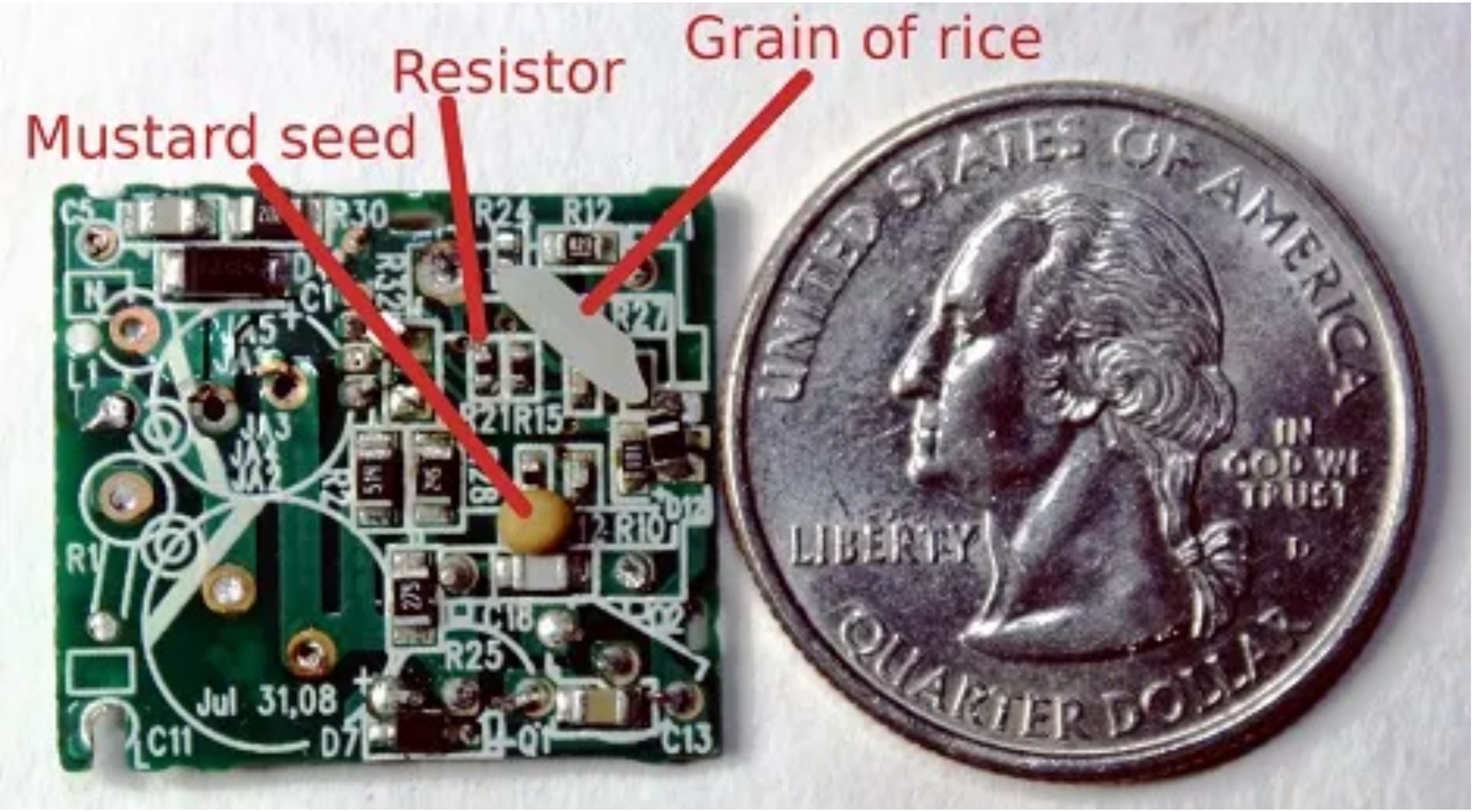
Tolerance: Select a Color

Resistance value: Enter Value... Ω

Output

Resistor value:

https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code

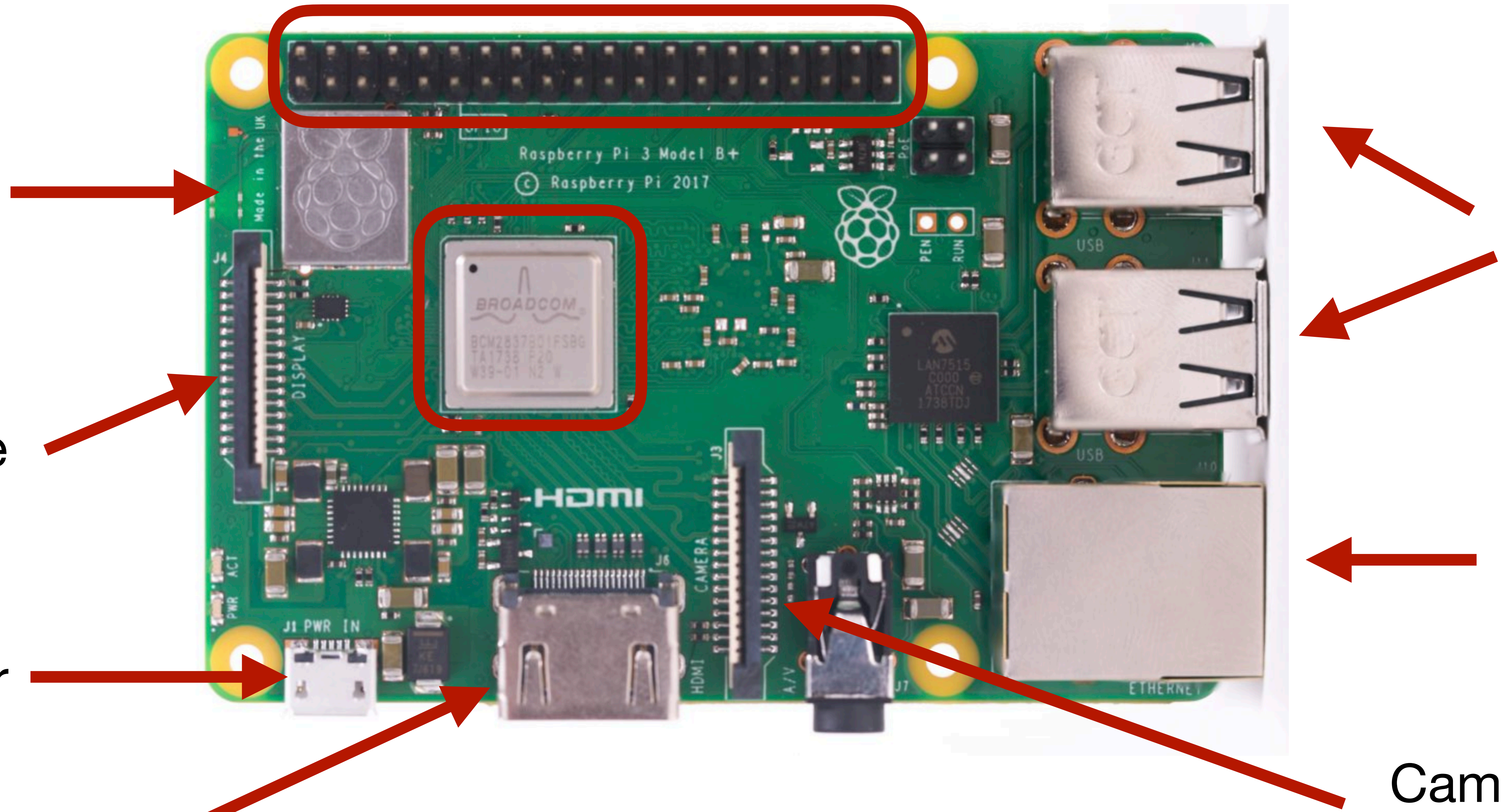

Grain of rice
Resistor
Mustard seed

Peripheral I/O

- General Purpose Input/Output (GPIO)
- Pulse Width Modulation (PWM)
- Serial Communication

Raspberry Pi 3 Model B

40-pin GPIO connector



Wireless Networking

Composite Video

Power

HDMI

Four USB Ports

Wired Networking

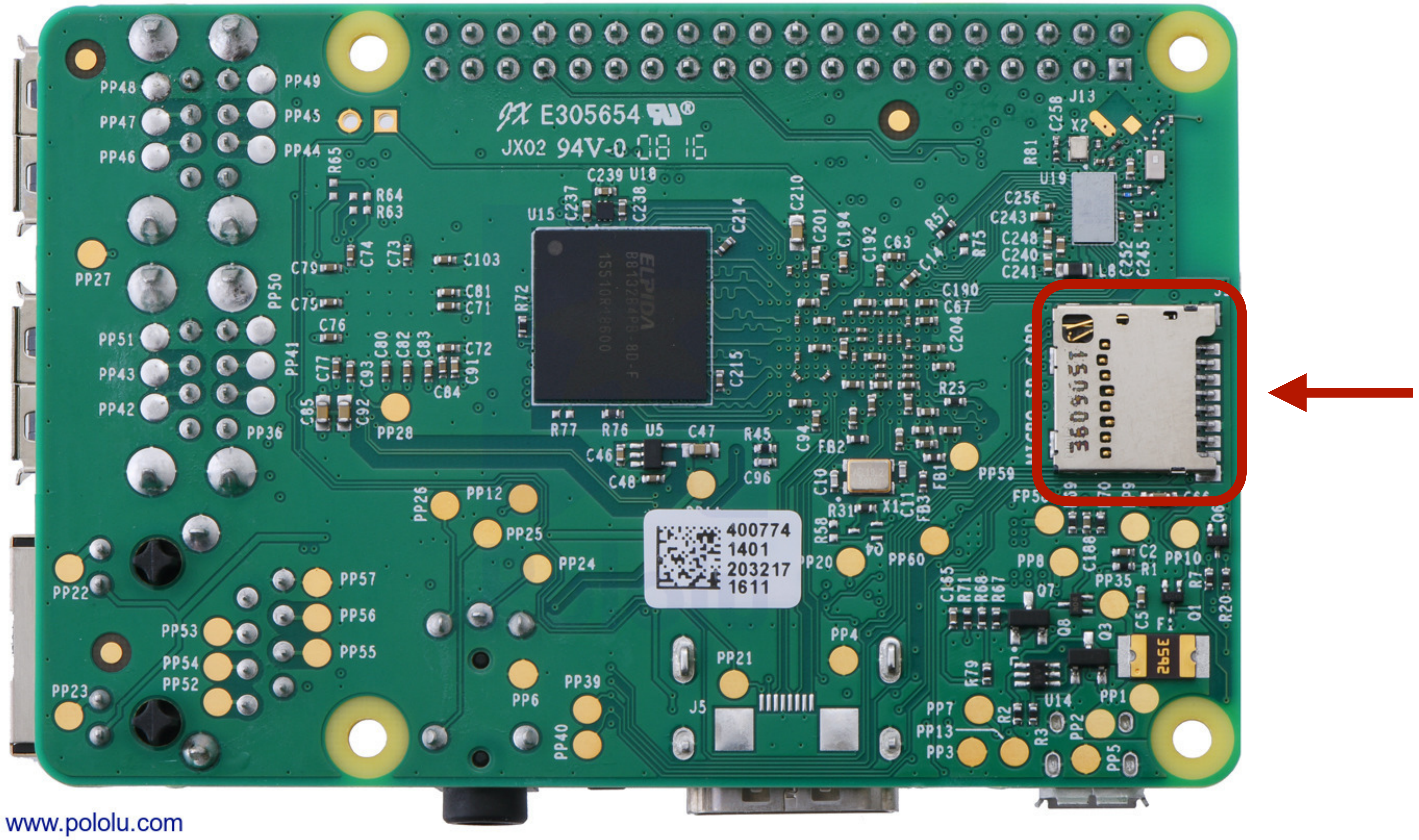
Camera connection

Quad-core 64-bit ARM Cortex-A53

1.2GHz

https://developer.android.com/things/hardware/raspberrypi.html

Raspberry Pi 3 Model B



Micro SD card reader

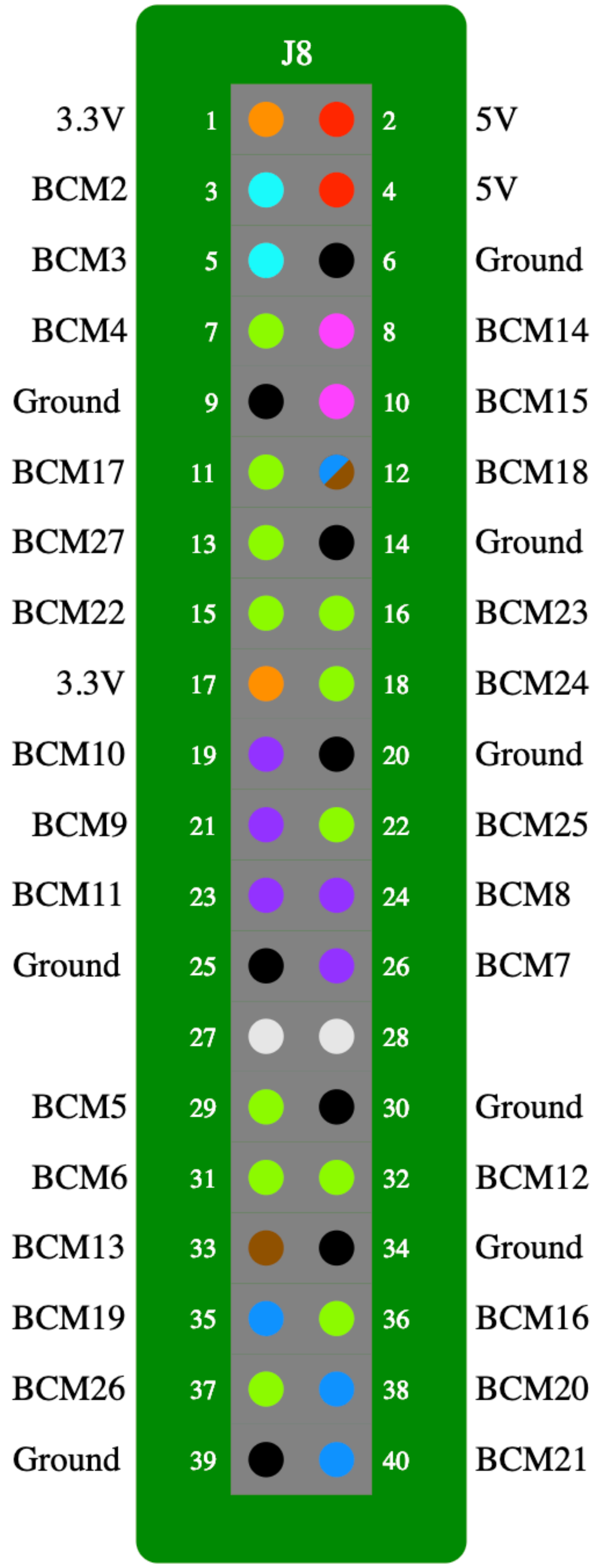
www.pololu.com

https://developer.android.com/things/hardware/raspberrypi.html

I/O Pinouts

GPIO Signal	Alternate Functions	
BCM2	I2C1 (SDA)	
BCM3	I2C1 (SCL)	
BCM7	SPI0 (SS1)	
BCM8	SPI0 (SS0)	
BCM9	SPI0 (MISO)	
BCM10	SPI0 (MOSI)	
BCM11	SPI0 (SCLK)	
BCM13	PWM1	
BCM14	UART0 (TXD)	MINIUART (TXD)
BCM15	UART0 (RXD)	MINIUART (RXD)
BCM18	I2S1 (BCLK)	PWM0
BCM19	I2S1 (LRCLK)	
BCM20	I2S1 (SDIN)	
BCM21	I2S1 (SDOUT)	

● = 5V	● = 1.8V	● = GPIO	● = I2C	● = SPI
● = 3.3V	● = Ground	● = PWM	● = I2S	● = UART

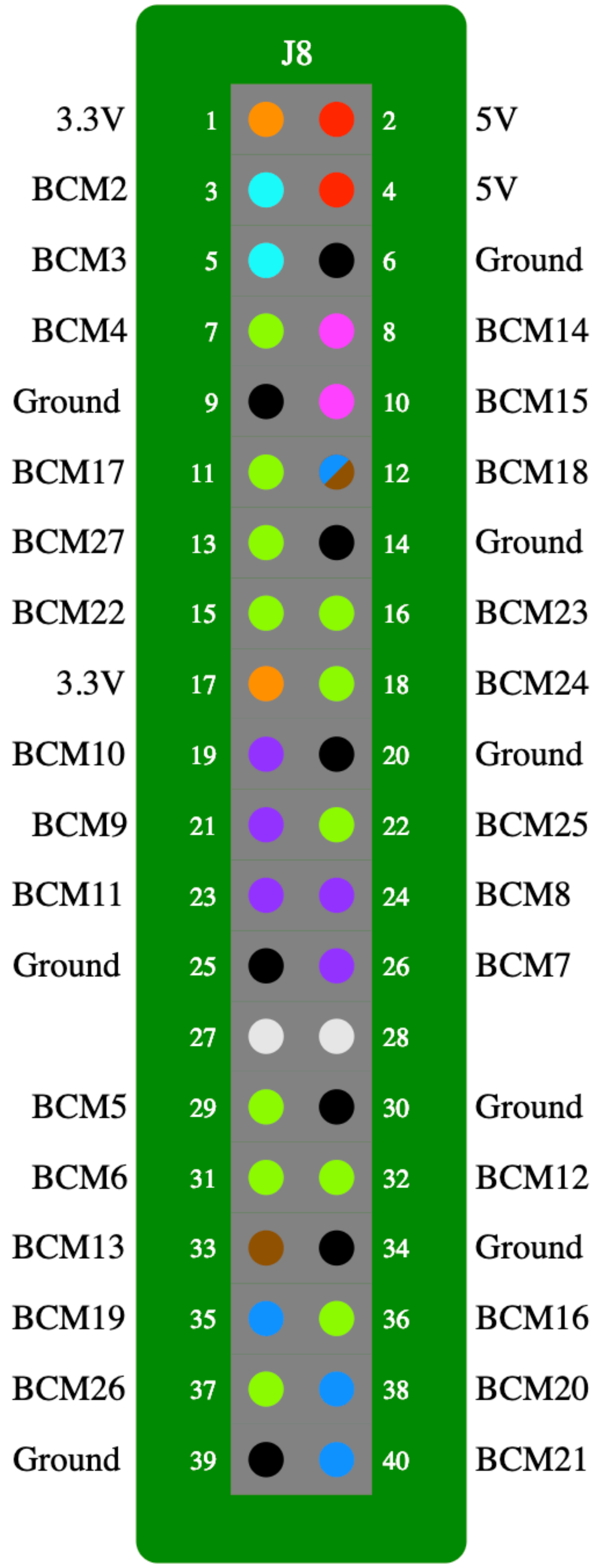


J8

3.3V	1	2	5V
BCM2	3	4	5V
BCM3	5	6	Ground
BCM4	7	8	BCM14
Ground	9	10	BCM15
BCM17	11	12	BCM18
BCM27	13	14	Ground
BCM22	15	16	BCM23
3.3V	17	18	BCM24
BCM10	19	20	Ground
BCM9	21	22	BCM25
BCM11	23	24	BCM8
Ground	25	26	BCM7
	27	28	
BCM5	29	30	Ground
BCM6	31	32	BCM12
BCM13	33	34	Ground
BCM19	35	36	BCM16
BCM26	37	38	BCM20
Ground	39	40	BCM21

Output and Input

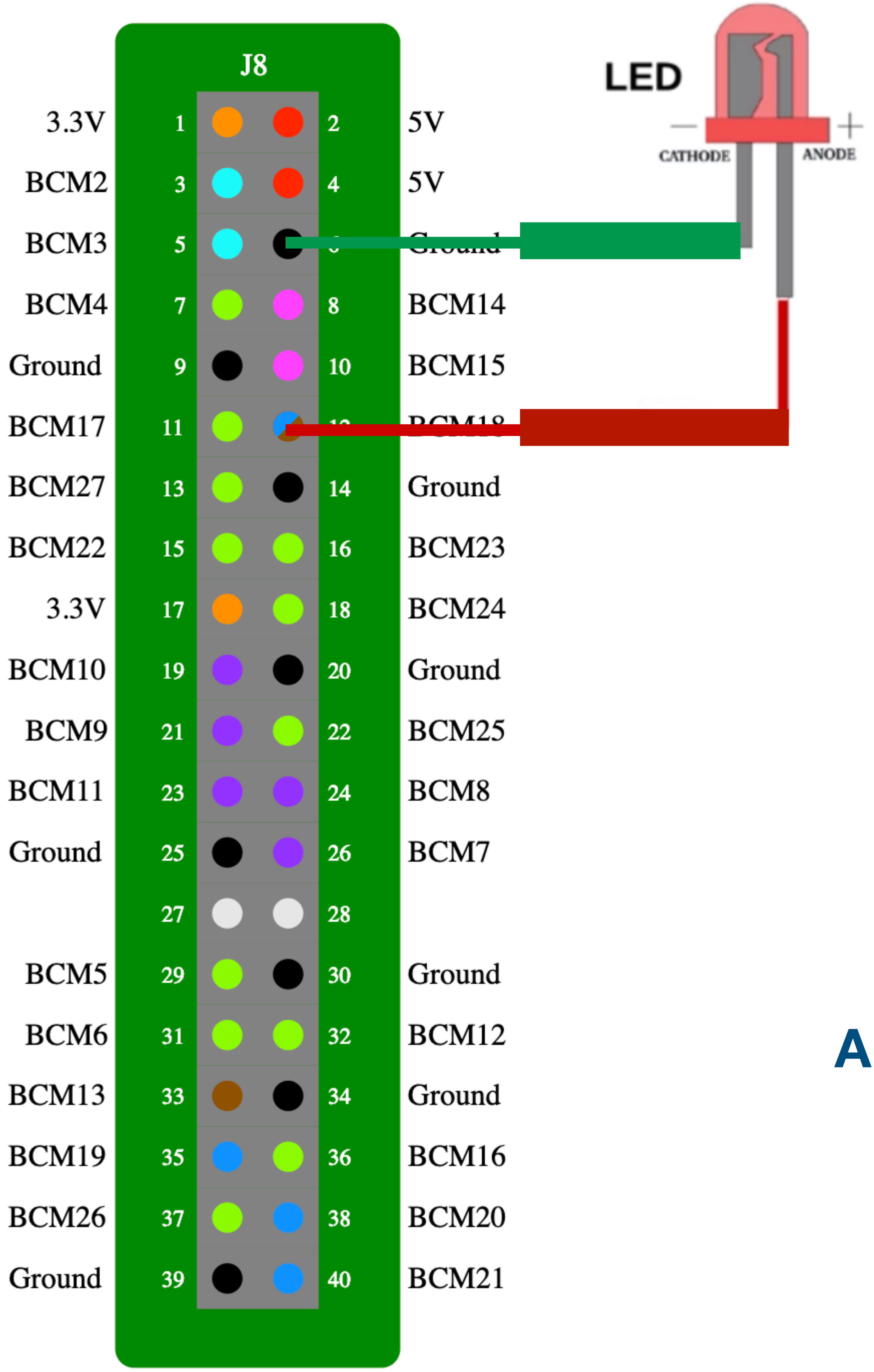
- Digital Pins
  - Two values:
    - Low (0)
    - High (1)
- Acts either:
  - Battery (OUTPUT)
  - Voltage meter (INPUT)



J8

3.3V	1	2	5V
BCM2	3	4	5V
BCM3	5	6	Ground
BCM4	7	8	BCM14
Ground	9	10	BCM15
BCM17	11	12	BCM18
BCM27	13	14	Ground
BCM22	15	16	BCM23
3.3V	17	18	BCM24
BCM10	19	20	Ground
BCM9	21	22	BCM25
BCM11	23	24	BCM8
Ground	25	26	BCM7
	27	28	
BCM5	29	30	Ground
BCM6	31	32	BCM12
BCM13	33	34	Ground
BCM19	35	36	BCM16
BCM26	37	38	BCM20
Ground	39	40	BCM21

Output



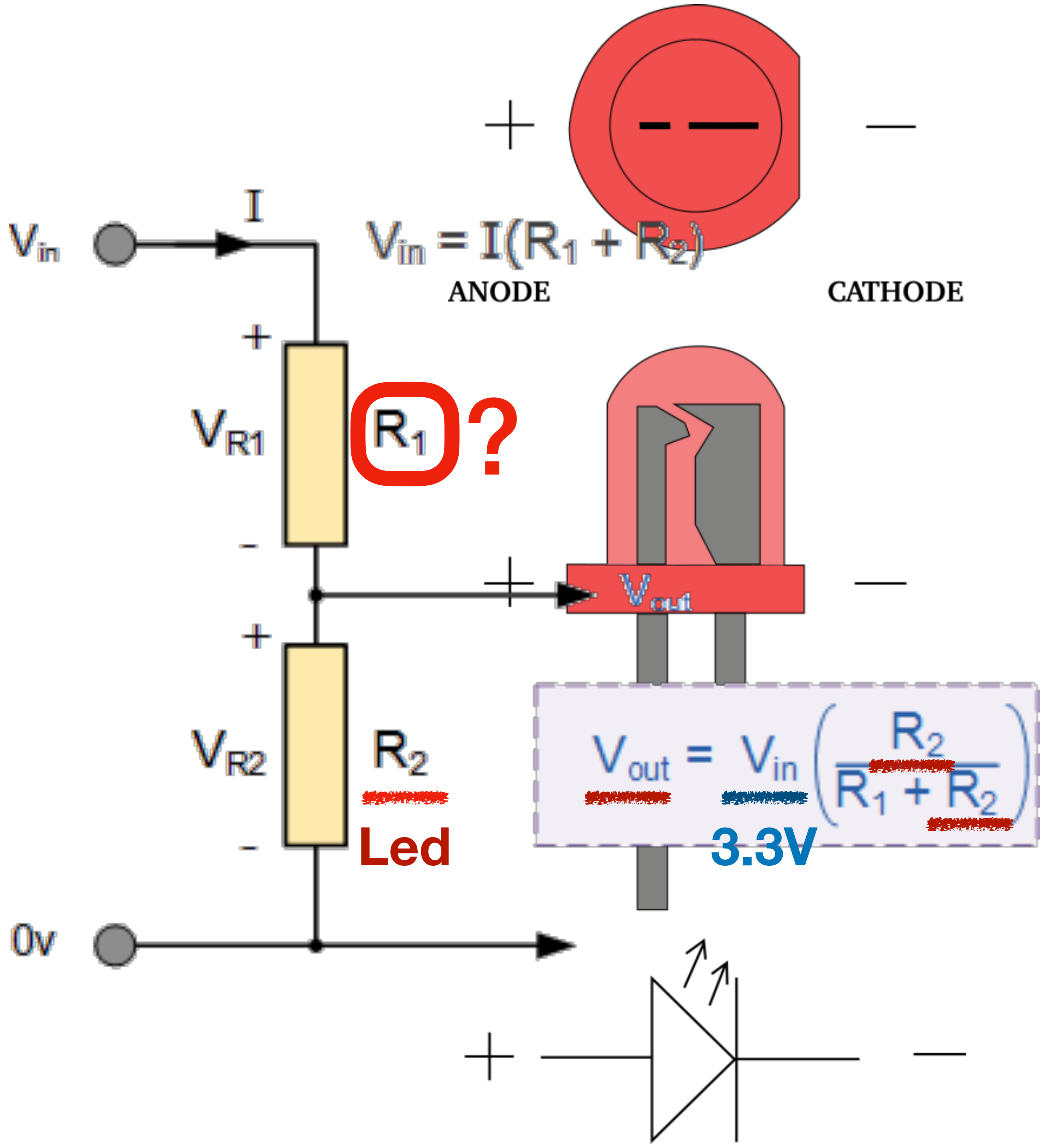
- Pin 12 can act like a battery (OUTPUT)
  - LOW - 0V
  - HIGH - 5V, 3.3V or 1.8V

Arduino

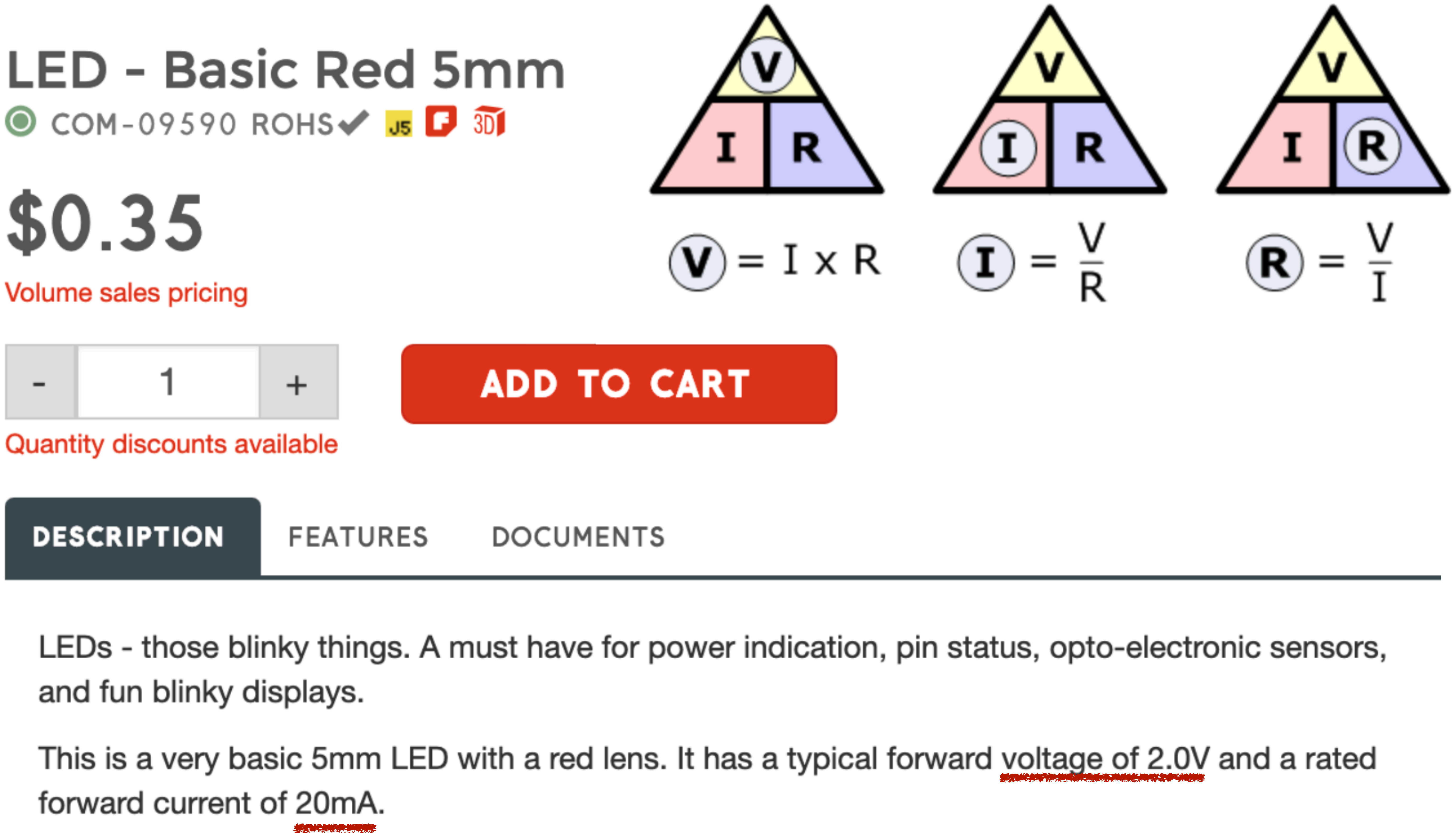
Raspberry Pi

Others

What resistor to use?



Led



LED - Basic Red 5mm

COM-09590 ROHS✓

$0.35

Volume sales pricing

- 1 +

ADD TO CART

Quantity discounts available

DESCRIPTION FEATURES DOCUMENTS

LEDs - those blinky things. A must have for power indication, pin status, opto-electronic sensors, and fun blinky displays.

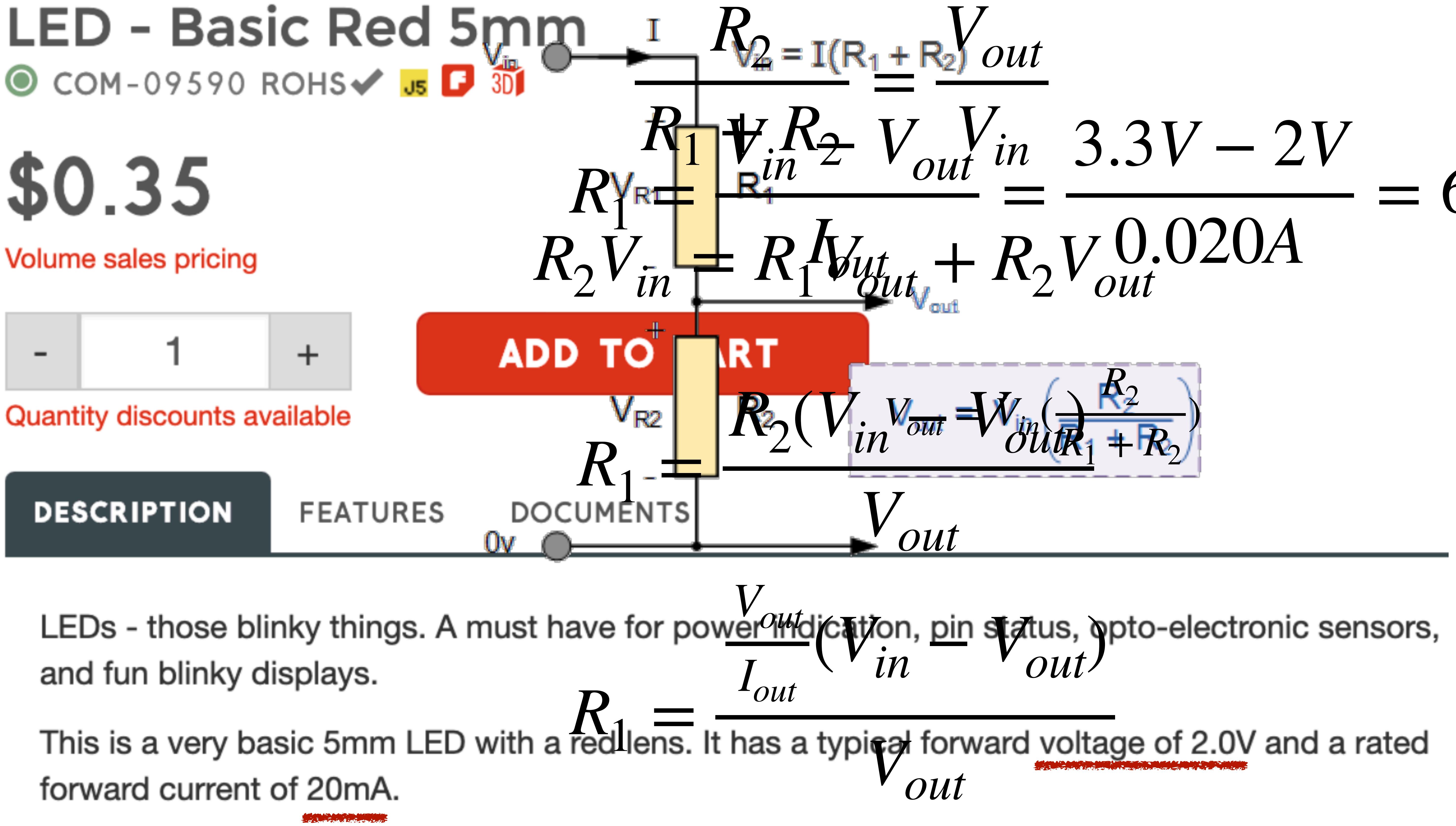
This is a very basic 5mm LED with a red lens. It has a typical forward voltage of 2.0V and a rated forward current of 20mA.

$V = I \times R$

$I = \frac{V}{R}$

$R = \frac{V}{I}$

Compute R1



LED - Basic Red 5mm

COM-09590 ROHS✓

$0.35

Volume sales pricing

- 1 +

ADD TO CART

Quantity discounts available

DESCRIPTION FEATURES DOCUMENTS

LEDs - those blinky things. A must have for power indication, pin status, opto-electronic sensors, and fun blinky displays.

This is a very basic 5mm LED with a red lens. It has a typical forward voltage of 2.0V and a rated forward current of 20mA.

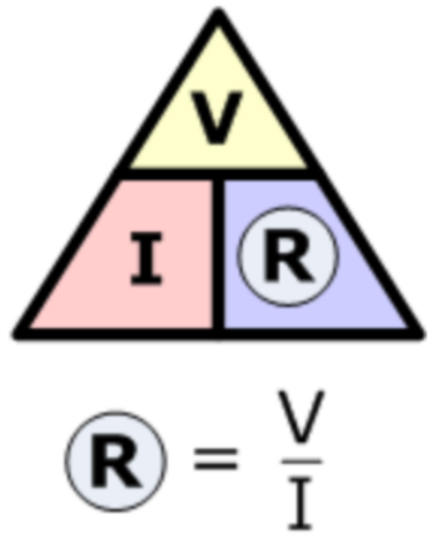
$$\frac{R_2}{R_1 + R_2} = \frac{V_{out}}{V_{in}}$$

$$R_1 = \frac{V_{in} - V_{out}}{I_{out}} = \frac{3.3V - 2V}{0.020A} = 65\Omega$$

$$R_2 V_{in} = R_1 V_{out} + R_2 V_{out}$$

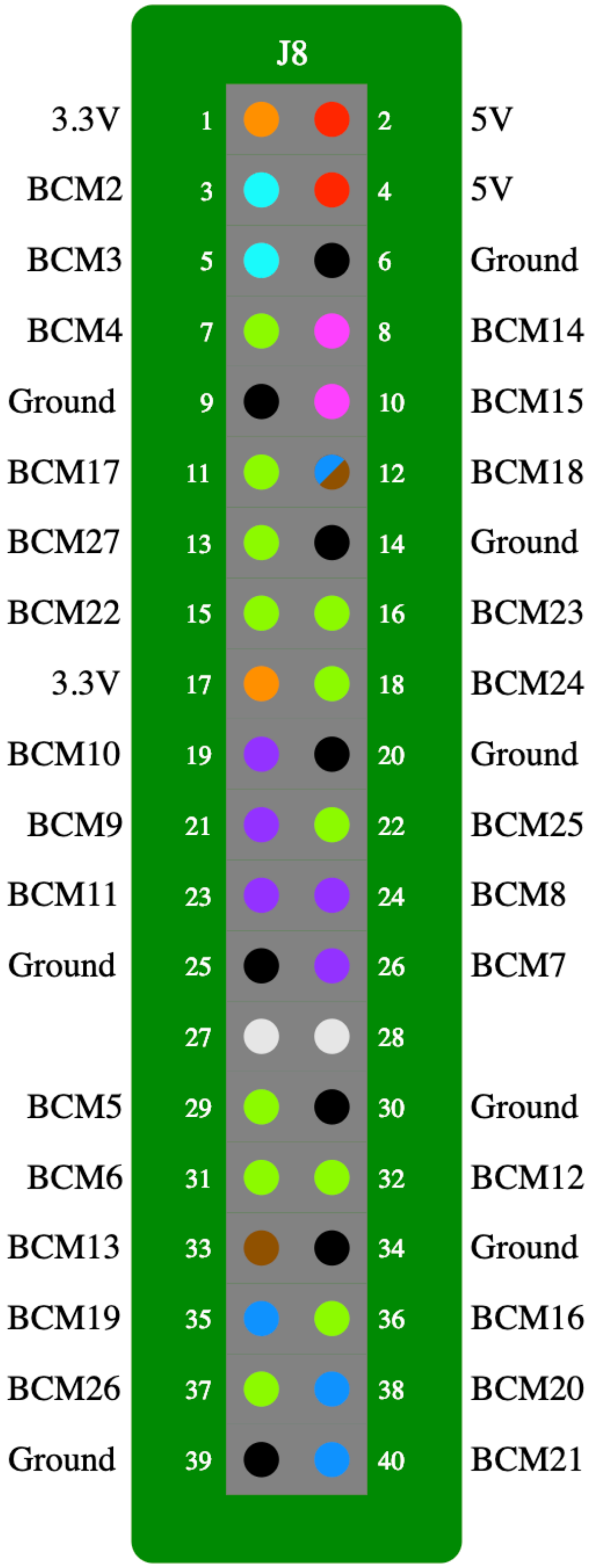
$$R_1 = \frac{R_2(V_{in} - V_{out})}{V_{out}}$$

$$R_1 = \frac{\frac{V_{out}}{I_{out}}(V_{in} - V_{out})}{V_{out}}$$

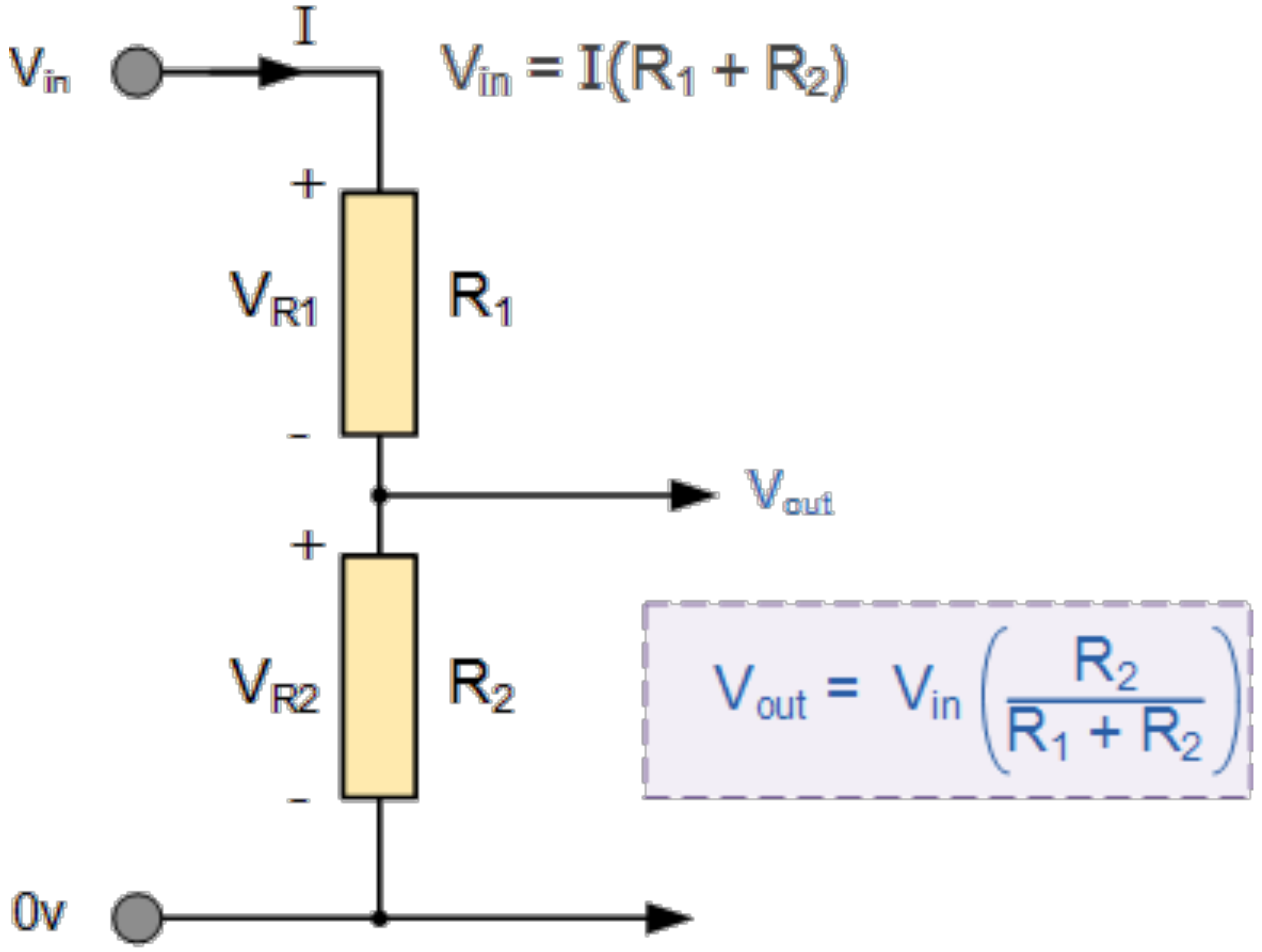


http://www.ohmslawcalculator.com/led-resistor-calculator

Input

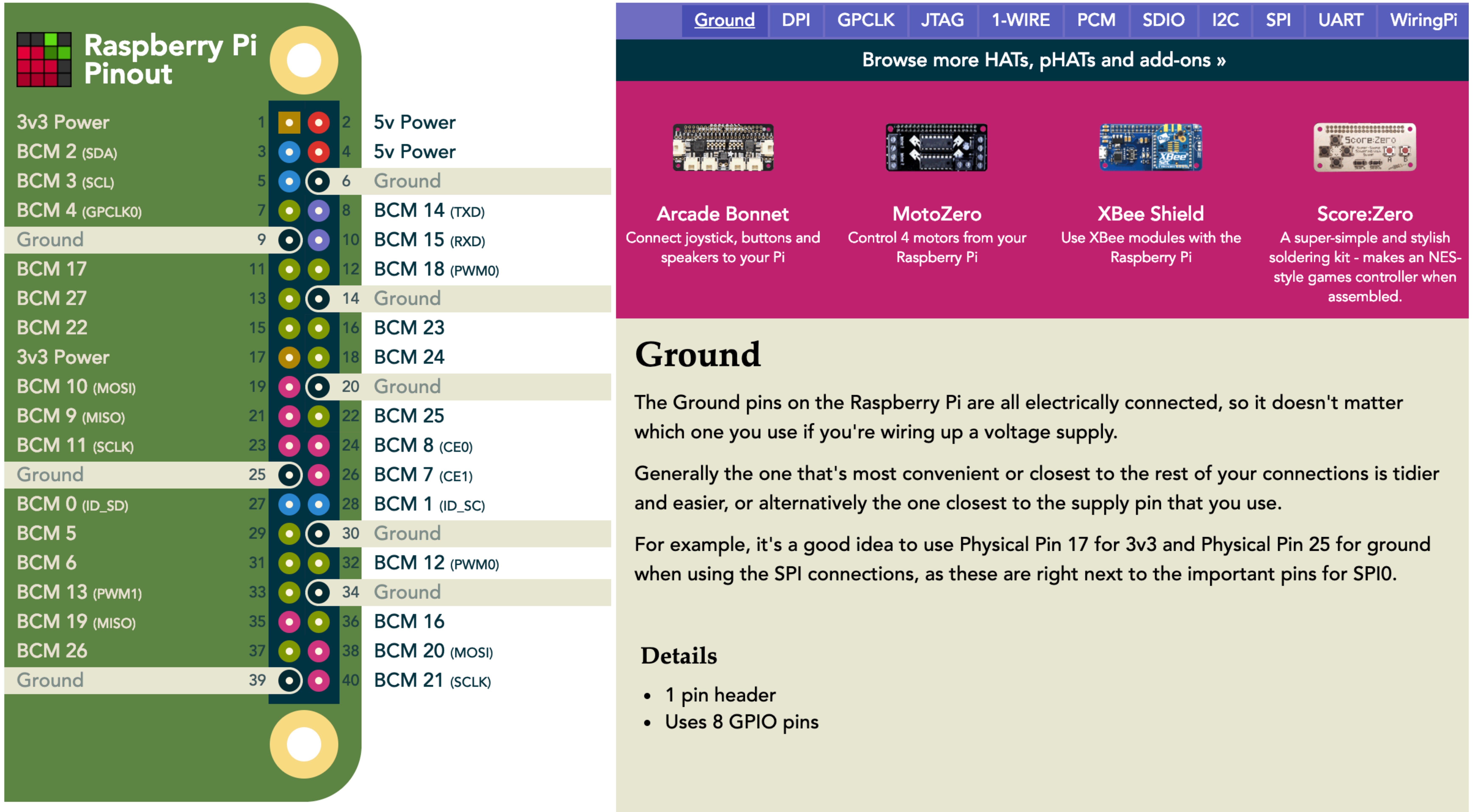


- In this case we are measuring V_{out}
- Represented on one bit.



$$V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$$

I/O Pinouts



Raspberry Pi Pinout

3v3 Power	1	2	5v Power
BCM 2 (SDA)	3	4	5v Power
BCM 3 (SCL)	5	6	Ground
BCM 4 (GPCLK0)	7	8	BCM 14 (TXD)
Ground	9	10	BCM 15 (RXD)
BCM 17	11	12	BCM 18 (PWM0)
BCM 27	13	14	Ground
BCM 22	15	16	BCM 23
3v3 Power	17	18	BCM 24
BCM 10 (MOSI)	19	20	Ground
BCM 9 (MISO)	21	22	BCM 25
BCM 11 (SCLK)	23	24	BCM 8 (CE0)
Ground	25	26	BCM 7 (CE1)
BCM 0 (ID_SD)	27	28	BCM 1 (ID_SC)
BCM 5	29	30	Ground
BCM 6	31	32	BCM 12 (PWM0)
BCM 13 (PWM1)	33	34	Ground
BCM 19 (MISO)	35	36	BCM 16
BCM 26	37	38	BCM 20 (MOSI)
Ground	39	40	BCM 21 (SCLK)

Arcade Bonnet
Connect joystick, buttons and speakers to your Pi

MotoZero
Control 4 motors from your Raspberry Pi

XBee Shield
Use XBee modules with the Raspberry Pi

Score:Zero
A super-simple and stylish soldering kit - makes an NES-style games controller when assembled.

Ground

The Ground pins on the Raspberry Pi are all electrically connected, so it doesn't matter which one you use if you're wiring up a voltage supply.

Generally the one that's most convenient or closest to the rest of your connections is tidier and easier, or alternatively the one closest to the supply pin that you use.

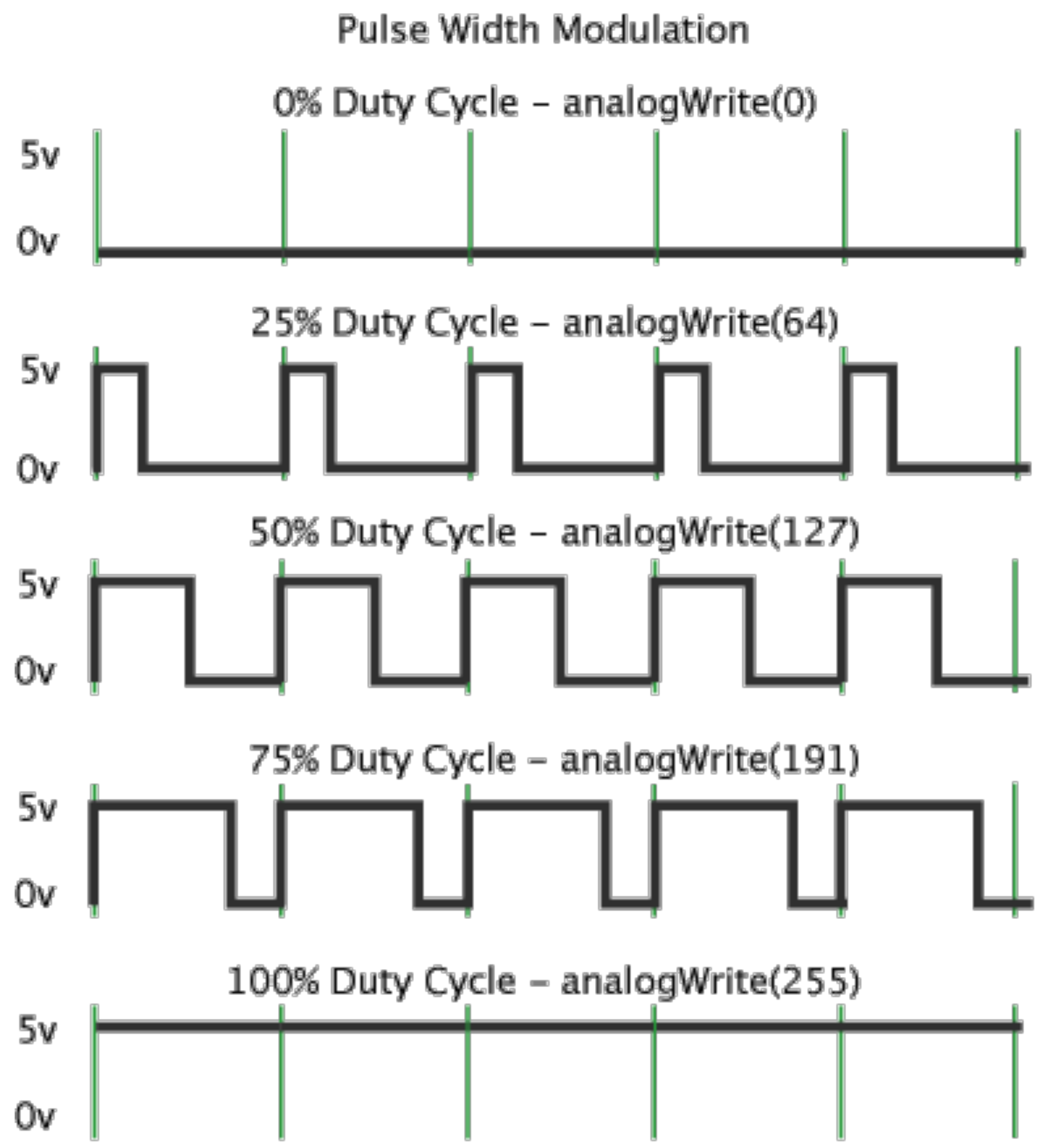
For example, it's a good idea to use Physical Pin 17 for 3v3 and Physical Pin 25 for ground when using the SPI connections, as these are right next to the important pins for SPI0.

Details

- 1 pin header
- Uses 8 GPIO pins

https://pinout.xyz

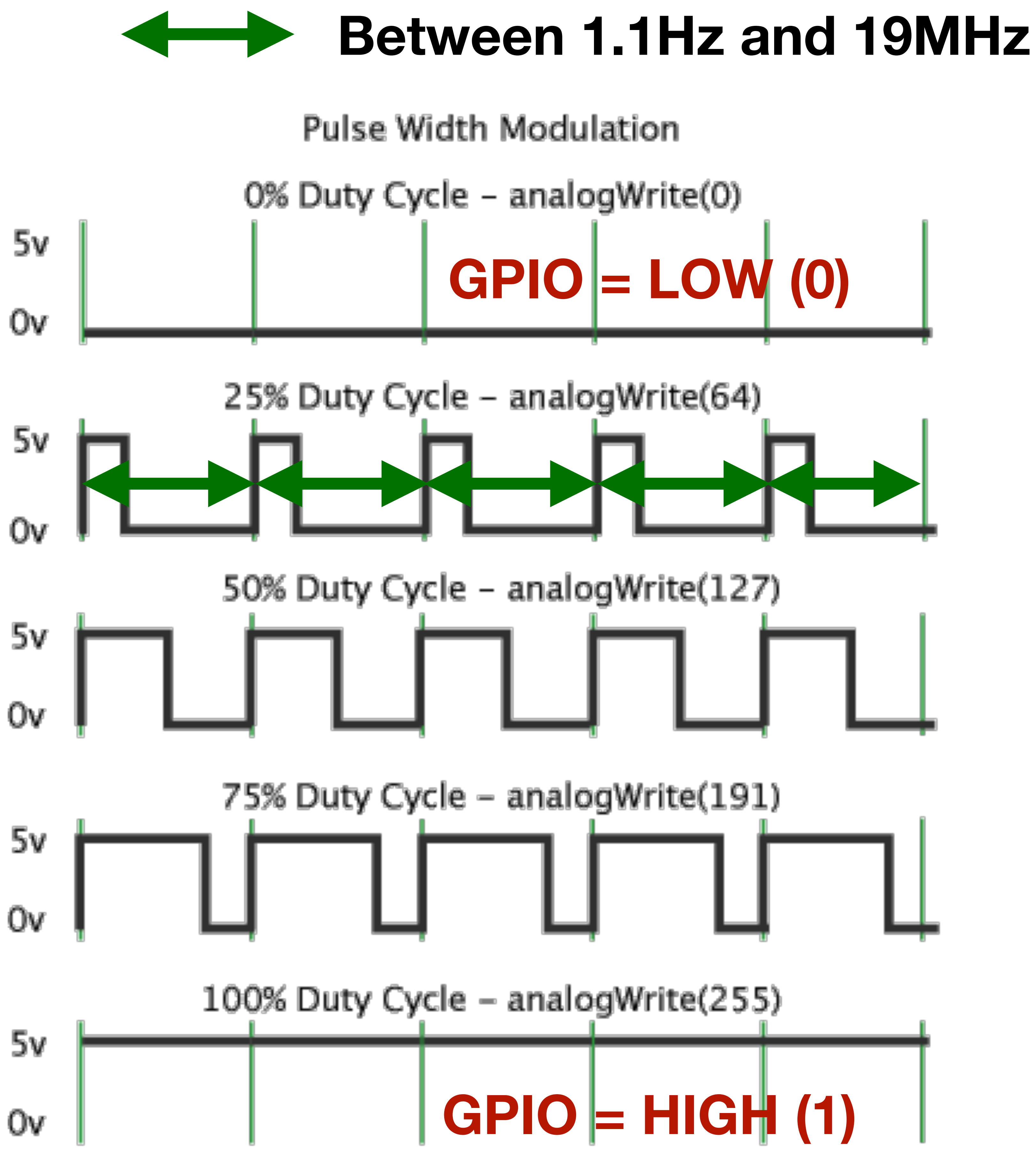
Pulse Width Modulation
PWM


Pulse Width Modulation
0% Duty Cycle - analogWrite(0)
5v
0v
25% Duty Cycle - analogWrite(64)
5v
0v
50% Duty Cycle - analogWrite(127)
5v
0v
75% Duty Cycle - analogWrite(191)
5v
0v
100% Duty Cycle - analogWrite(255)
5v
0v

https://www.arduino.cc/en/Tutorial/PWM

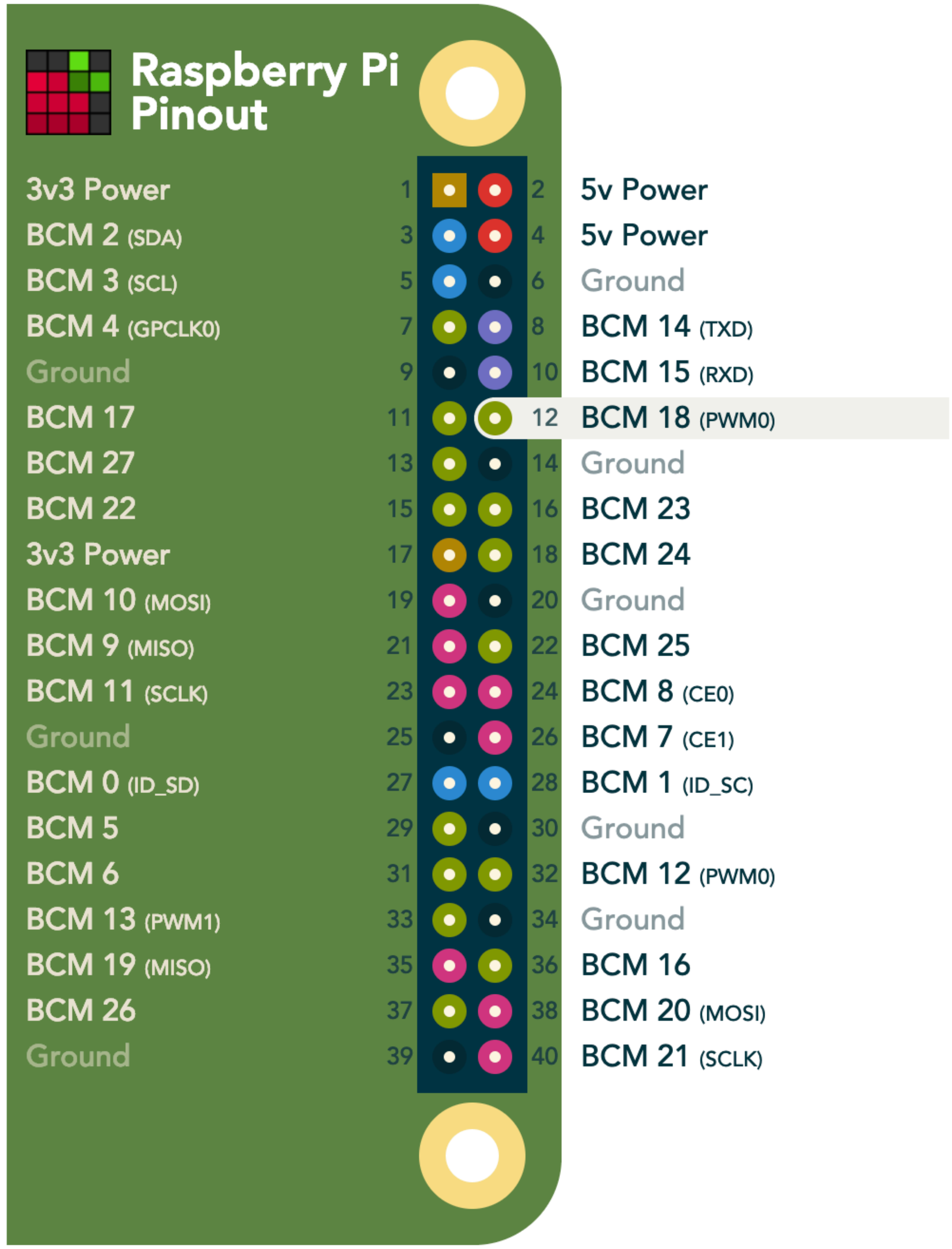
Pulse Width Modulation PWM

- PWM Pins
  - Capable to generate square wave signals.
- We control the % of the duty cycle:
  - 0 - 0%
  - 255 - 100% (check hardware specs)
- Possible usage:
  - Led dimming.
  - Control a servo motor.


Between 1.1Hz and 19MHz
Pulse Width Modulation
0% Duty Cycle - analogWrite(0)
GPIO = LOW (0)
25% Duty Cycle - analogWrite(64)
50% Duty Cycle - analogWrite(127)
75% Duty Cycle - analogWrite(191)
100% Duty Cycle - analogWrite(255)
GPIO = HIGH (1)
5v
0v

https://www.arduino.cc/en/Tutorial/PWM

Analog to Digital Convertors



Raspberry Pi Pinout

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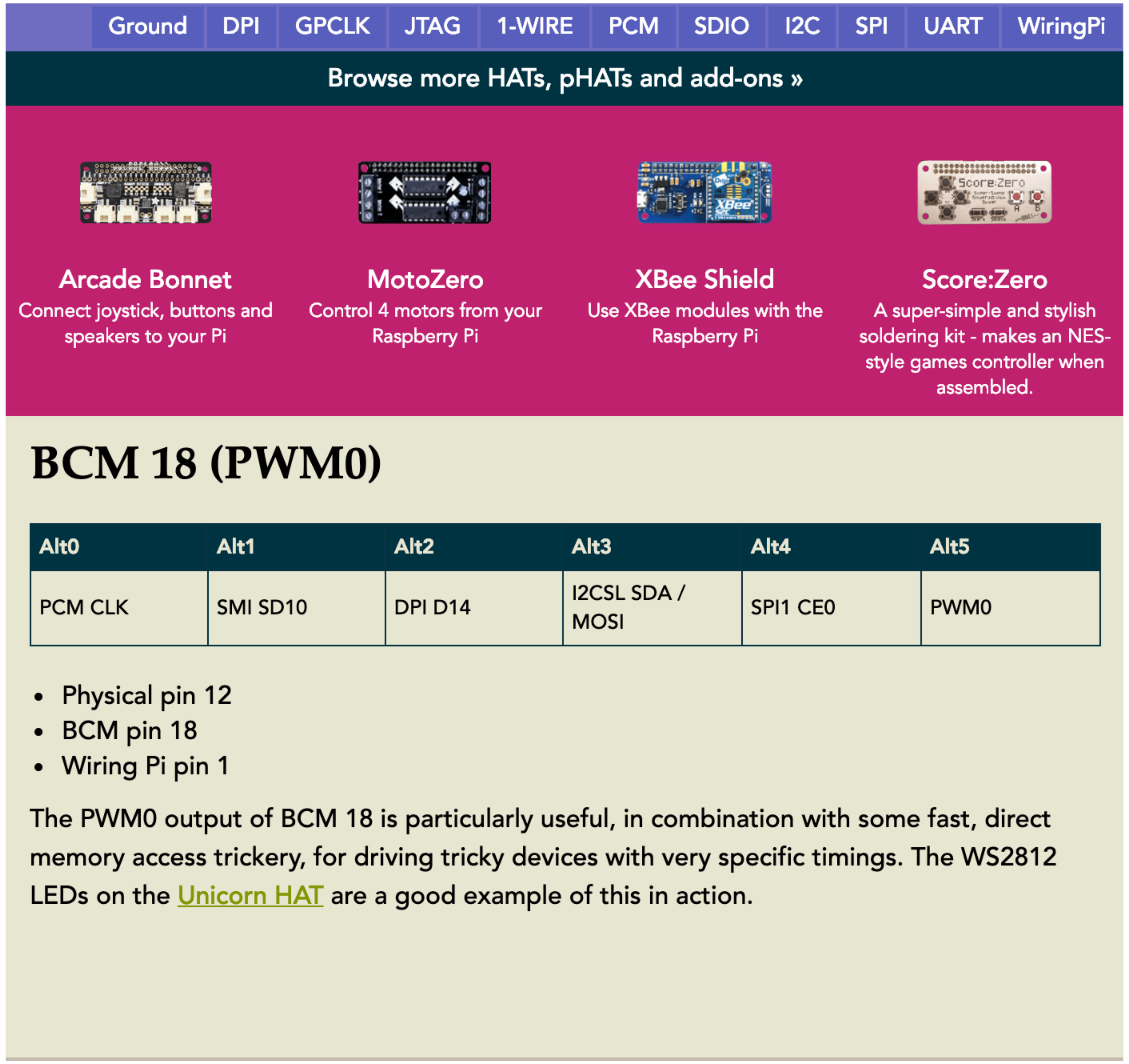

Browse more HATs, pHATs and add-ons »

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BCM 18 (PWM0)

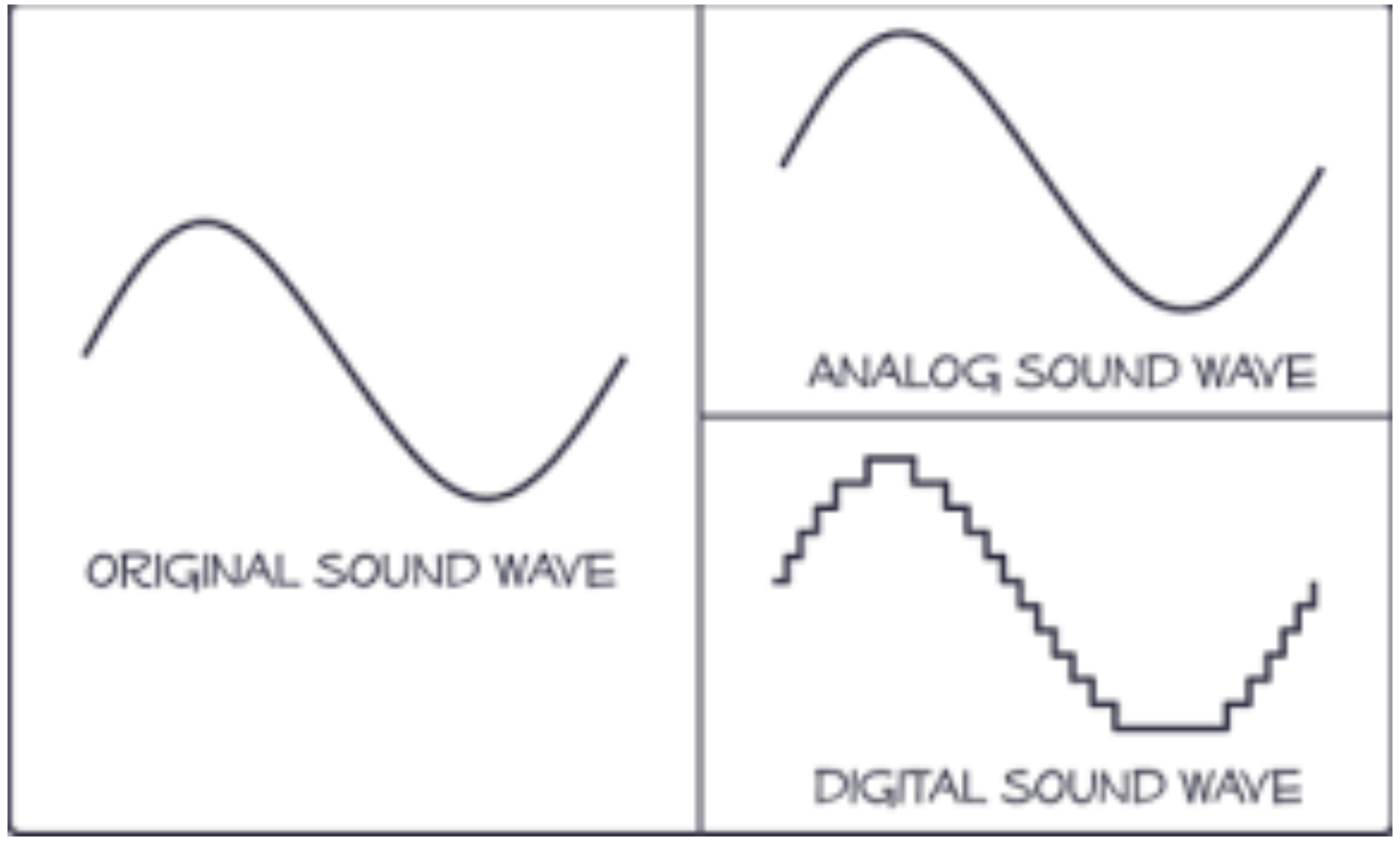
Alt0	Alt1	Alt2	Alt3	Alt4	Alt5
PCM CLK	SMI SD10	DPI D14	I2CSL SDA / MOSI	SPI1 CE0	PWM0

- Physical pin 12
- BCM pin 18
- Wiring Pi pin 1

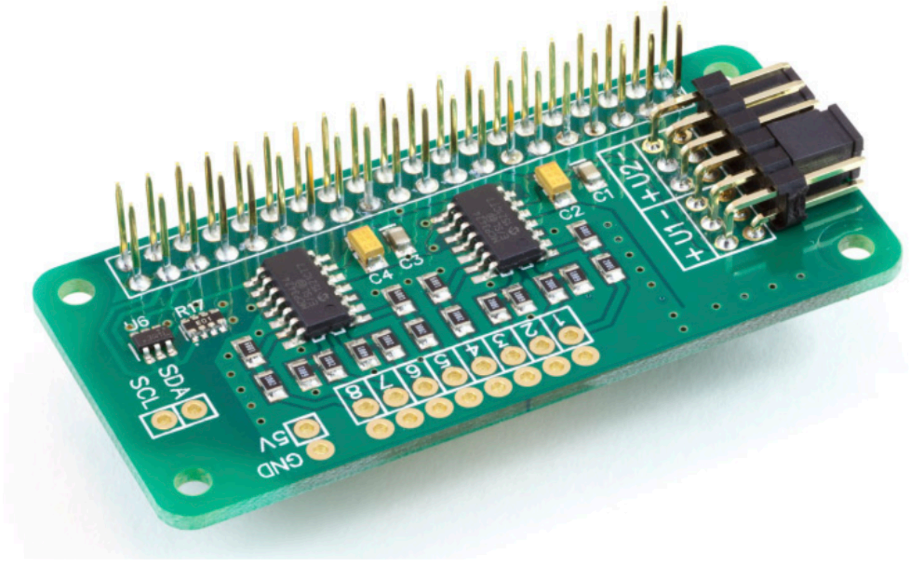
The PWM0 output of BCM 18 is particularly useful, in combination with some fast, direct memory access trickery, for driving tricky devices with very specific timings. The WS2812 LEDs on the Unicorn HAT are a good example of this in action.

Analog to Digital Convertors

- When reading or writing digital signals we need to establish values for:
  - Bits per sample.
    - 1 bit - GPIO Input.
    - n bits - 0..2^n - 1
  - Sampling rate.



ADC Pi

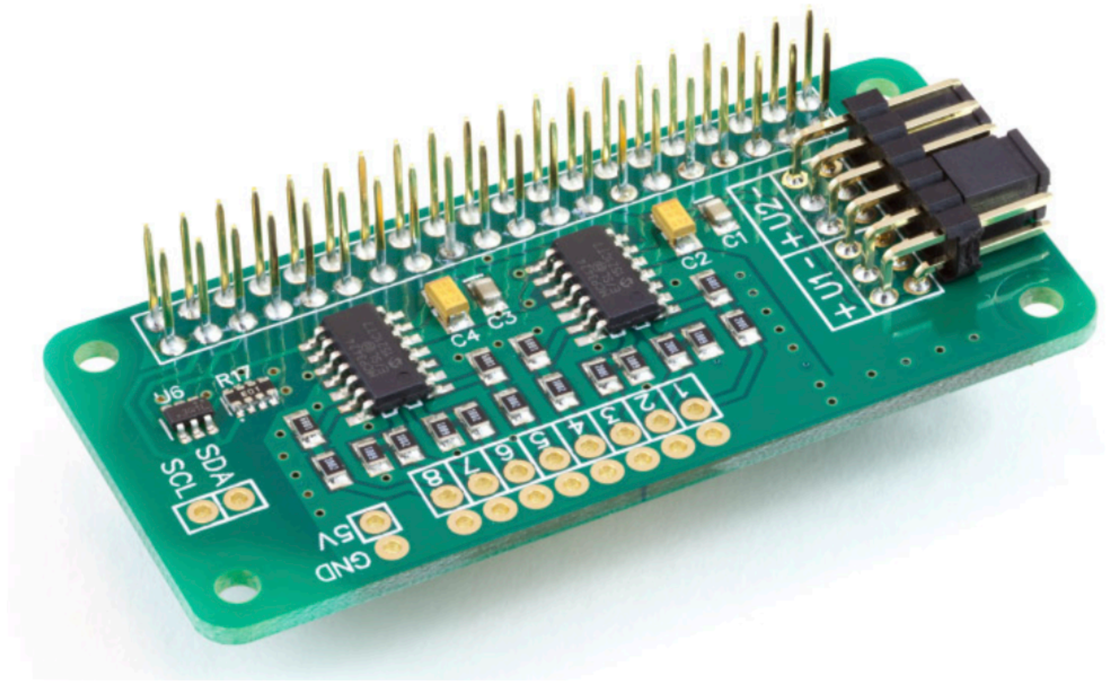


Analog to Digital Convertors

Features

- 8 x 17-bit 0 to 5V Single Ended Inputs
- Control via the Raspberry Pi I2C port
- Stack up to 4 ADC Pi boards on a single Raspberry Pi
- ...

ADC Pi



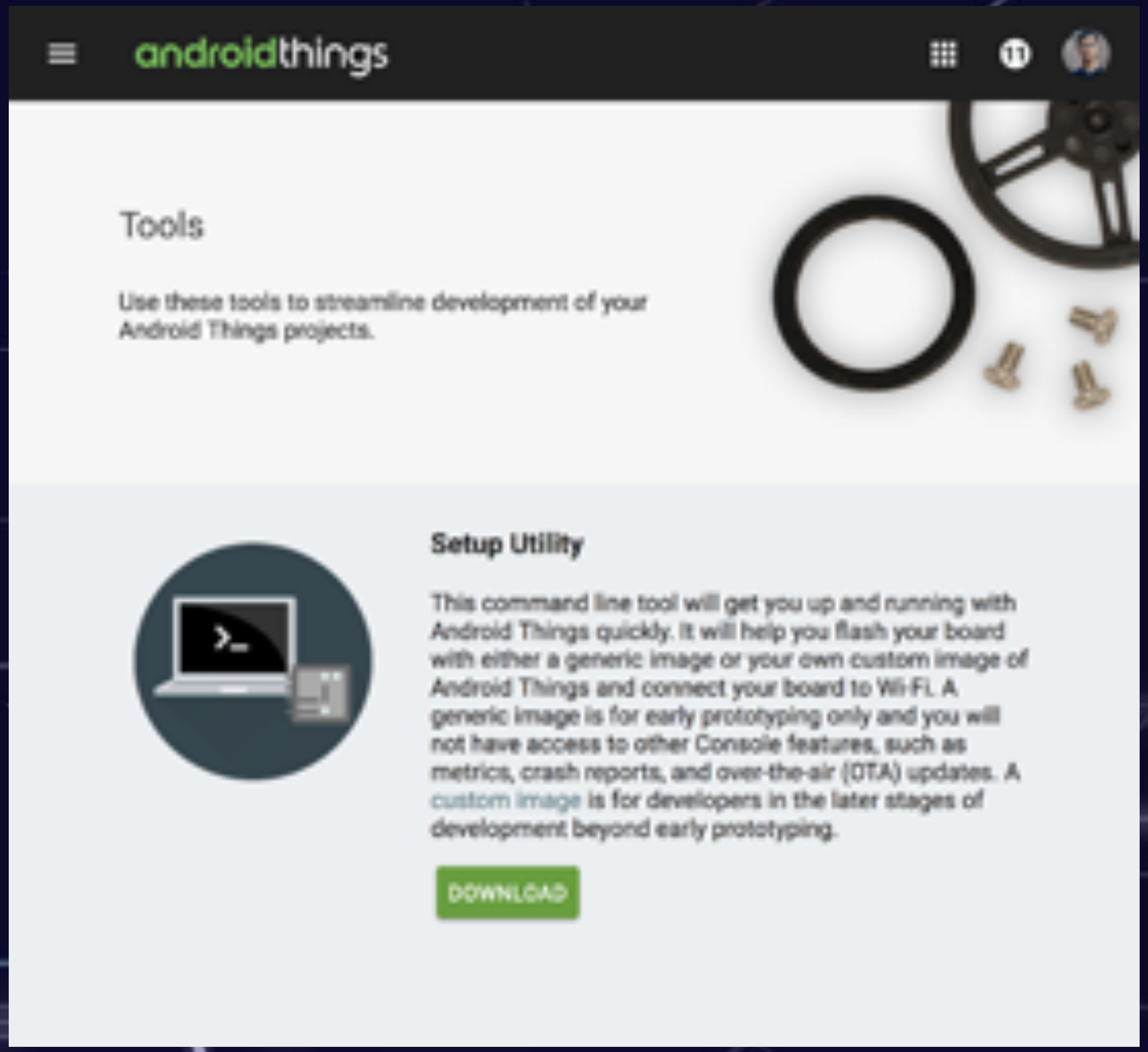
https://www.abelectronics.co.uk/p/69/adc-pi-raspberry-pi-analogue-to-digital-converter

Setup

Image source: https://rehhoff.me

Flashing the Image

- Prerequisite:
  - Micro-USB cable.
  - Ethernet cable.
  - MicroSD card reader.
  - 8GB or larger microSD card.
  - Optional items:
    - HDMI cable.
    - HDMI-enabled display.



Tools

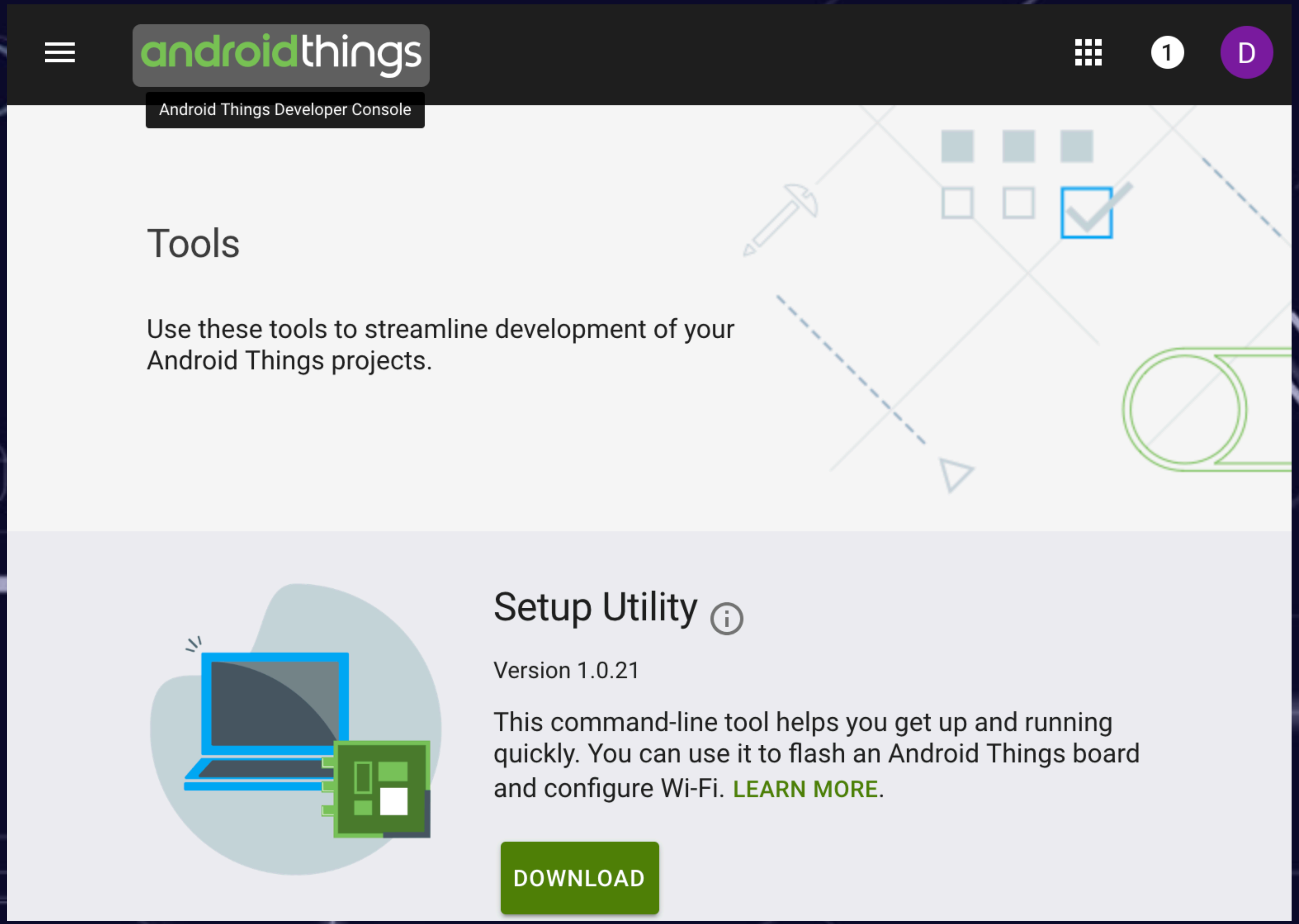
Use these tools to streamline development of your Android Things projects.

Setup Utility

This command line tool will get you up and running with Android Things quickly. It will help you flash your board with either a generic image or your own custom image of Android Things and connect your board to Wi-Fi. A generic image is for early prototyping only and you will not have access to other Console features, such as metrics, crash reports, and over-the-air (OTA) updates. A custom image is for developers in the later stages of development beyond early prototyping.

Step 1

- Download the Android Things Setup Utility.
  - https://partner.android.com/things/console/#/tools
- Using the setup utility:
  - Select the option to install Android Things and optionally set up Wi-Fi.
  - Insert the microSD card into the microSD slot on the underside of the Raspberry Pi.



Tools

Use these tools to streamline development of your Android Things projects.

Setup Utility

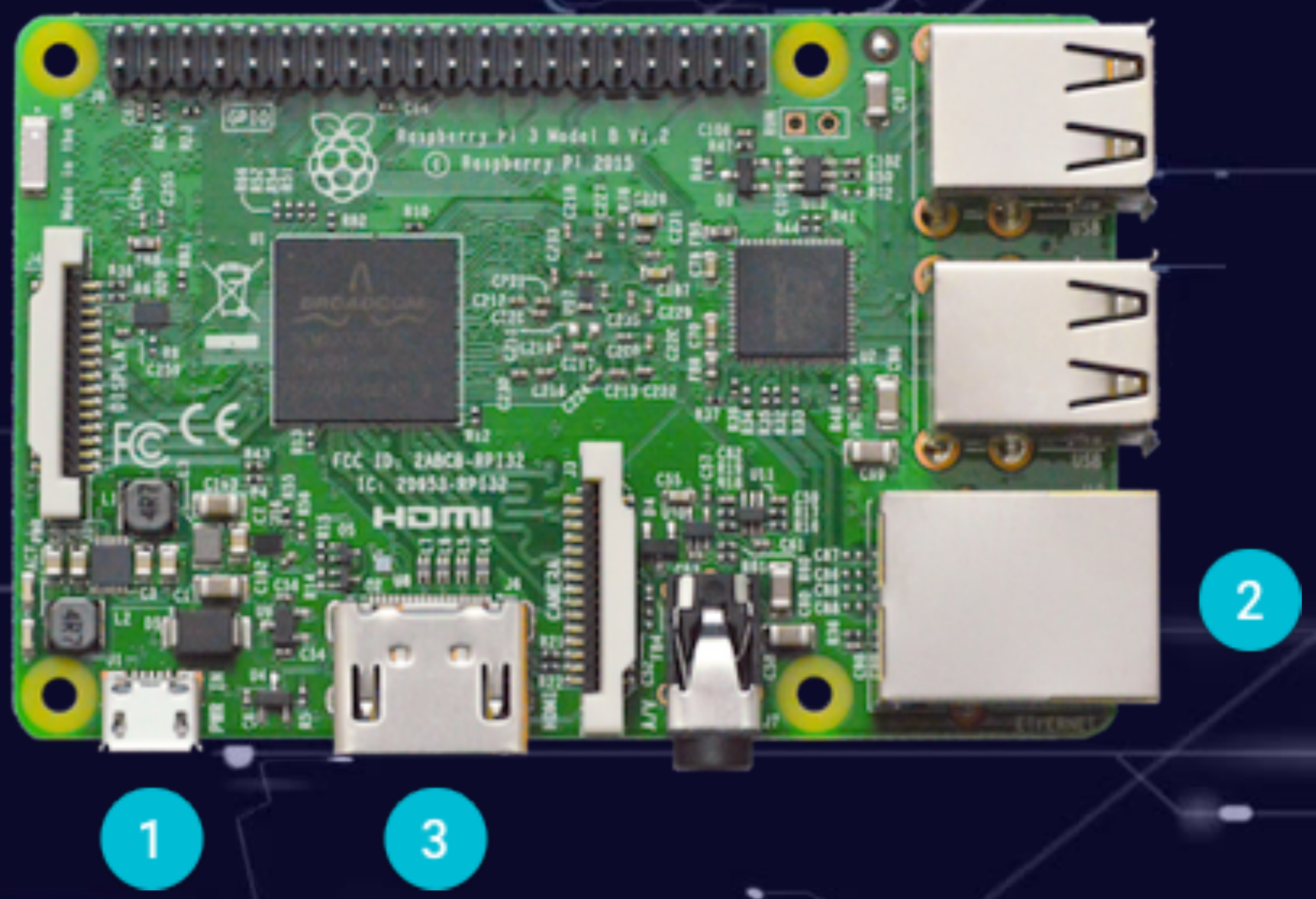
Version 1.0.21

This command-line tool helps you get up and running quickly. You can use it to flash an Android Things board and configure Wi-Fi. LEARN MORE.

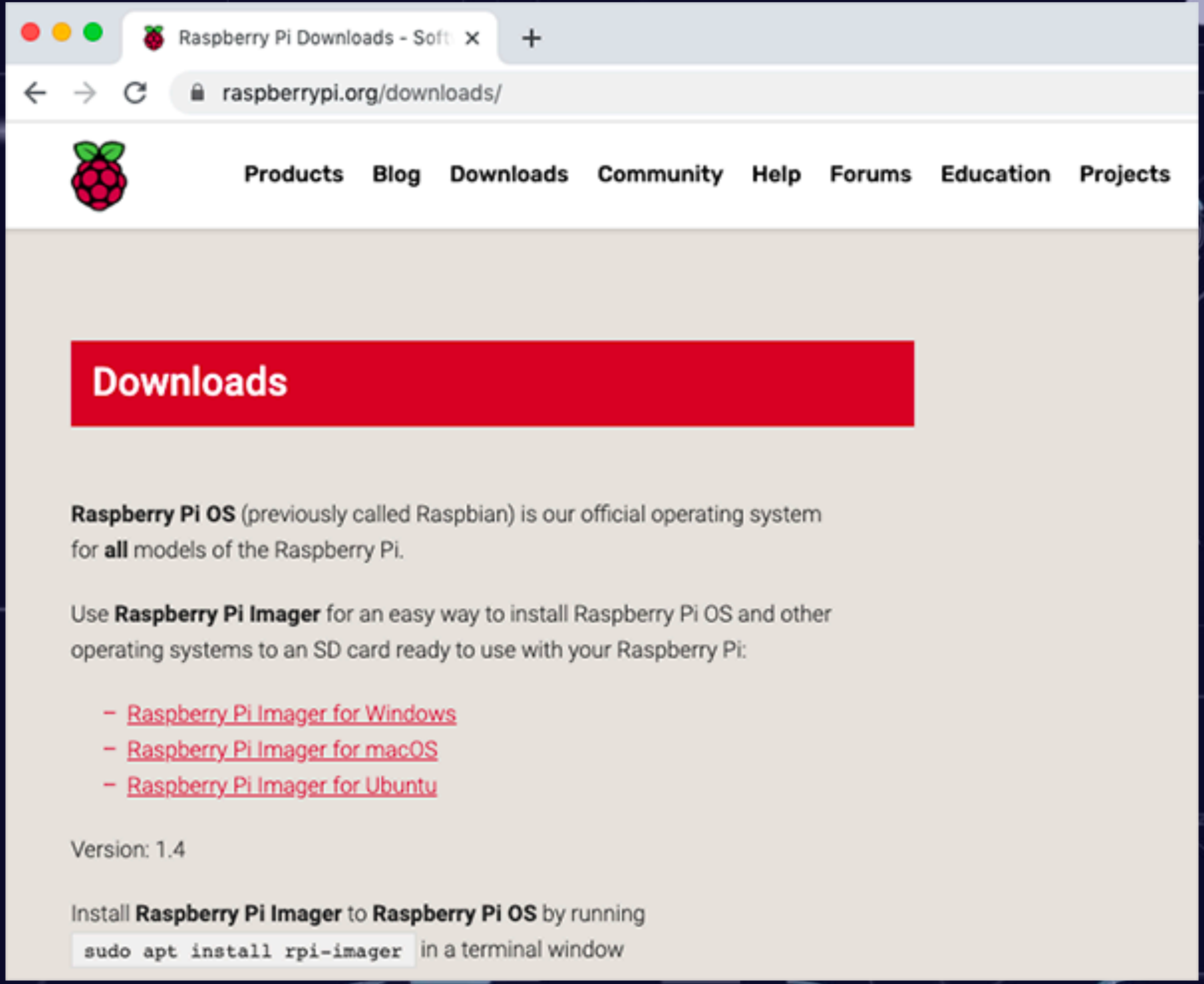
Step 2

- Connect a USB cable to J1 for power.
- Connect an Ethernet cable to your local network.
- (Optional) Connect an HDMI cable to an external display.
- Verify that Android is running on the device.
  - Connect to the IP address using the adb tool:
    - adb connect <ip-address>

connected to <ip-address>:5555



Raspberry Pi OS



Downloads

Raspberry Pi OS (previously called Raspbian) is our official operating system for **all** models of the Raspberry Pi.

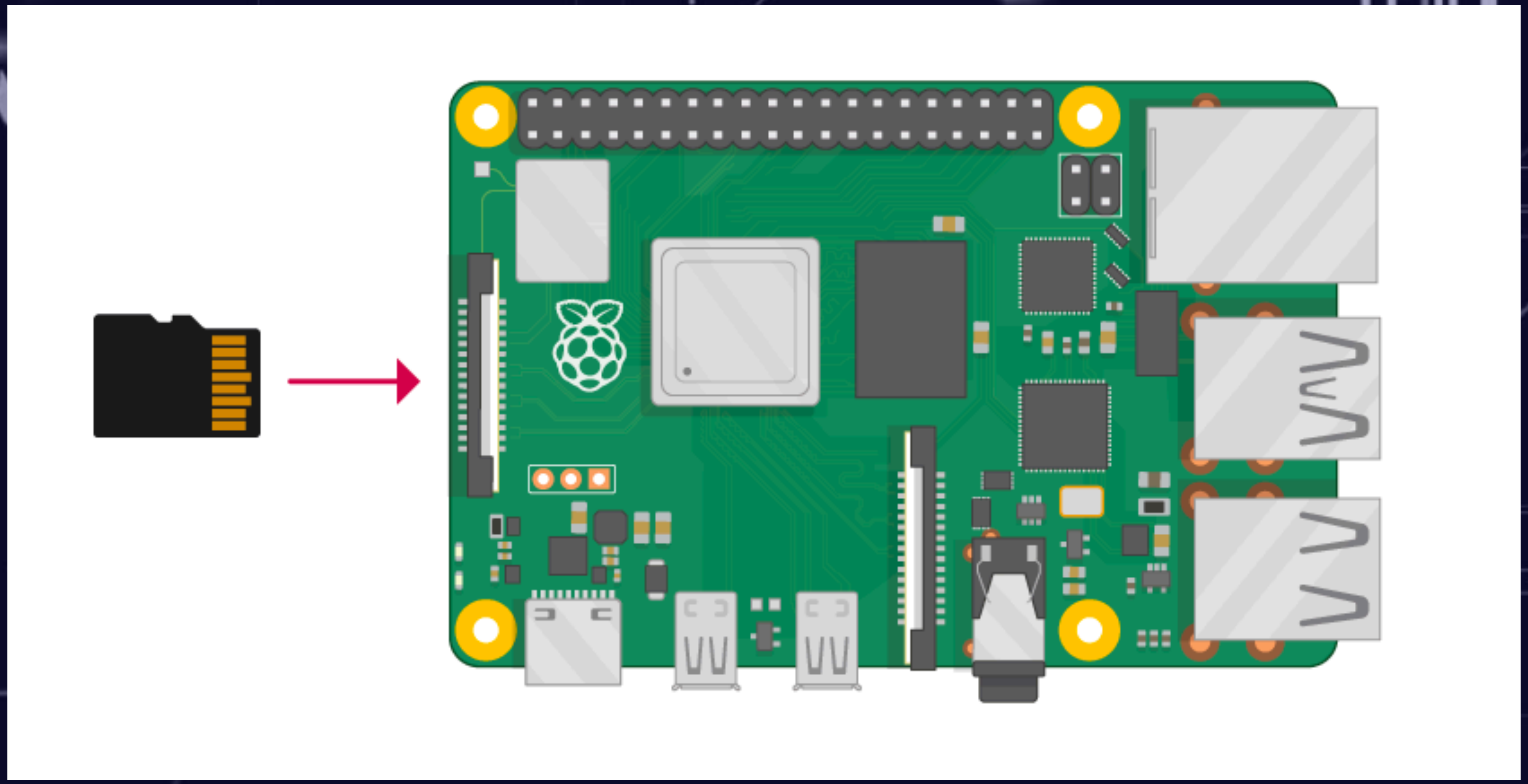
Use **Raspberry Pi Imager** for an easy way to install Raspberry Pi OS and other operating systems to an SD card ready to use with your Raspberry Pi:

- Raspberry Pi Imager for Windows
- Raspberry Pi Imager for macOS
- Raspberry Pi Imager for Ubuntu

Version: 1.4

Install **Raspberry Pi Imager** to **Raspberry Pi OS** by running `sudo apt install rpi-imager` in a terminal window

Raspberry Pi OS



https://projects.raspberrypi.org/en/projects/raspberry-pi-setting-up

Lecture outcomes

- Understand how to establish the needed components.
- How to establish the hardware characteristics for the needed components.
- How to use the available pins for input and output.
- Setup the development platform.