Raspberry Pi Introduction

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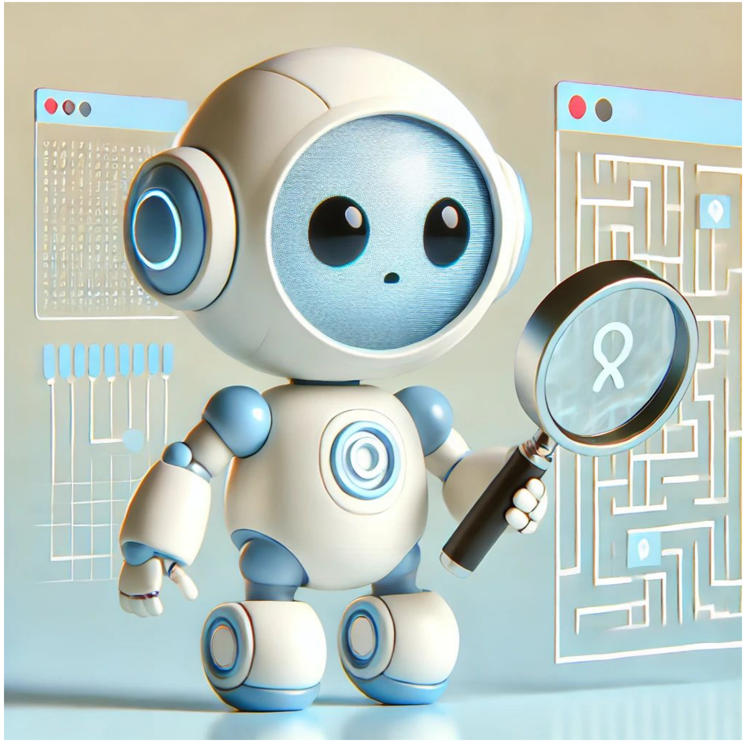


Outline

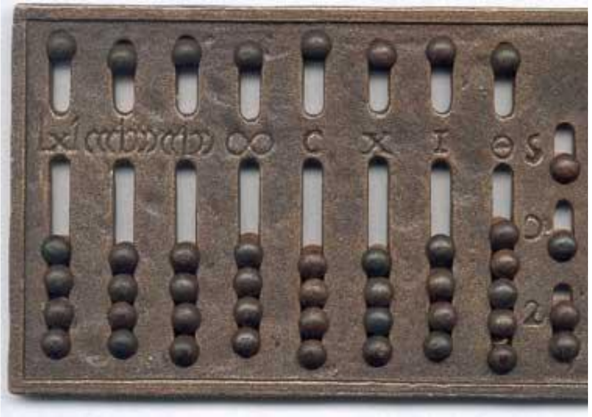
1. History of Computers
2. Introduction to Raspberry Pi & Hardware Setup
3. Installing and setting up the Raspberry Pi OS
4. Basic Commands and Interface
5. Number System

1

History of Computers

History of Computers

Computers have been around in various forms for centuries. When you ask most people what a computer is, they will generally think of modern electronic devices. Computers, however, don’t need to be electronic at all!



Abacus

Fragment of the Antikythera Machine

History of Computers

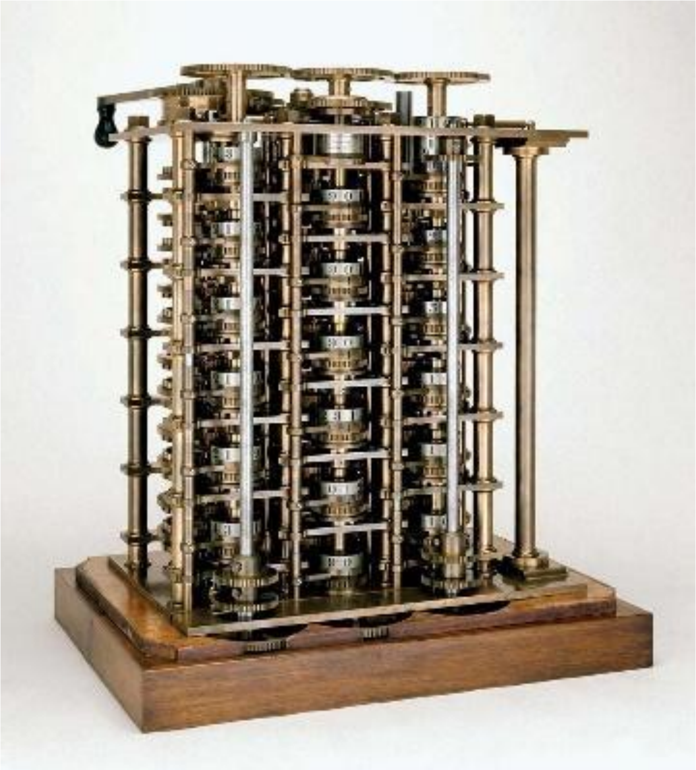
Ancient computers were primarily **analog computers**. Analog computers have variable inputs with a near infinite number of settings. Because you are moving a dial or turning a wheel you can set the device however you want. Over time, **digital computers** became popular. In a digital computer, inputs and outputs are discrete quantities. One of the first digital computers was developed by Charles Babbage. His **Difference Engine** could calculate complex mathematics known as polynomial functions. The device was very heavy and difficult to use, however.

Difference Engine

1822 Babbage's Difference Engine

This machine, created by Charles Babbage, was an automatic calculator that could calculate polynomial functions.

Complex	Heavy	Difficult to use

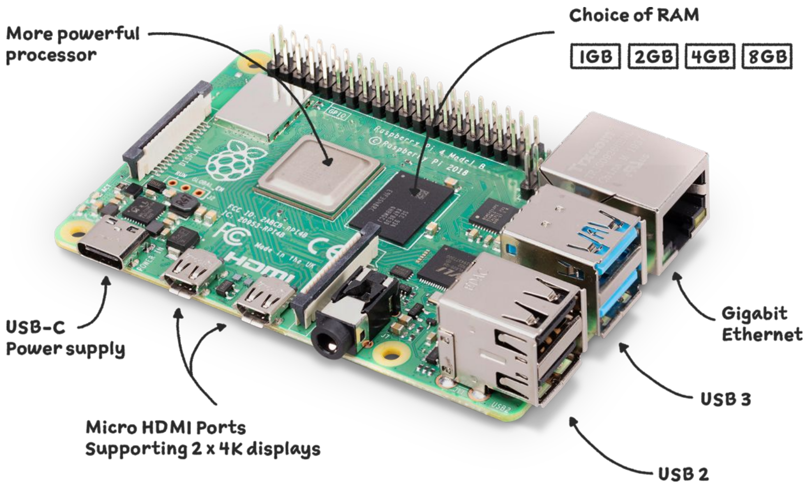


2

Introduction to Raspberry Pi & Hardware Setup

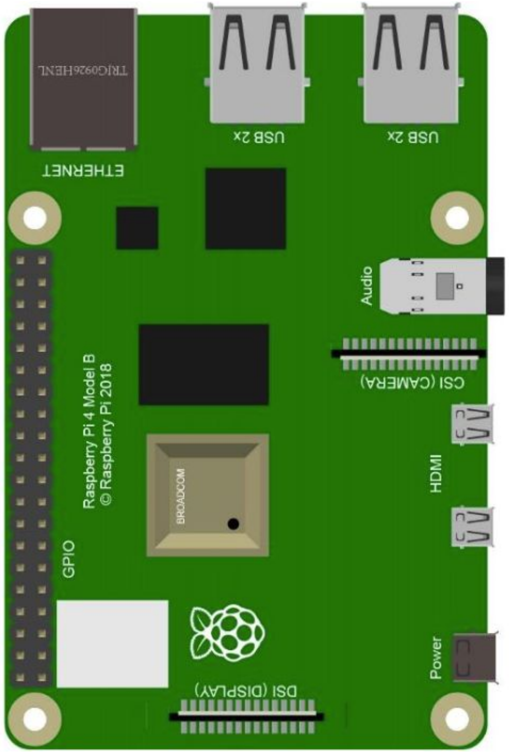
What is Raspberry Pi?

- The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and in developing countries.
- Over 5 million Raspberry Pis have been sold before February 2015, making it the best-selling British computer. By November 2016 they had sold 11 million units.

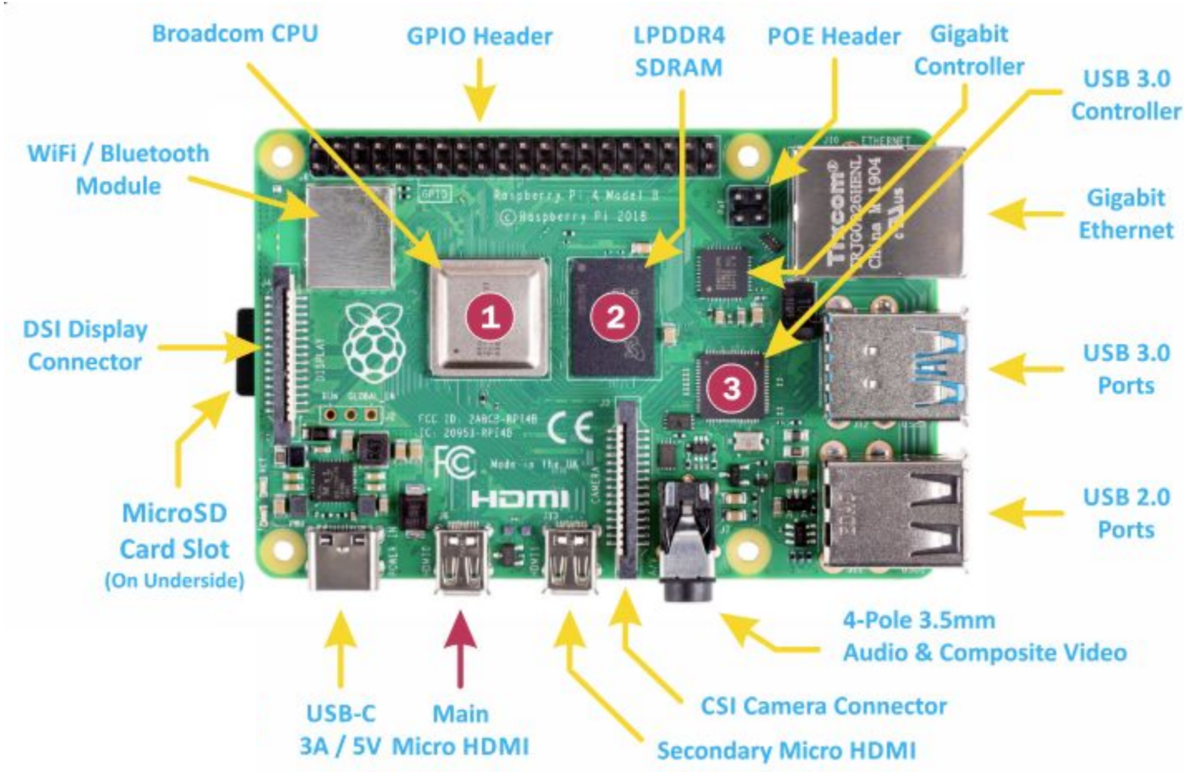


https://www.raspberrypi.com/products/raspberry-pi-4-model-b/

Raspberry Pi 4 Model B



Hardware interface diagram of RPi 4B



Case Installation

https://www.youtube.com/watch?v=1VyE5-gv6jA

Heatsink Installation

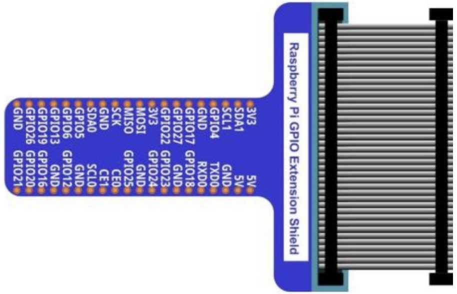
Preparation

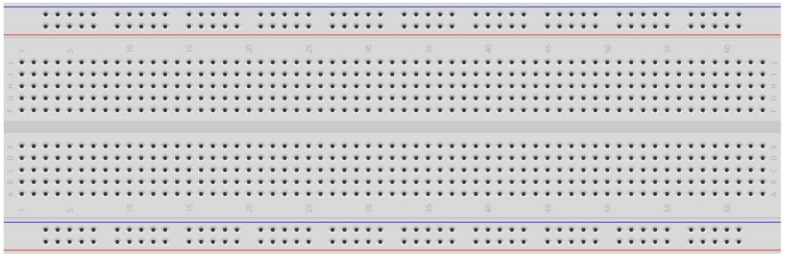
- Peel off the protective film from the bottom of each heatsink.

Placement

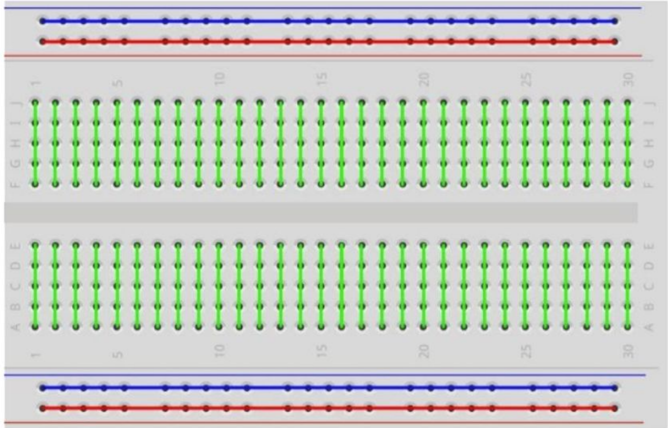
- Larger square heatsink: Place firmly on the Broadcom CPU (1).
- Rectangular heatsink: Place firmly on the SDRAM chip (2).
- Smaller square heatsink: Place firmly on the USB 3.0 Controller (3).

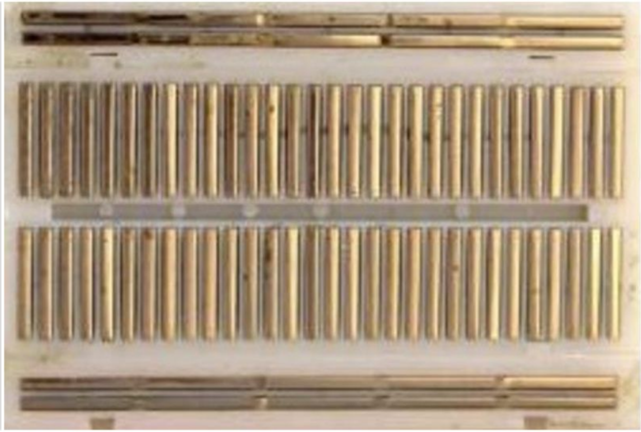
Extension Board & Ribbon Connection





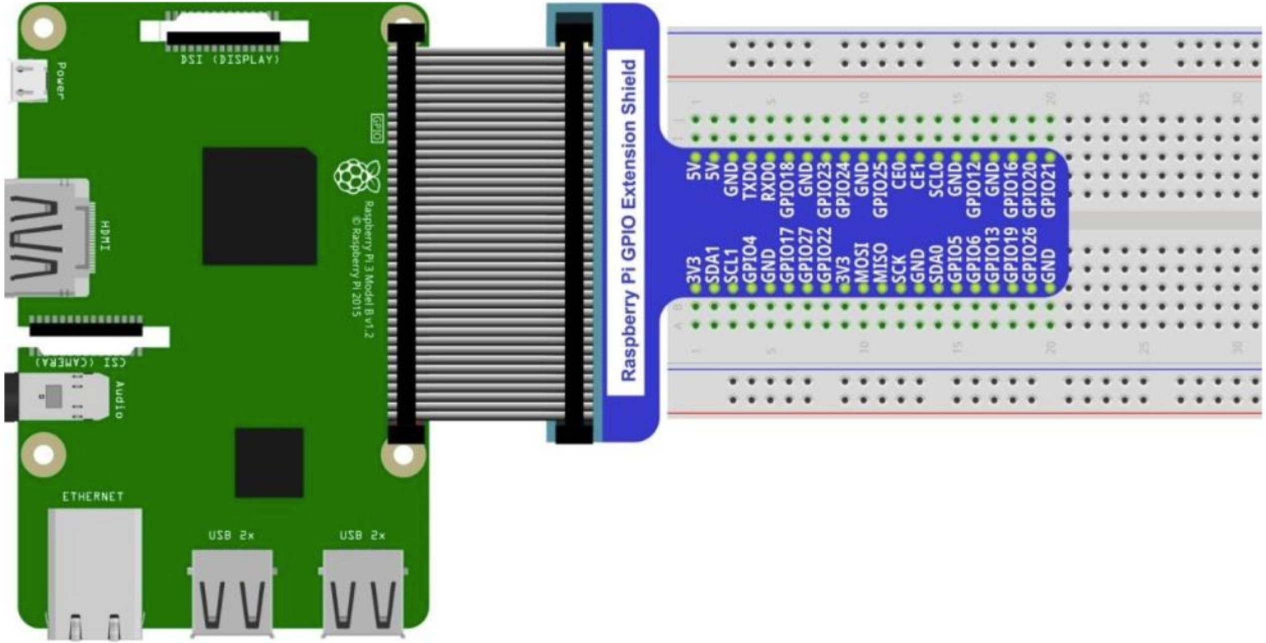
Breadboard



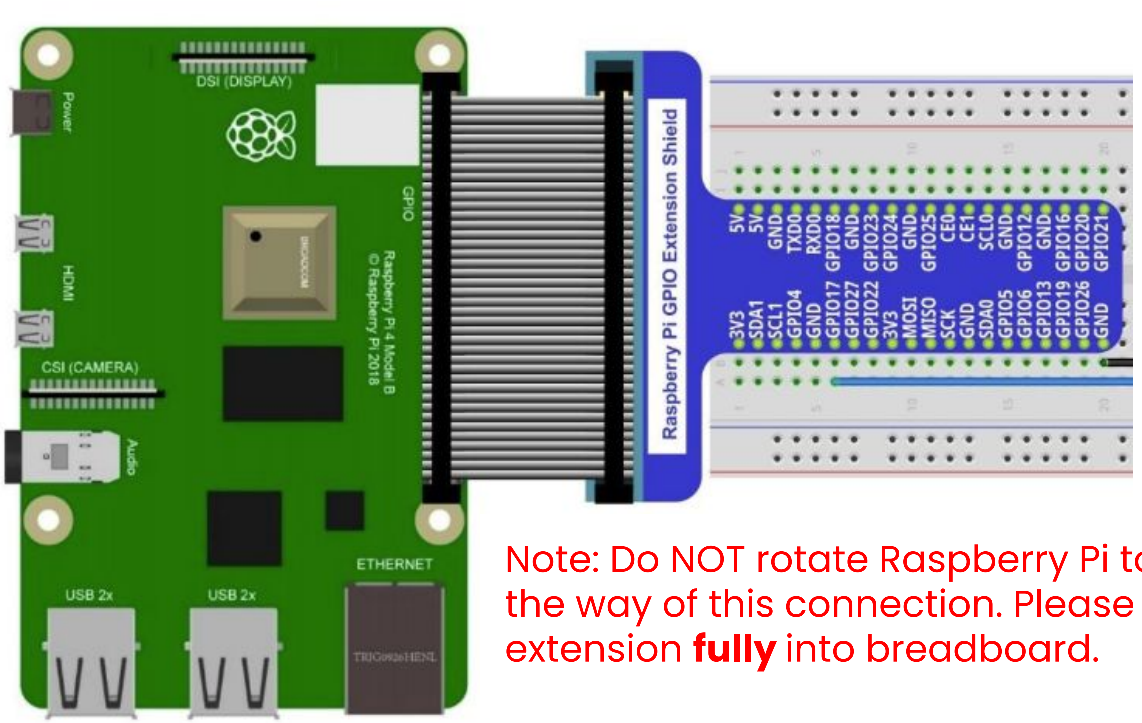


The left picture shows the ways the pins have shared electrical connection, and the right picture shows the actual internal metal, which connects these rows electrically.

GPIO Extension Board

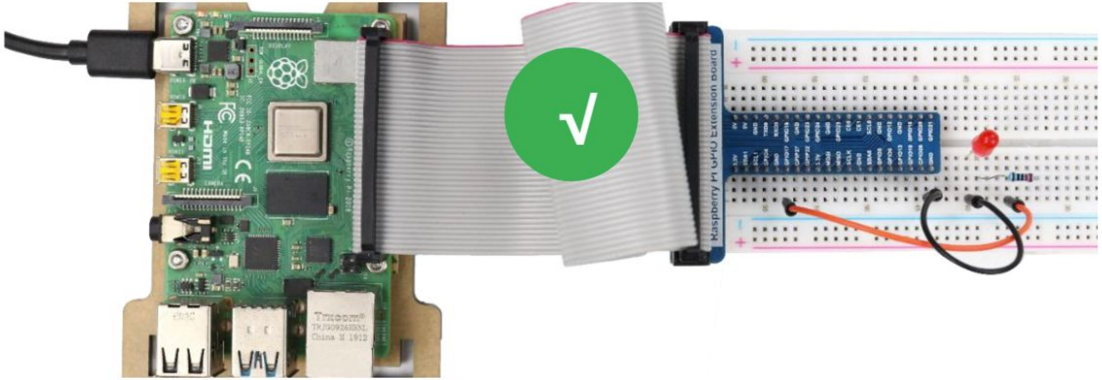


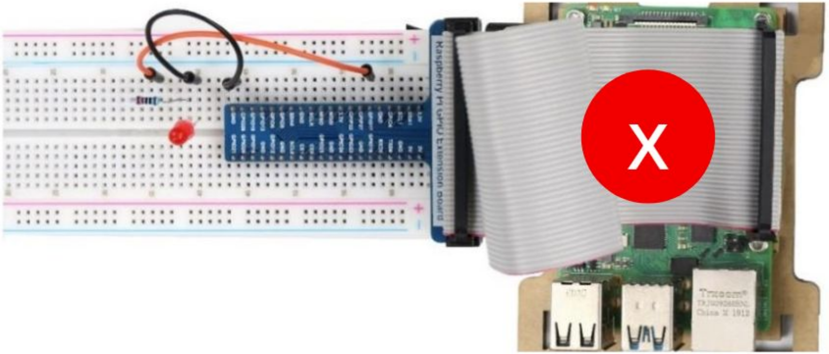
Extension Board & Ribbon Connection



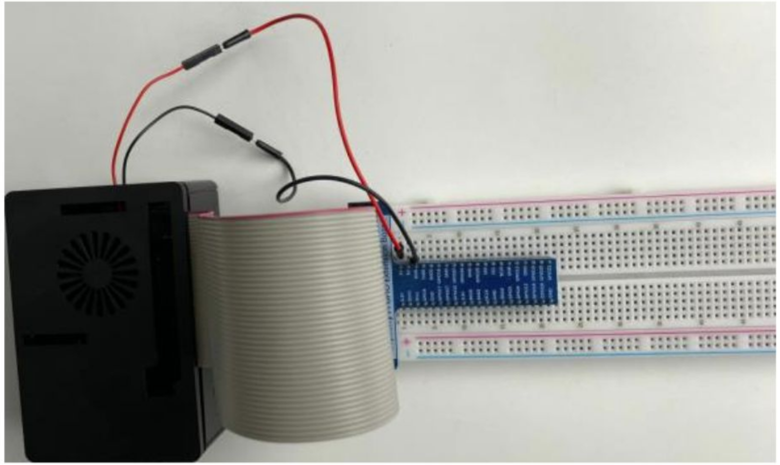
Note: Do NOT rotate Raspberry Pi to change the way of this connection. Please plug T extension **fully** into breadboard.

Extension Board & Ribbon Connection

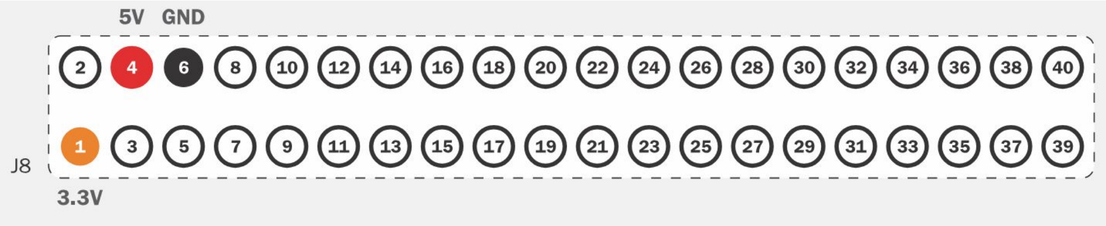




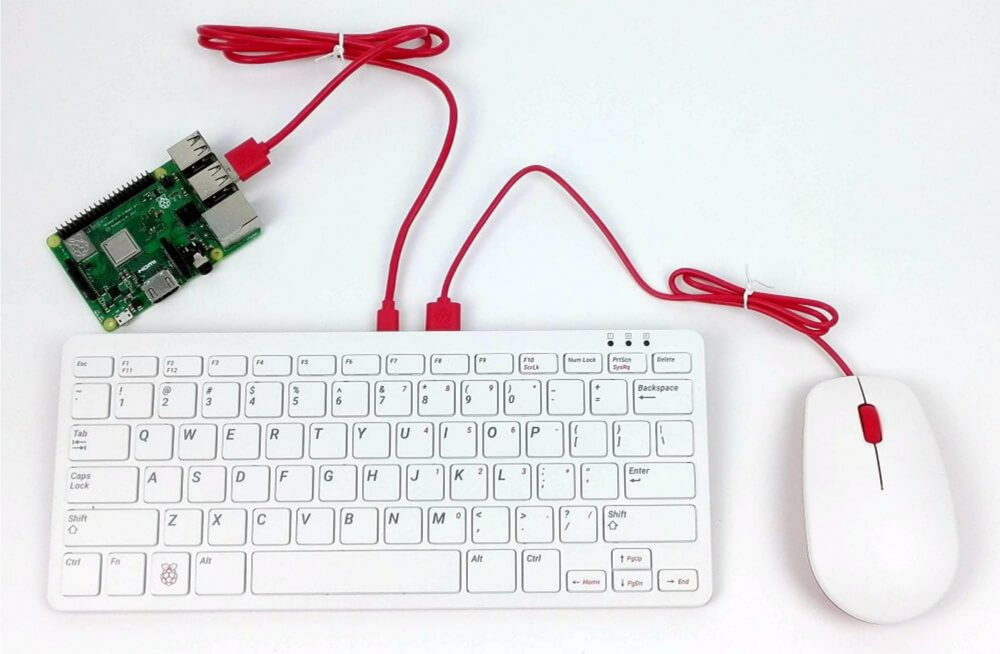
Fan Installation



https://www.stephenwagner.com/2020/03/17/canakit-raspberry-pi-4-cooling-fan/



Mouse and Keyboard



https://www.cytron.io/p-official-raspberry-pi-mouse

HDMI Monitor

https://www.canakit.com/raspberry-4-mico-hdmi-cable.html

Using a Micro HDMI Cable

- Connect a HDMI monitor or TV to the Raspberry Pi using a Micro HDMI cable.

Main Micro HDMI Port

- Ensure the cable is connected to the Main Micro HDMI port (labeled HDMI0).
- The HDMI0 port is the port nearest to the USB-C power port.

3

Installing and setting up the Raspberry Pi OS

Download Imager

https://www.raspberrypi.com/software/

Install Raspberry Pi OS using Raspberry Pi Imager

Raspberry Pi Imager is the quick and easy way to install Raspberry Pi OS and other operating systems to a microSD card, ready to use with your Raspberry Pi.

Download and install Raspberry Pi Imager to a computer with an SD card reader. Put the SD card you'll use with your Raspberry Pi into the reader and run Raspberry Pi Imager.

Download for Windows

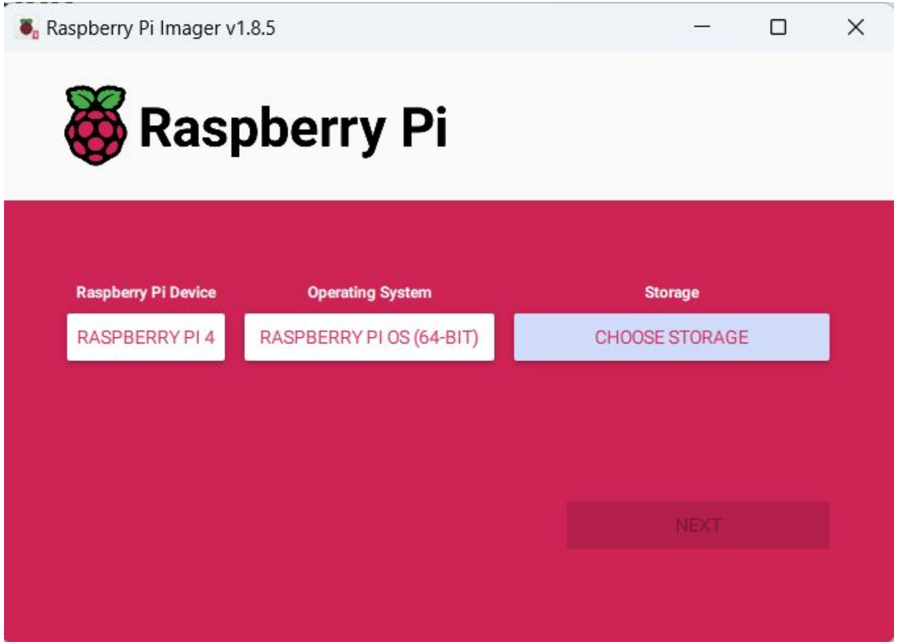
Download for macOS

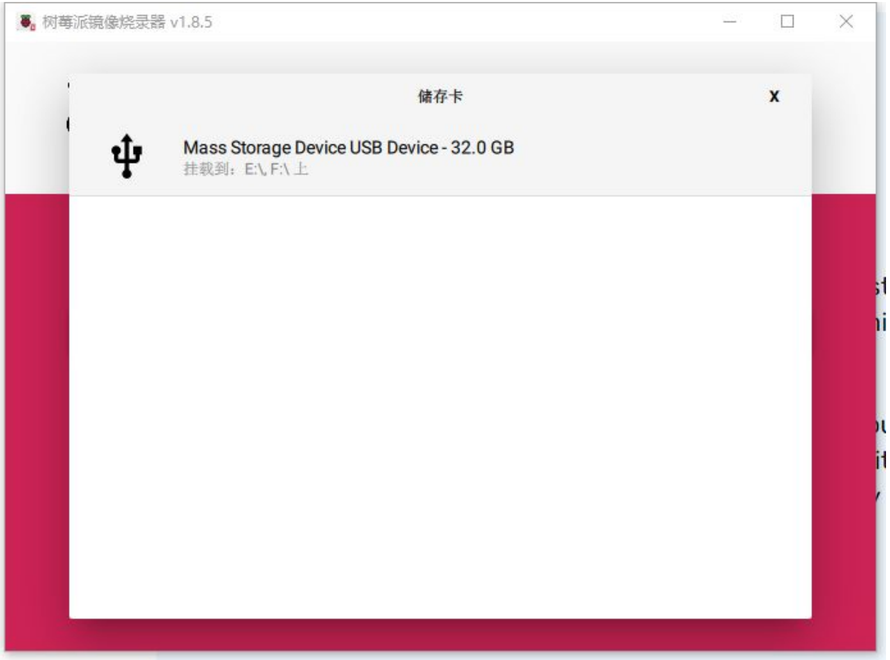
Download for Ubuntu for x86

SD Card Reader

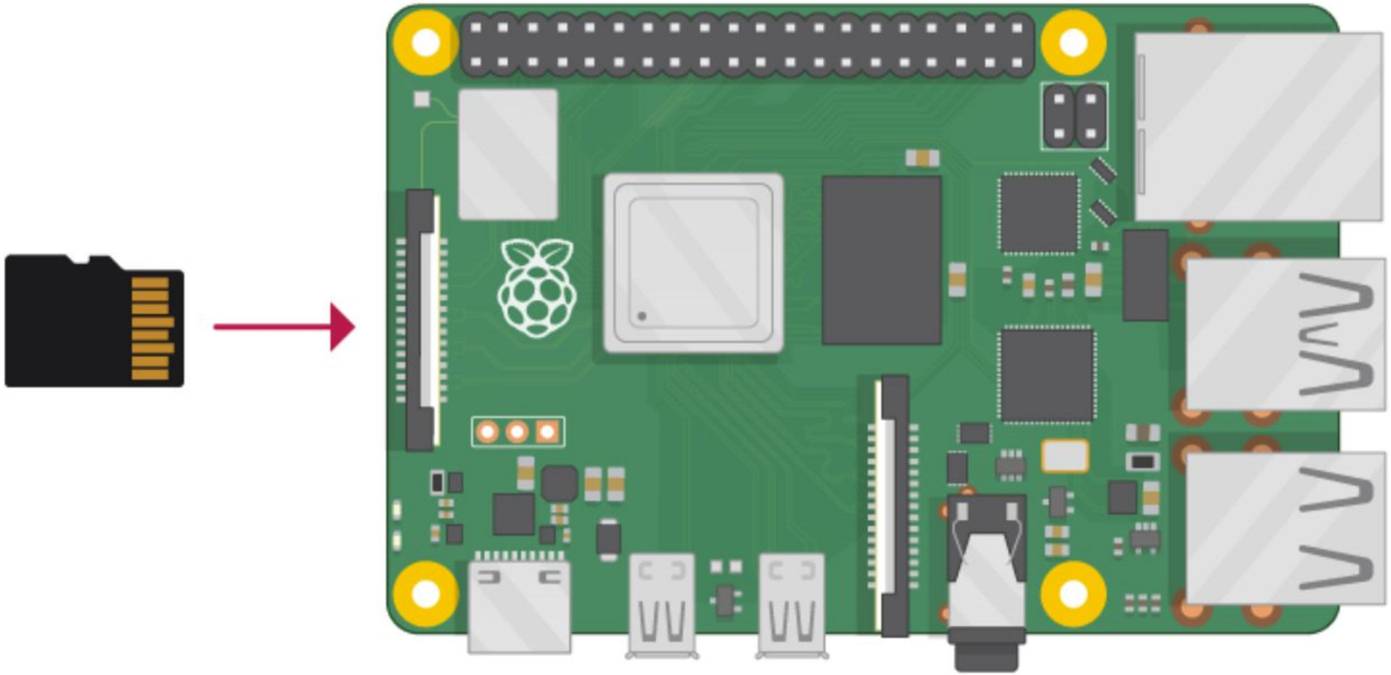
Put Micro SD card into card reader and connect it to USB port of PC

Write to SD Card via Imager





Installing Operating System



Power On

Connect the Power Adapter

- Use a 3A USB-C power adapter to connect to the Raspberry Pi board.

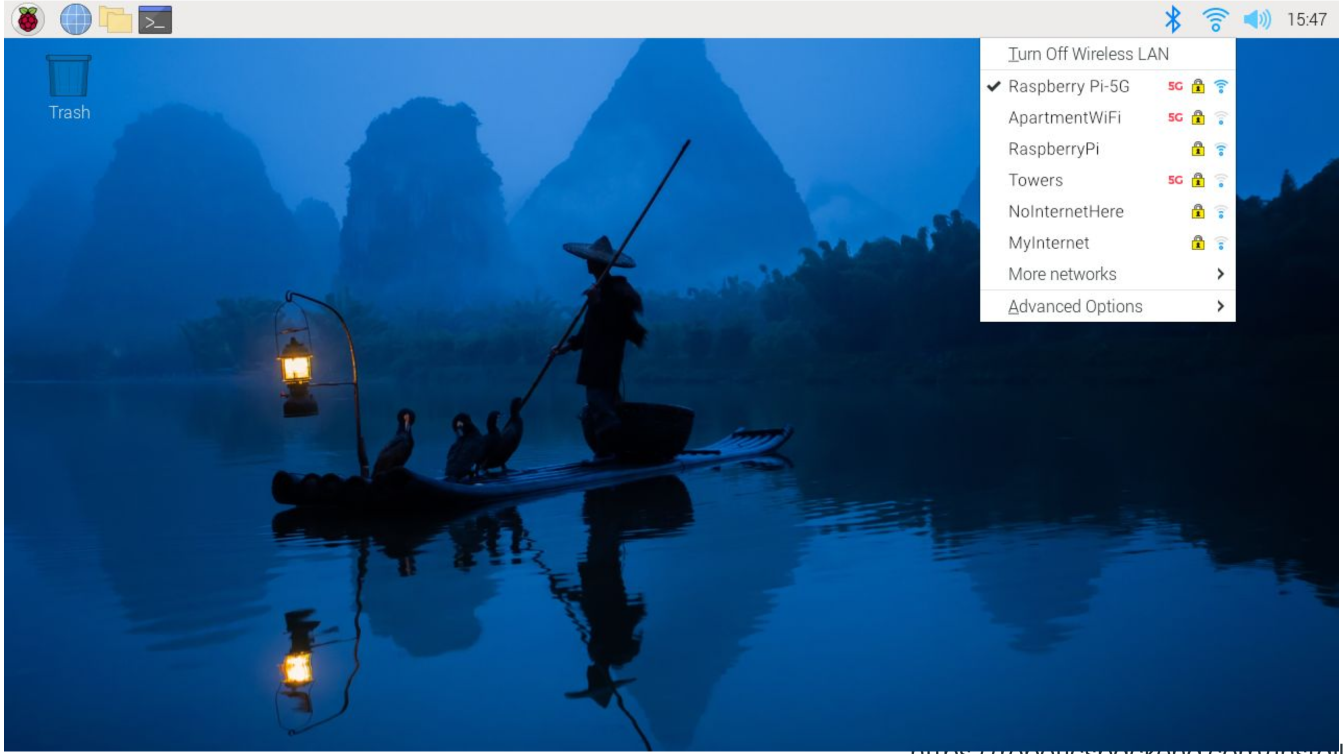
Booting Up

- Once the power is connected, the Raspberry Pi will start to boot.

Initial Menu

- You should be presented with the initial menu on the screen.

WiFi Connection



https://roboticsbackend.com/install-raspbian-desktop-on-a-virtual-machine-virtualbox/

4

Basic Commands and Interface

General Command

- **apt-get update:** Synchronizes the list of packages on your system to the list in the repositories. Use it before installing new packages to make sure you are installing the latest version.
- **apt-get upgrade:** Upgrades all of the software packages you have installed.
- **clear:** Clears previously run commands and text from the terminal screen.
- **raspi-config:** Opens the configuration settings menu.
- **reboot:** To reboot immediately.
- **shutdown -h now:** To shutdown immediately.
- **shutdown -h 01:22:** To shutdown at 1:22 AM.

File and Directory Commands

- **cat example.txt:** Displays the contents of the file example.txt.
- **cd /abc/xyz:** Changes the current directory to the /abc/xyz directory.
- **nano example.txt:** Opens the file example.txt in text editor Nano.
- **find / -name example.txt:** Searches the whole system for the file example.txt and outputs a list of all directories that contain the file.
- **cp XXX:** Copies the file or directory XXX and pastes it to a specified location
  - i.e. `cp examplefile.txt /home/pi/office/` copies examplefile.txt in the current directory and pastes it into the /home/pi/ directory.
  - If the file is not in the current directory, add the path of the file’s location (i.e. `cp /home/pi/documents/examplefile.txt /home/pi/office/` copies the file from the documents directory to the office directory).

File and Directory Commands

- **touch example.txt:** Creates a new, empty file named example.txt in the current directory.
- **mv XXX:** Moves the file or directory named XXX to a specified location.
  - `mv examplefile.txt /home/pi/office/` moves examplefile.txt in the current directory to the /home/pi/office directory.
  - If the file is not in the current directory, add the path of the file’s location
  - This command can also be used to rename files (but only within the same directory). For example, `mv examplefile.txt newfile.txt` renames examplefile.txt to newfile.txt, and keeps it in the same directory.

File and Directory Commands

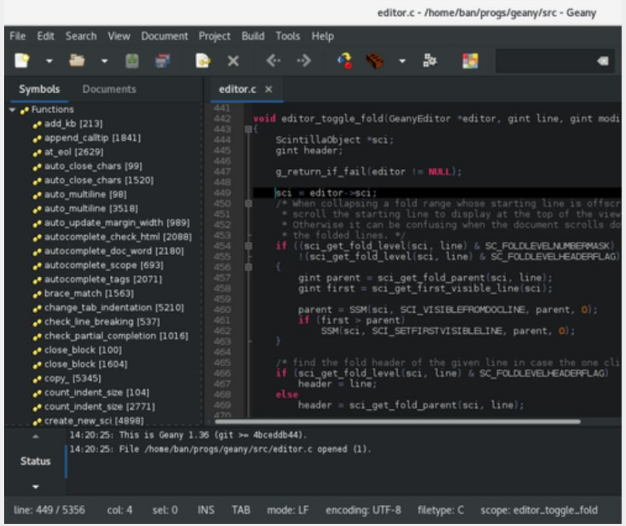
- **ls -l:** Lists files in the current directory, along with file size, date modified, and permissions.
- **mkdir example_directory:** Creates a new directory named example_directory inside the current directory.
- **rm example.txt:** Deletes the file example.txt.
- **rmdir example_directory**: Deletes the directory example_directory (only if it is empty).

Geany IDE

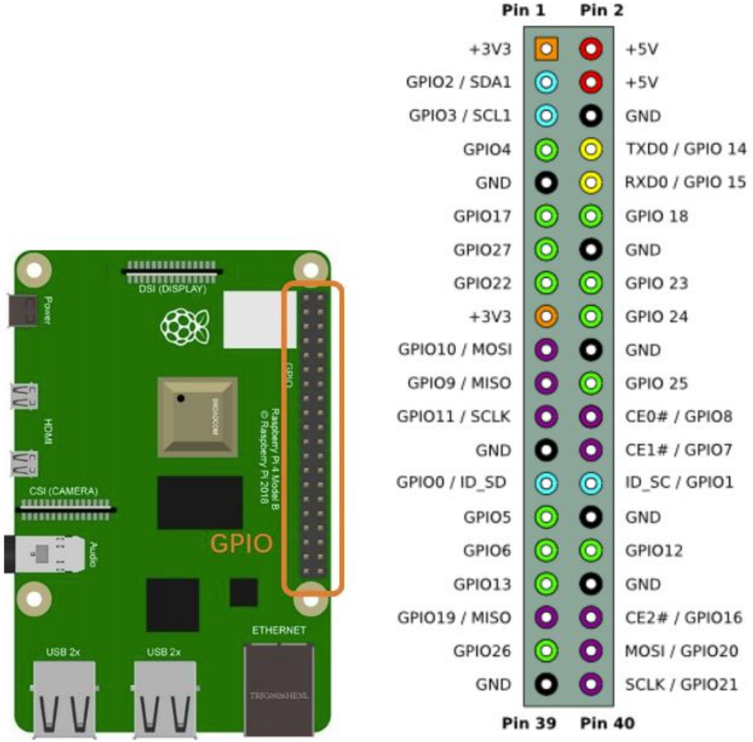
Geany - The Flyweight IDE

Geany is a powerful, stable and lightweight programmer's text editor that provides tons of useful features without bogging down your workflow. It runs on Linux, Windows and macOS, is translated into over 40 languages, and has built-in support for more than 50 programming languages.

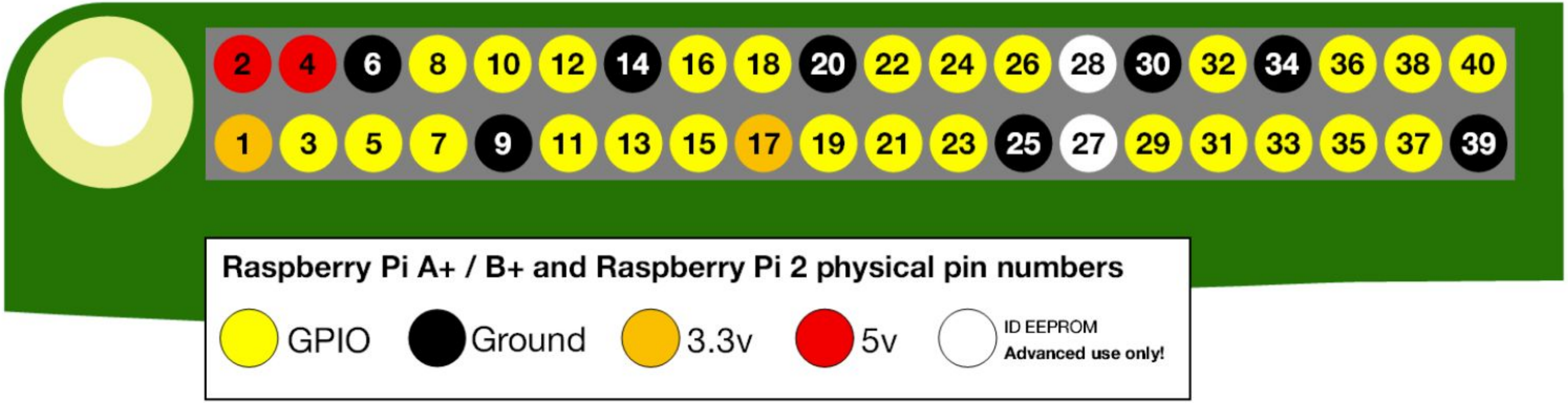
Download Geany 2.1.0 »



Board Pinout



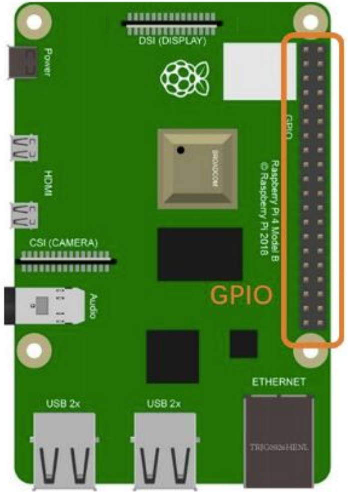
Physical Numbering

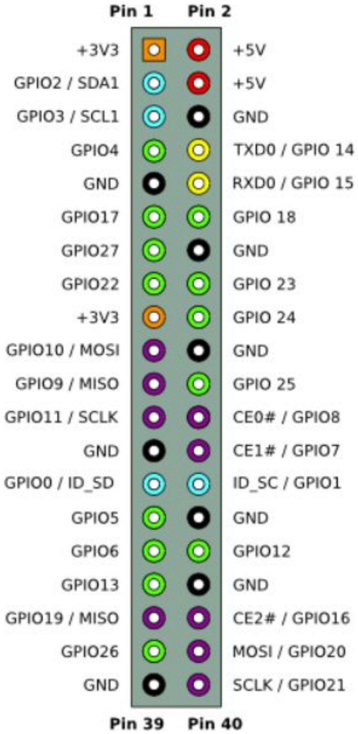


Raspberry Pi GPIO Pinout

[3v3 Power at Raspberry Pi GPIO Pinout]

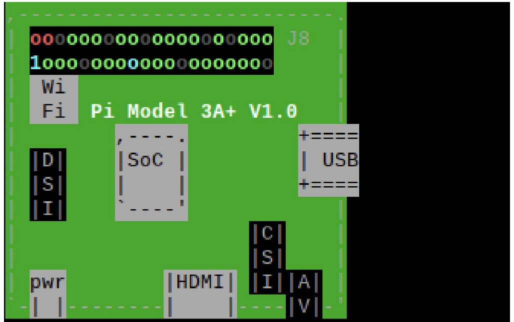
3v3 Power	1	2	5v Power
GPIO 2 (CTS / Clear to Send)	3	4	5v Power
GPIO 3 (RTS / Request to Send)	5	6	Ground
GPIO 4 (TXD / Transmit)	7	8	GPIO 14 (TXD / Transmit)
Ground	9	10	GPIO 15 (RXD / Receive)
GPIO 17 (RTS / Request to Send)	11	12	GPIO 18 (PCM CLK)
GPIO 27	13	14	Ground
GPIO 22	15	16	GPIO 23
3v3 Power	17	18	GPIO 24
GPIO 10 (CTS / Clear to Send)	19	20	Ground
GPIO 9 (RXD / Receive)	21	22	GPIO 25
GPIO 11 (RTS / Request to Send)	23	24	GPIO 8 (TXD / Transmit)
Ground	25	26	GPIO 7 (RTS / Request to Send)
GPIO 0 (TXD / Transmit)	27	28	GPIO 1 (RXD / Receive)
GPIO 5 (RXD / Receive)	29	30	Ground
GPIO 6 (CTS / Clear to Send)	31	32	GPIO 12 (TXD / Transmit)
GPIO 13 (RXD / Receive)	33	34	Ground
GPIO 19 (PCM FS)	35	36	GPIO 16 (CTS / Clear to Send)
GPIO 26	37	38	GPIO 20 (PCM DIN)
Ground	39	40	GPIO 21 (PCM DOUT)





“pinout” Command

```
pi@raspberrypi:~ $ pinout
```




```
Revision              : 9020e0
SoC                   : BCM2837
RAM                   : 512MB
Storage               : MicroSD
USB ports             : 1 (of which 0 USB3)
Ethernet ports        : 0 (0Mbps max. speed)
Wi-fi                 : True
Bluetooth             : True
Camera ports (CSI)    : 1
Display ports (DSI)   : 1
```

3V3	(1)	(2)	5V
GPIO2	(3)	(4)	5V
GPIO3	(5)	(6)	GND
GPIO4	(7)	(8)	GPIO14
GND	(9)	(10)	GPIO15
GPIO17	(11)	(12)	GPIO18
GPIO27	(13)	(14)	GND
GPIO22	(15)	(16)	GPIO23
3V3	(17)	(18)	GPIO24
GPIO10	(19)	(20)	GND
GPIO9	(21)	(22)	GPIO25
GPIO11	(23)	(24)	GPIO8
GND	(25)	(26)	GPIO7
GPIO0	(27)	(28)	GPIO1
GPIO5	(29)	(30)	GND
GPIO6	(31)	(32)	GPIO12
GPIO13	(33)	(34)	GND
GPIO19	(35)	(36)	GPIO16
GPIO26	(37)	(38)	GPIO20
GND	(39)	(40)	GPIO21

Microcontroller & Electronics

07/07/2025
Jing Jia

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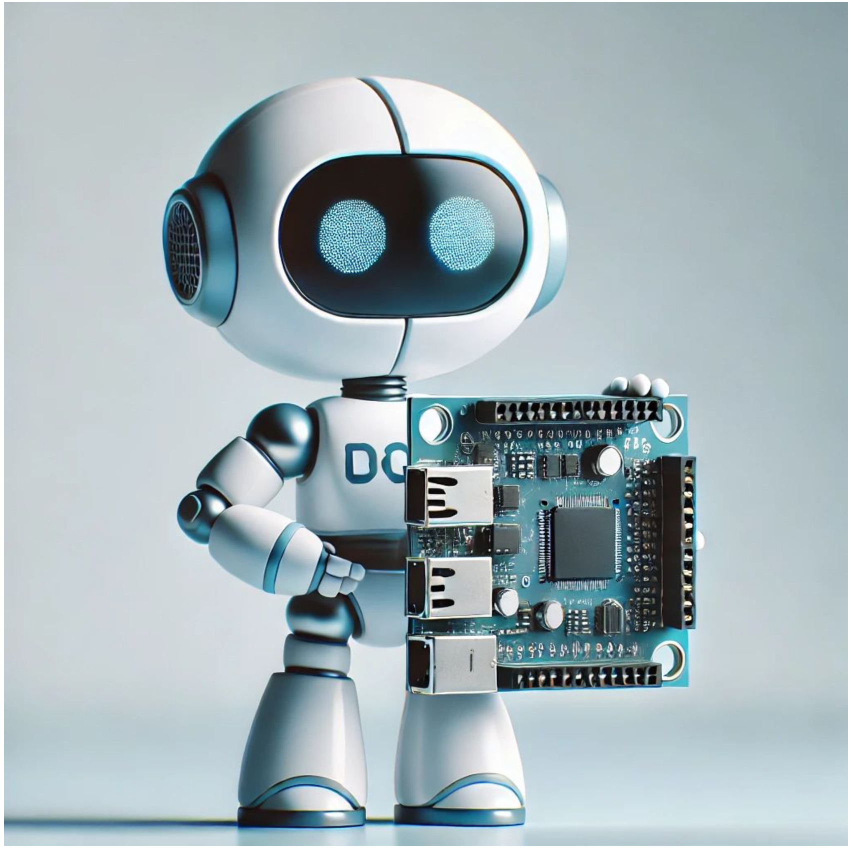


1

Basic Electrical Concepts

The Properties of Charge

Conservation of Charge

- You cannot make or destroy charge; you can only move it around.

Conductors vs. Insulators

- Charge moves freely in conductors (e.g., metals, salty water).
- Charge cannot move in insulators (e.g., air, wood, plastics).

Work Done by Moving Charge

- Charge movement can do useful work (e.g., lighting a room).
- Charge movement can do useless work (e.g., heating a processor chip)

Types of Charge

- Charge comes in two kinds: positive and negative.
- Mixing positive and negative charges cancels them out.

Current

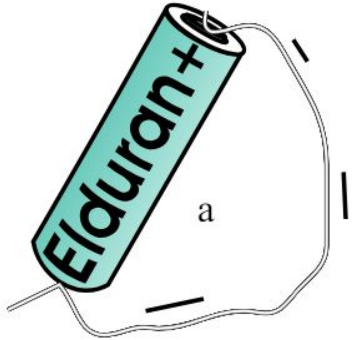
Moving charges form what is called **Electric Current**. Current is measured by the amount of charge that passes a point in one second. The symbol for current is "I," and the unit of current is the Ampere (A). When a current of 1 Ampere is flowing, a charge of 1 Coulomb passes each point in one second. The relationships are given by:

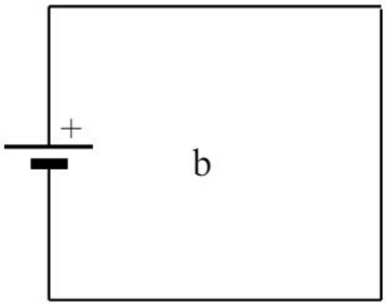
$$I = \frac{Q}{t}$$
$$Q = I \times t$$

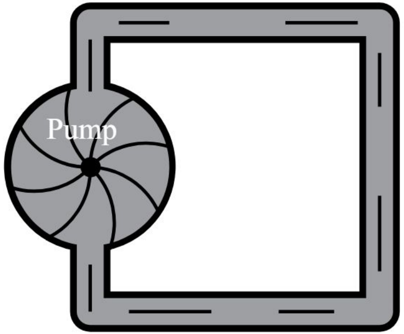
where Q is the charge passing a point in time t

Current

To move charges, an energy source is needed to act as a pump for the electrical fluid. Common sources include batteries, which convert chemical energy into electrical energy, and generators, which convert mechanical energy. Because charge cannot be created or destroyed, current can only flow in complete circuits made of conductive materials, known as **Electrical Circuits.**







https://physerver.hamilton.edu/courses/Spring17/Phy245/Resources/EBookS15aV1.pdf

Voltage

Just as water flows through pipes due to applied pressure, electrical current flows in a circuit due to electrical pressure, known as Electric Potential, measured in Volts.

Electric potential, similar to fluid pressure, is a relative quantity measured between two points in a circuit. A **Voltmeter**, used to measure this potential difference, has two terminals (typically colored red and black). If the electrical pressure pushes charge into the red terminal and out of the black terminal, the potential difference is POSITIVE. Conversely, if it pushes charge into the black terminal and out of the red terminal, the potential difference is NEGATIVE. Both terminals of the meter must be connected to measure the potential difference accurately.

Resistance

The relationship between voltage and current in these components is given by:

$$V = k \times I$$

The constant is a characteristic of the circuit and is called **Resistance (R).**

This linear relationship is known as Ohm's Law and can be expressed in different forms depending on the known quantities and what needs to be determined.

The unit of resistance is the **Ohm**, symbolized by **Ω**.

E.g. A resistor of 1 Ohm allows 1 Ampere of current to flow when there is 1 Volt across its terminals.

Ohm's Law

If the current (I) flowing through a known resistor (R) is known, the voltage (V) across the resistor is:

$$V = I \times R$$

If the voltage (V) across the resistor and its value (R) are known, the current (I) flowing through the resistor is:

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

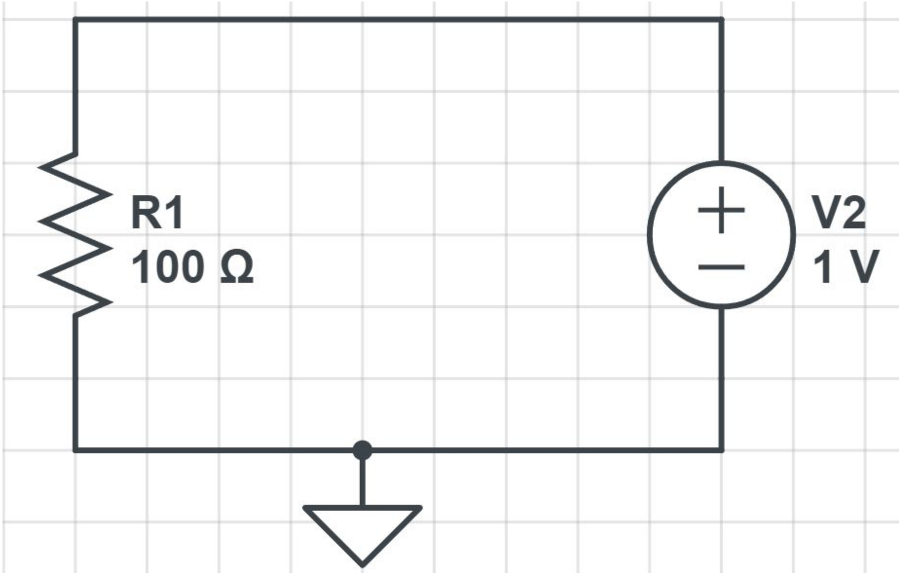
If both the voltage (V) and the current (I) are known, the resistance (R) can be found using:

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

Ohm's Law

if we connect a 100 Ω resistor across the terminals of a 1V battery, then we can find the current that flows in the resistor using the second form of Ohm’s law

$I = V/R = 1\ V / 100\ \Omega = 0.01\ A = 10mA$



2

Basic Components

Direct current (DC)

Direct current (DC) is an electric current that is unidirectional, so the flow of charge is always in the same direction.[2] As opposed to alternating current, the direction and amperage of direct currents do not change. It is used in many household electronics and in all devices that use batteries.[3]

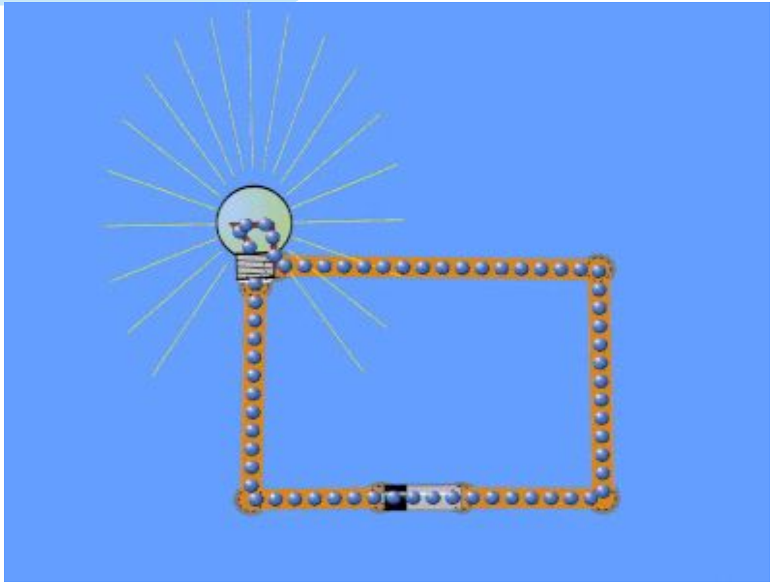


Figure 1: An animation from a PhET simulation[1] of direct current which has been slowed down considerably. See alternating current for a comparison.

https://energyeducation.ca/encyclopedia/Direct_current

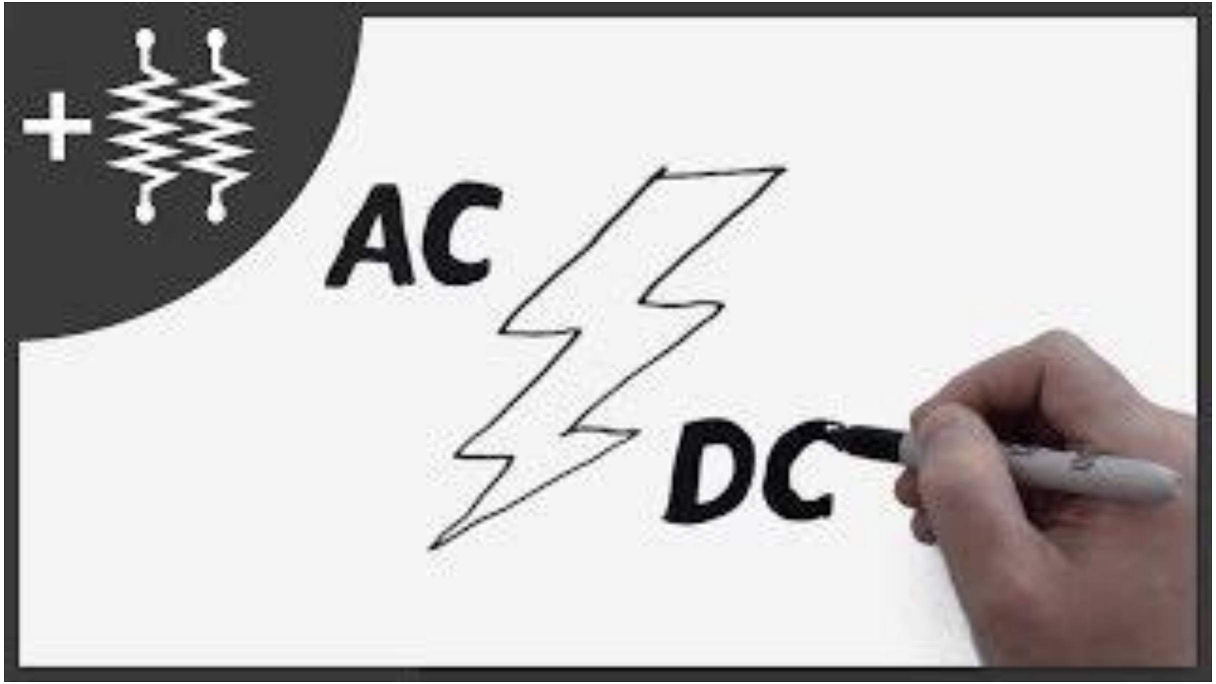
http://phet.colorado.edu/sims/circuit-construction-kit/circuit-construction-kit-ac_en.jnlp

R.T. Paynter, “Basic Electric Components and Meters,” in Introduction to Electricity, 1rst ed. NJ: Prentice-Hall, 2011, ch. 2, sec. 2.3, pp. 43-49.

What is Direct Current [Online]. Available:http://www.powerinverters.org/pages/What-is-Direct-Current.html

Direct current (DC)

https://www.youtube.com/watch?v=vN9aR2wKv0U



Resistors

A resistor is an electrical component that causes resistance in the flow of current. They can be found in practically all electrical networks and electronic circuits. Resistance is expressed in ohms (Ω). When a current of one ampere (A) passes through a resistor with a one volt (V) drop across its terminals, the resistance is measured in ohms. The voltage across the terminal ends determines the current. Ohm's law can be used to express this ratio:

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

- https://www.scienceabc.com/innovation/what-are-resistors.html

Resistors Slows Current Everywhere

Common Misconception

- Resistors only reduce current at their location, like a traffic jam, slowing electrons before the resistor but allowing them to speed up afterward.

Correct Concept

- Resistors' Function: Restrict the flow of electrons throughout the entire circuit path, not just at the resistor.
- Like a small valve in a water pipe, the resistor restricts total flow both before and after the valve.

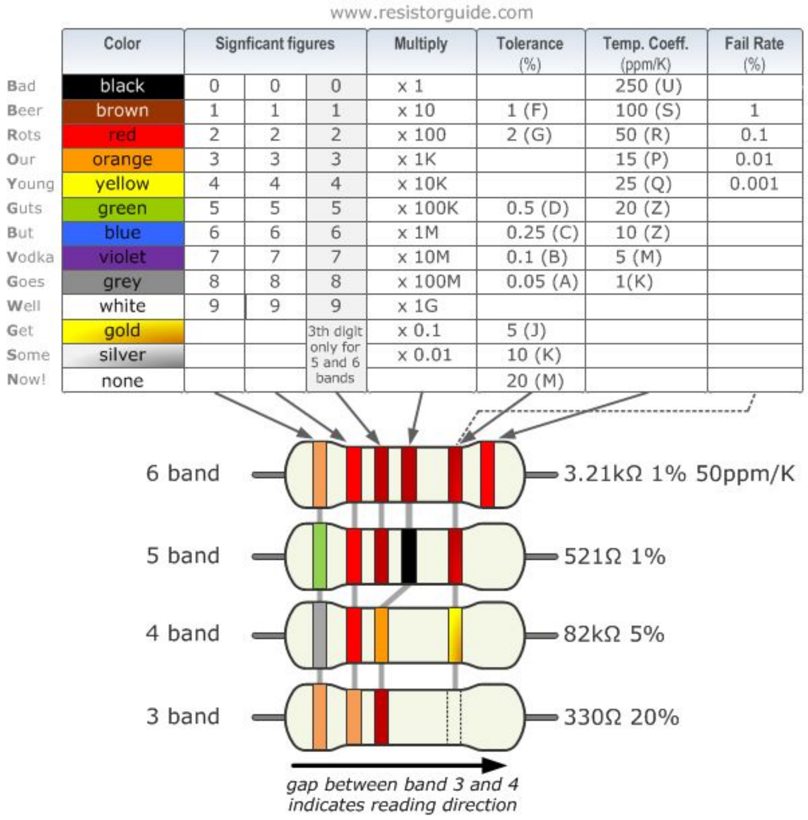
What is a resistor?

https://www.youtube.com/watch?v=Gc1wVdbVI0E

Resistor Color Code

Exercise

- Find 10k Ω Resistor
- Find 220 Ω Resistor
- Find 1k Ω Resistor



www.resistorguide.com

	Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
Bad	black	0	0	0	x 1		250 (U)	
Beer	brown	1	1	1	x 10	1 (F)	100 (S)	1
Rots	red	2	2	2	x 100	2 (G)	50 (R)	0.1
Our	orange	3	3	3	x 1K		15 (P)	0.01
Young	yellow	4	4	4	x 10K		25 (Q)	0.001
Guts	green	5	5	5	x 100K	0.5 (D)	20 (Z)	
But	blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
Vodka	violet	7	7	7	x 10M	0.1 (B)	5 (M)	
Goes	grey	8	8	8	x 100M	0.05 (A)	1(K)	
Well	white	9	9	9	x 1G			
Get	gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
Some	silver				x 0.01	10 (K)		
Now!	none					20 (M)		

Resistor Colour Code Calculator:
https://www.newark.com/resistor-colour-code-calculator

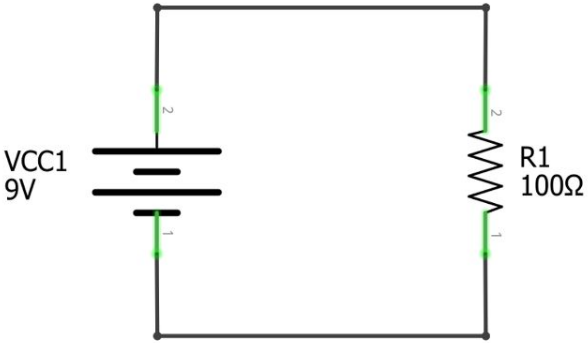
https://eepower.com/resistor-guide/resistor-standards-and-codes/resistor-color-code/

Electrical Power P

- **Electric Power:** The rate of doing work, similar to mechanical power.
- **SI Unit:** Watt (W), equivalent to one joule per second (J/s).
- **Battery**: Converts chemical potential energy to electrical energy (producing power).
- **Resistor**: Converts electrical energy to heat energy (absorbing power).
- **Total Power:** Power delivered equals power absorbed in a circuit.

$$P = V * I$$

Power Dissipation of Resistor



Ohm's Law:

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

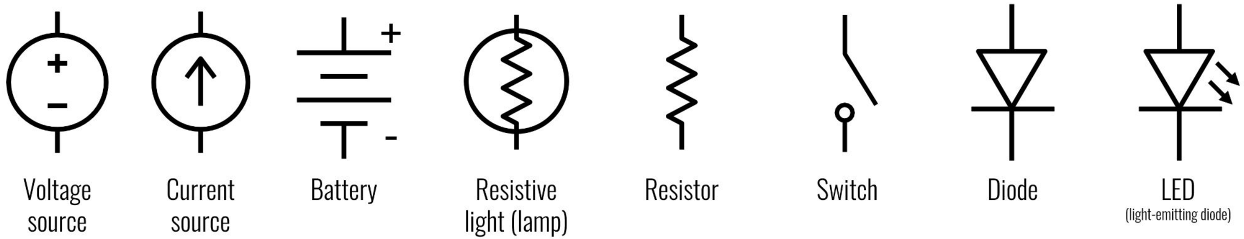
Power:

$$P = I * V \Rightarrow \frac{V^2}{R}$$

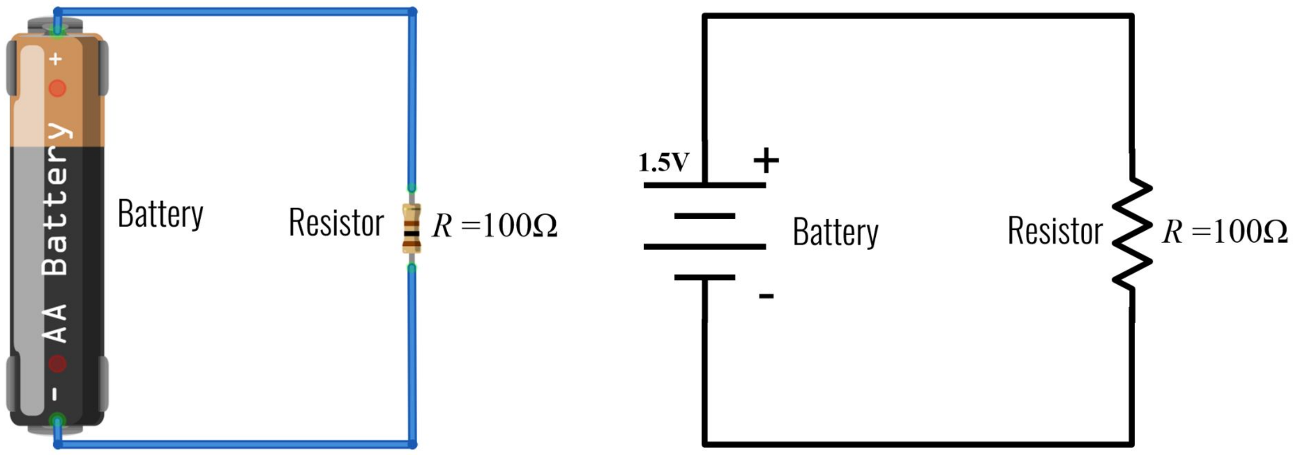
$$P = \frac{V^2}{R} \Rightarrow \frac{9^2 V}{100\Omega} \Rightarrow \boxed{0.81W}$$

Common electronic symbols

- Symbols are clean and distinguishable, representing the essence of the components.
- Resistor and Lamp: Both share a zig-zaggy line as resistive elements.
- Diode and LED: Similar symbols with the LED including arrows indicating light emission.

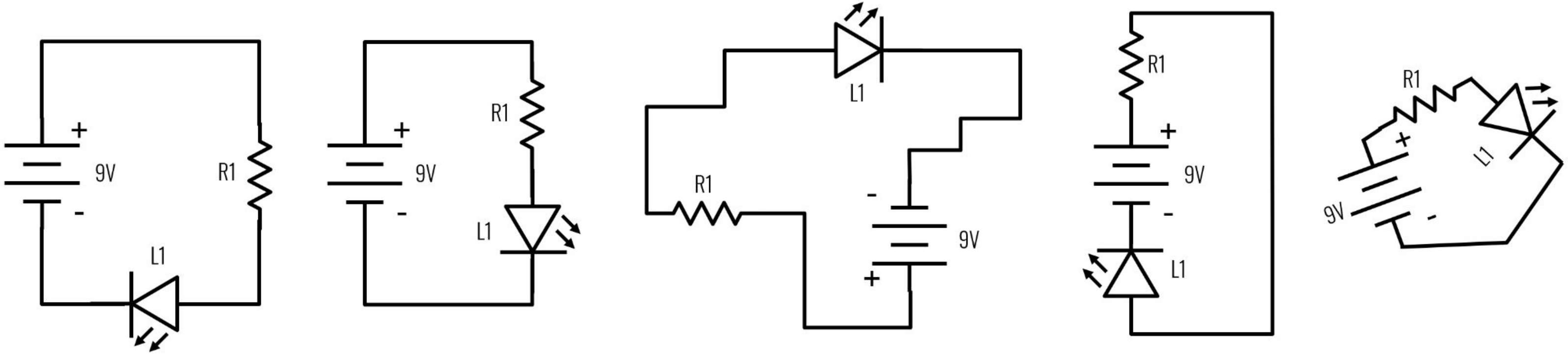


Pictorial vs. circuit schematics



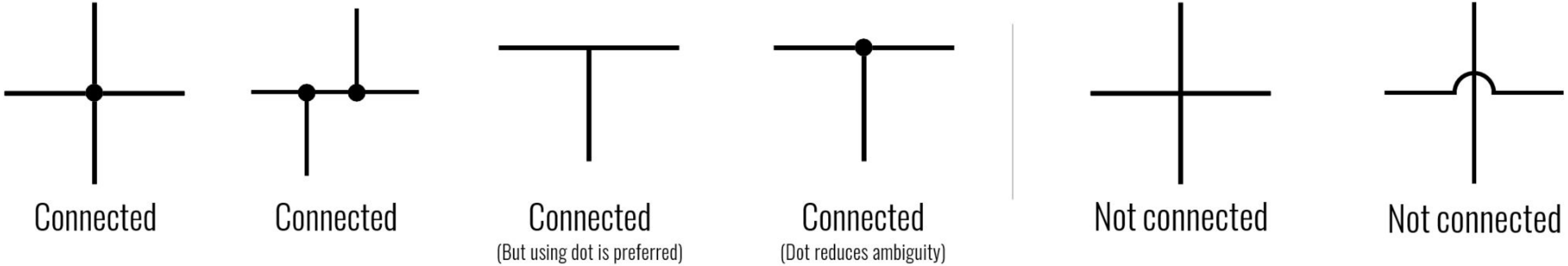
Physical Arrangement

- Physical Arrangement: Schematics capture the connections and relative ordering of components, not their physical layout.
- Functionality: Follow schematics like instructions, focusing on electrical relationships rather than spatial arrangement.

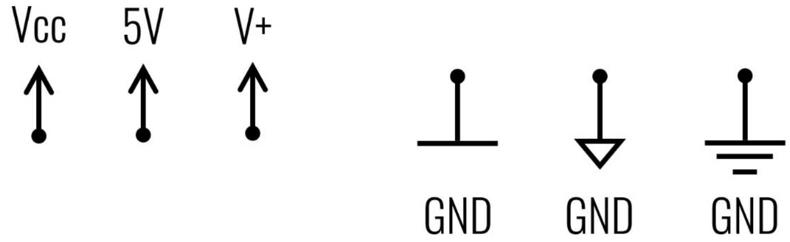


Connected vs. Unconnected wires

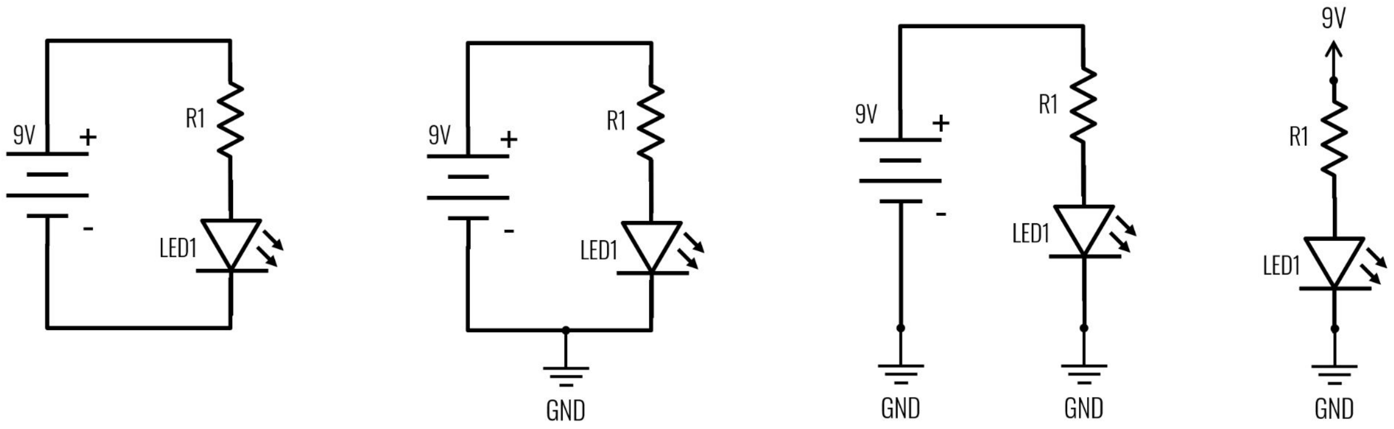
- Solid Lines: Represent wires in a circuit.
- Junctions (Nodes): Black dot where two or more wires connect.
- Crossing Wires: No black dot indicates wires do not connect.



Voltage Source and Ground Node



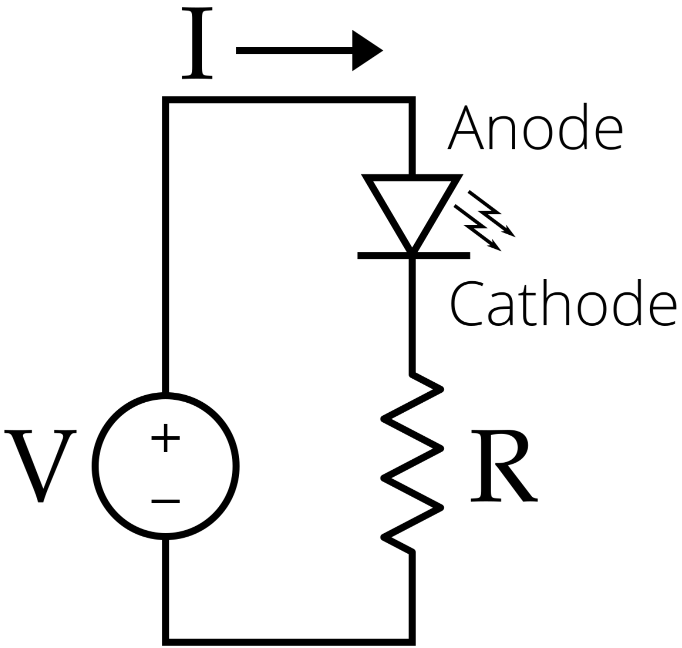
Equivalent circuit diagrams



Light-Emitting Diode (LED)

Diode is an electrical component that allows the flow of current in only one direction. When current passes through a light-emitting diode (LED), it produces light. Electrons recombine with electron holes in the semiconductor, producing energy in the form of photons.

- Question
  - How do I turn on a LED?
  - What happened if I reverse its polarity?



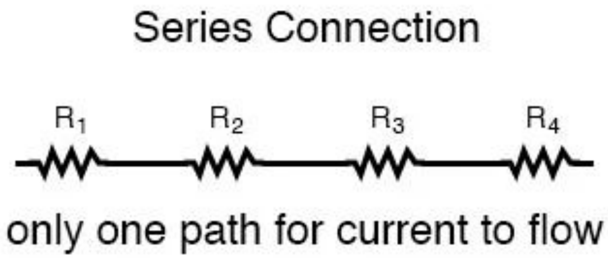
https://circuitdigest.com/electronic-circuits/push-button-led-circuit

Light-Emitting Diode (LED)

https://www.youtube.com/watch?v=Yo6JI_bzUzo

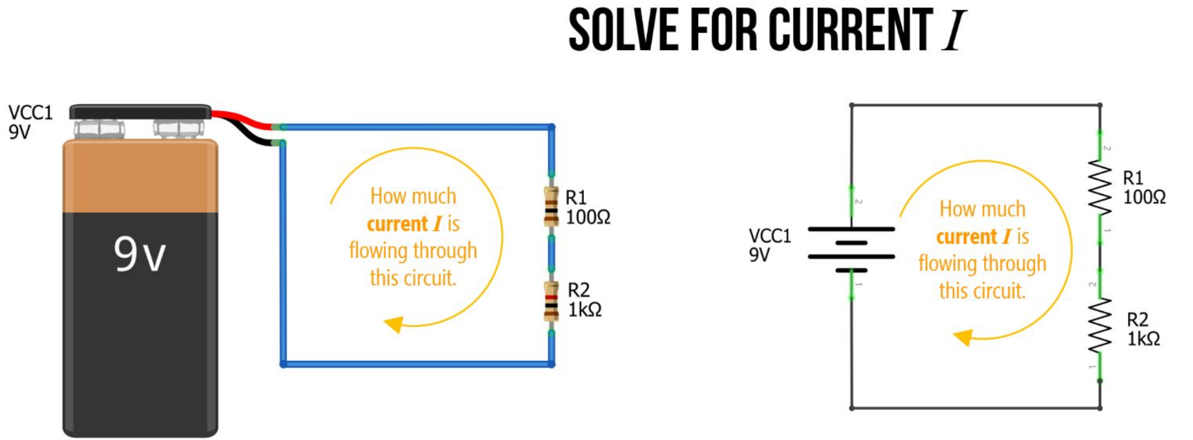
What Is a Series Connection?

The basic idea of a "series" connection is that components are connected end-to-end in a line to form a single path through which current can flow:



https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/#:~:text=In%20a%20series%20circuit%2C%20all,sets%20of%20electrically%20common%20points.

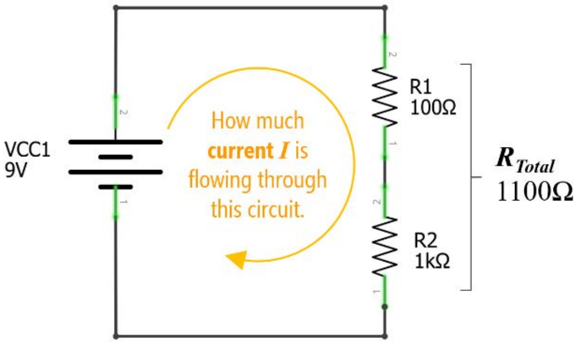
Solve for current



$$I = \frac{V}{R_{Total}}$$

https://makeabilitylab.github.io/physcomp/electronics/series-parallel.html

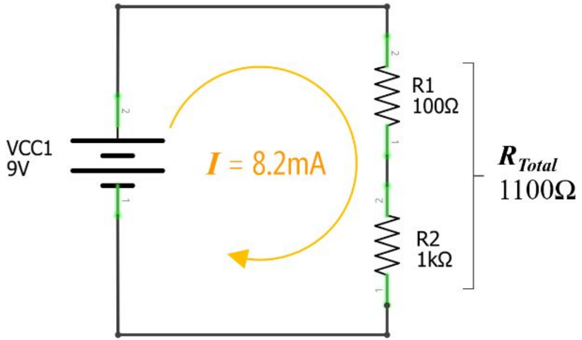
Solve for total resistance



$$\boldsymbol{I} = \frac{V}{R_{Total}}$$

$$\boldsymbol{R_{Total}} = R_1 + R_2 \Rightarrow 1100\Omega$$

Solve for current



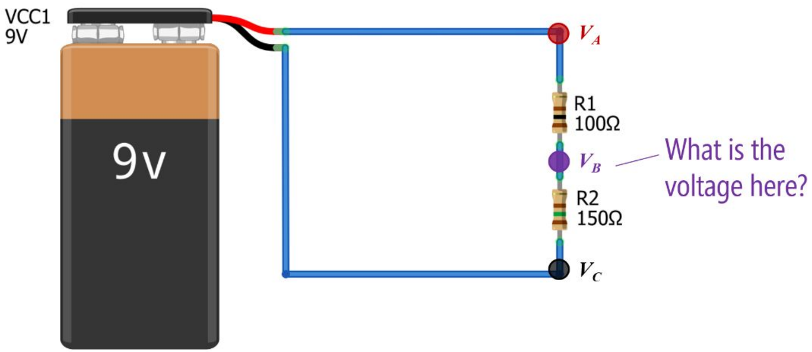
$$\boldsymbol{I} = \frac{V}{R_{Total}}$$

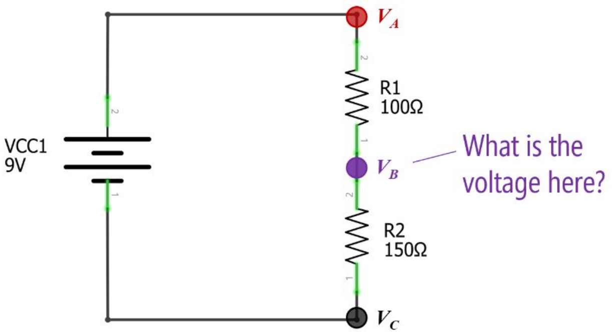
$$\boldsymbol{R_{Total}} = R_1 + R_2 \Rightarrow 1100\Omega$$

$$\boxed{\boldsymbol{I} = \frac{9V}{1100\Omega} \Rightarrow 8.2mA}$$

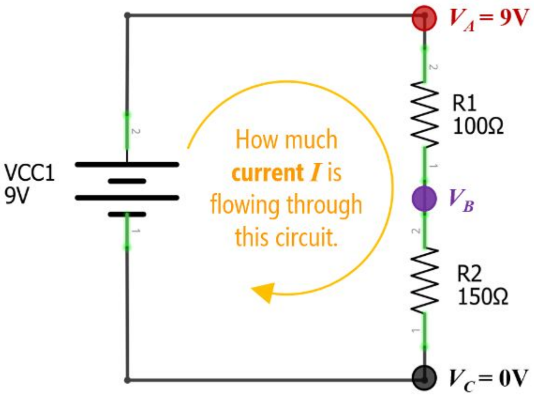
Voltage dividers: Solve for voltage at VB

SOLVE FOR VOLTAGE AT V_B





Solve for the current

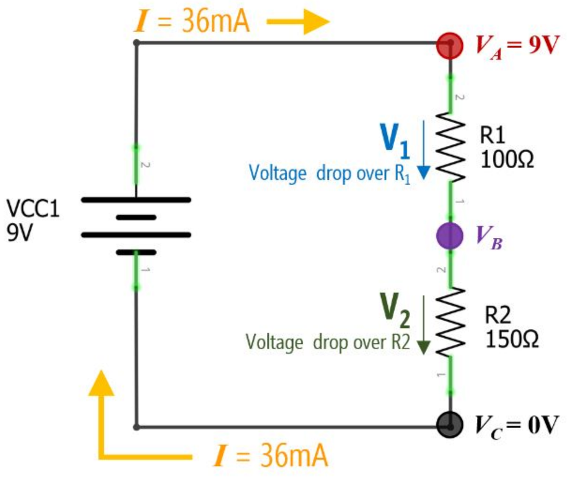


$$\boldsymbol{I} = \frac{V}{R_{Total}}$$

$$\boldsymbol{R_{Total}} = R_1 + R_2 \Rightarrow 250\Omega$$

$$\boxed{\boldsymbol{I} = \frac{9V}{250\Omega} \Rightarrow 36mA}$$

Calculate voltage drop across resistors

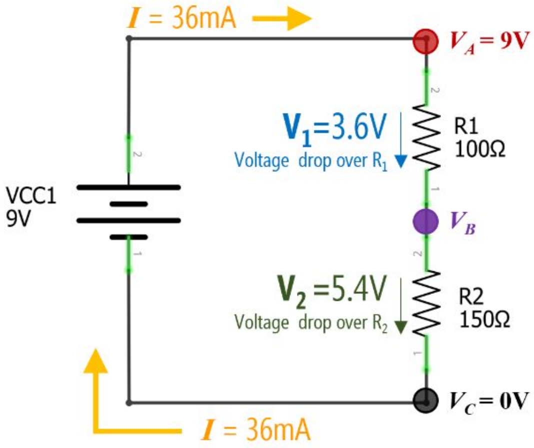


$$\boldsymbol{V} = I * R$$

$$\begin{aligned}\boldsymbol{V_1} &= I * R_1 \\ &= 0.036A * 100\Omega \\ &= 3.6V\end{aligned}$$

$$\begin{aligned}\boldsymbol{V_2} &= I * R_2 \\ &= 0.036A * 150\Omega \\ &= 5.4V\end{aligned}$$

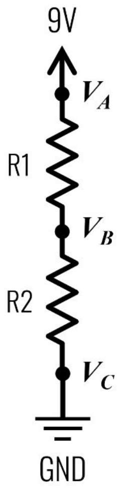
Calculate VB



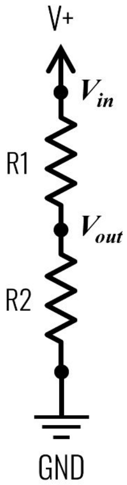
V_B is equal to the battery's positive terminal voltage minus the voltage drop over V_1

$$\boxed{\boldsymbol{V_B} = 9V - 3.6V = 5.4V}$$

Voltage Divider Pattern



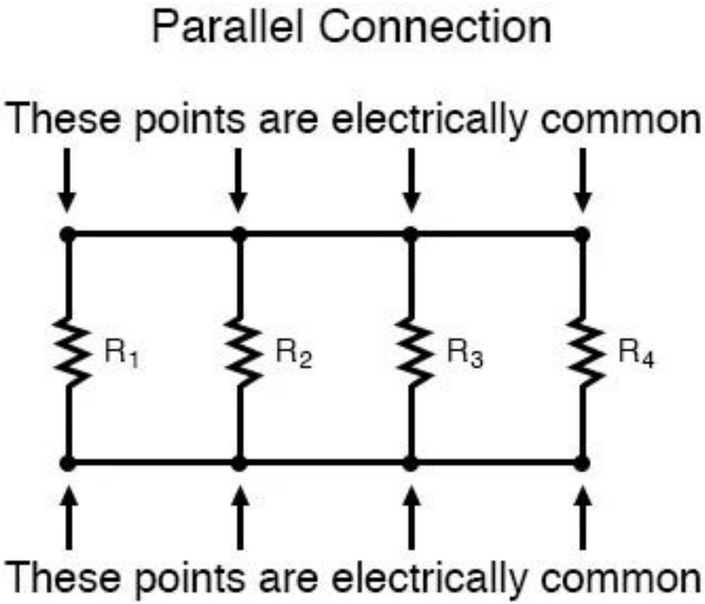
$$V_B = V_A * \frac{R_2}{R_1 + R_2}$$



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

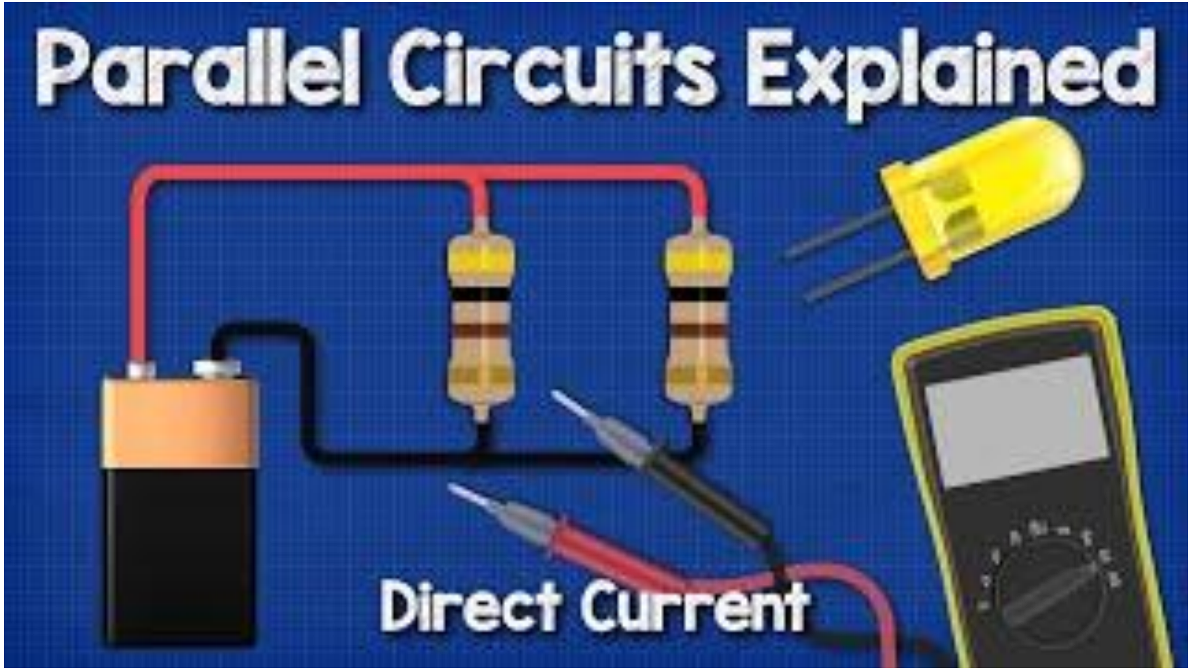
What Is a Parallel Connection?

The basic idea of a "parallel" connection, on the other hand, is that all components are connected across each other's leads. In a purely parallel circuit, there are never more than two sets of electrically common points, no matter how many components are connected. There are many paths for current flow, but only one voltage across all components:

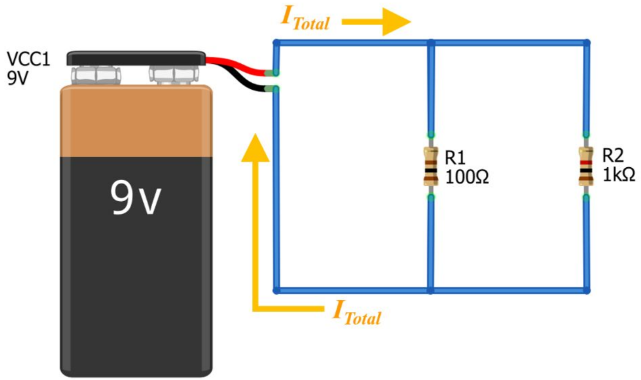


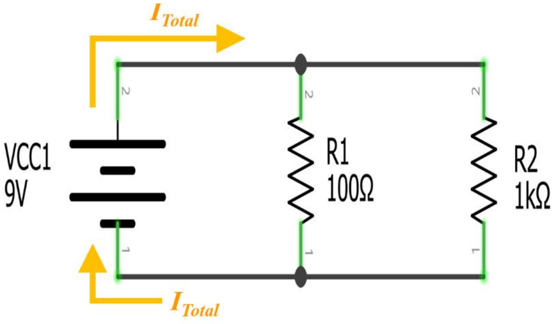
Parallel Connection

https://www.youtube.com/watch?v=5uyJezQNSHw

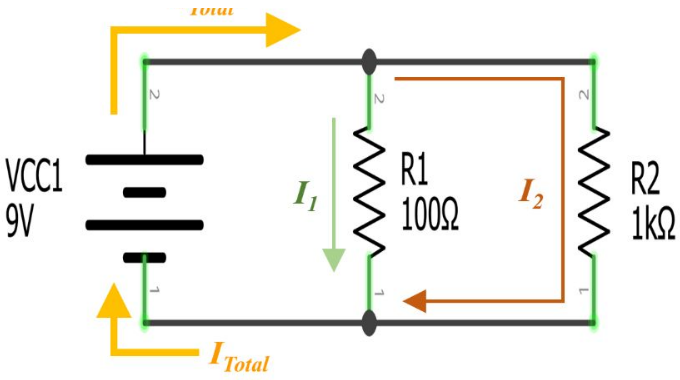


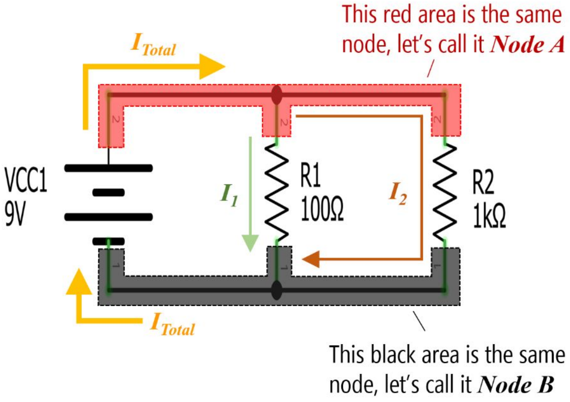
Solve for I_{Total}



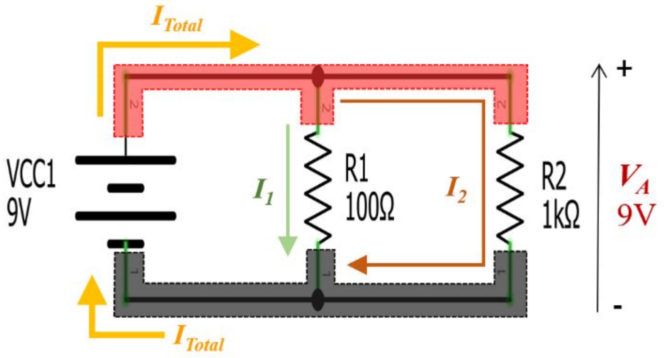


Node A and Node B





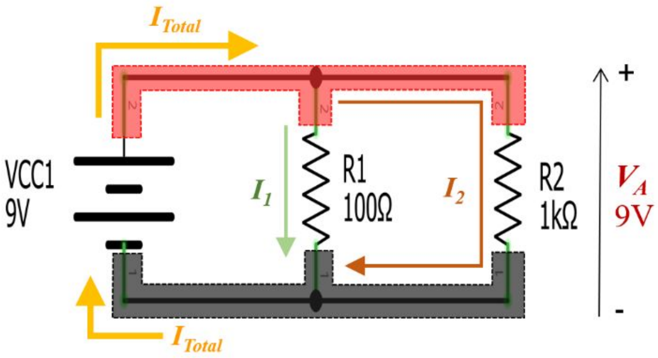
Solve for I_1 and I_2



$$I_1 = \frac{V_A}{R_1} \Rightarrow \frac{9V}{100\Omega} \Rightarrow 90mA$$

$$I_2 = \frac{V_A}{R_2} \Rightarrow \frac{9V}{1k\Omega} \Rightarrow 9mA$$

Solve for I $_{Total}$



$$I_1 = \frac{V_A}{R_1} \Rightarrow \frac{9V}{100\Omega} \Rightarrow 90mA$$

$$I_2 = \frac{V_A}{R_2} \Rightarrow \frac{9V}{1k\Omega} \Rightarrow 9mA$$

$$\boxed{\begin{aligned} I_{Total} &= I_1 + I_2 \\ &= 90mA + 9mA \\ &= 99mA \end{aligned}}$$

Check with equation,

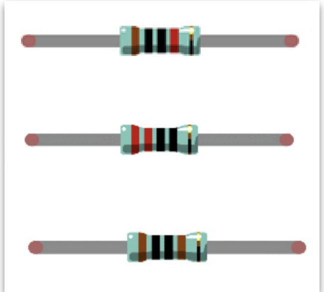
$$R_{equivalent} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_{N-1}} + \frac{1}{R_N}}$$

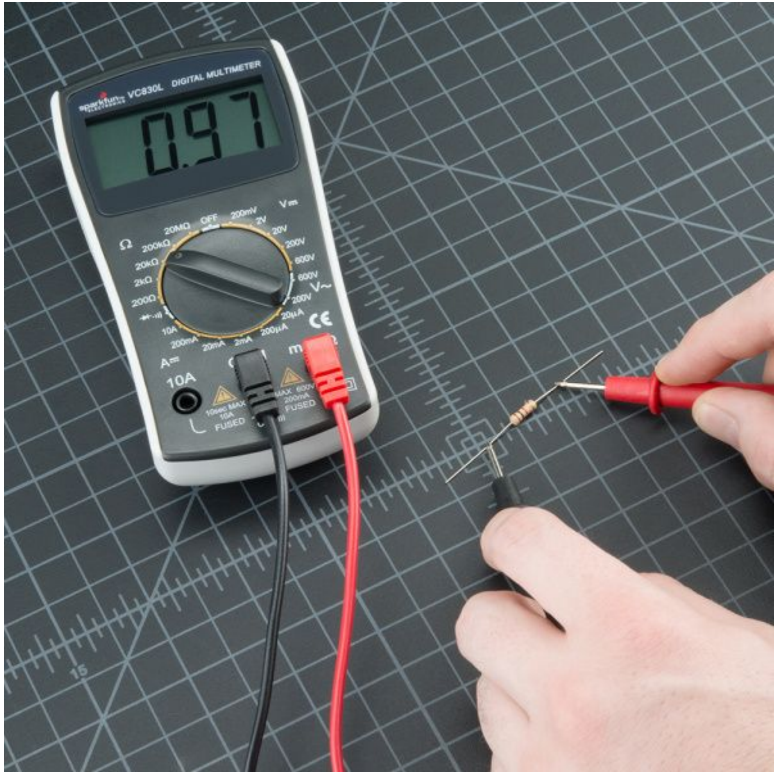
$$I_{Total} = \frac{V_A}{R_{equivalent}}$$

Multimeter

https://electricalacademia.com/instrumentation-and-measurements/digital-multimeter-working-principle/

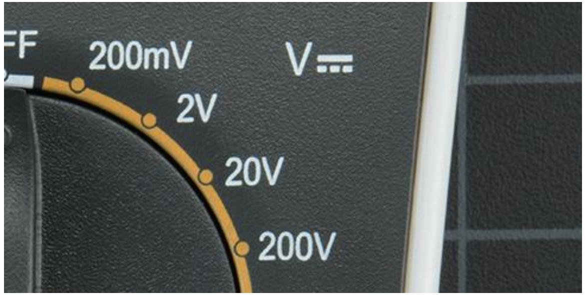
Measuring Resistance



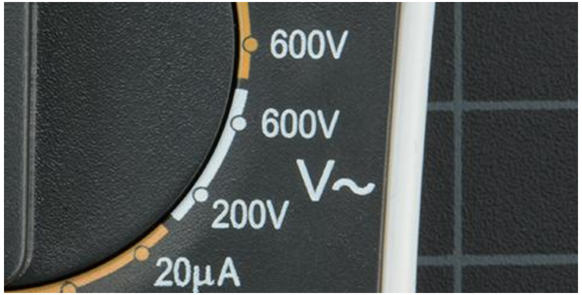


https://learn.sparkfun.com/tutorials/how-to-use-a-multimeter/all
#measuring-voltage

Measuring Voltage: in parallel

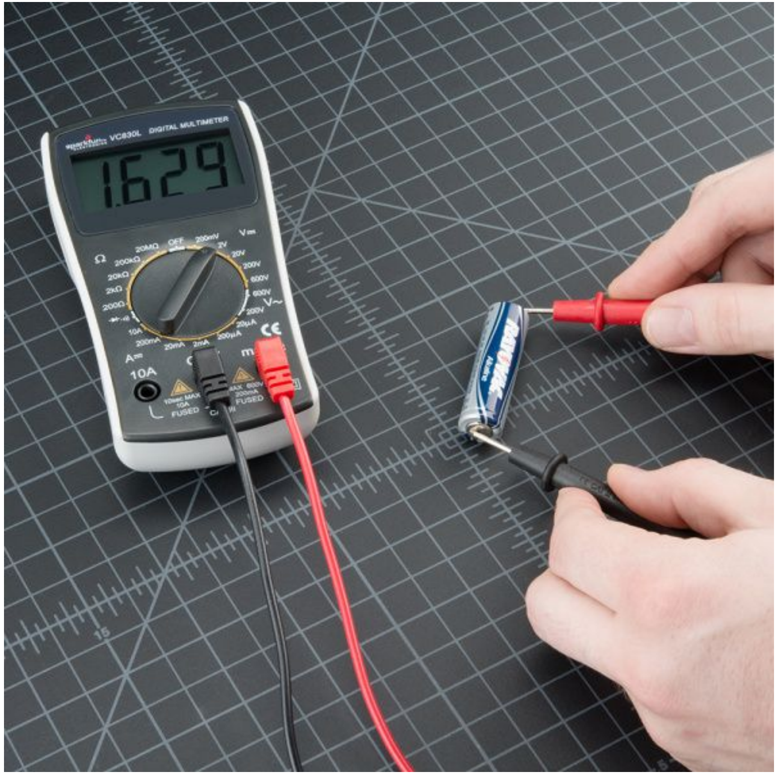


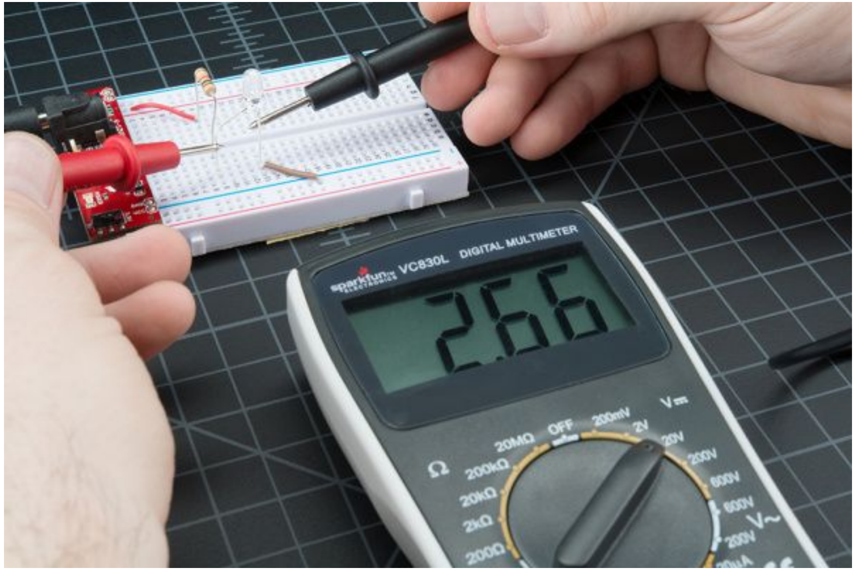
Use the V with a straight line to measure DC Voltage

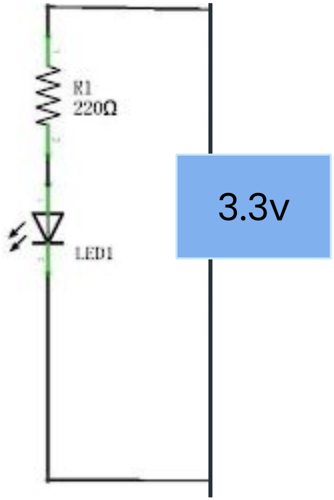


Use the V with a wavy line to measure AC Voltage

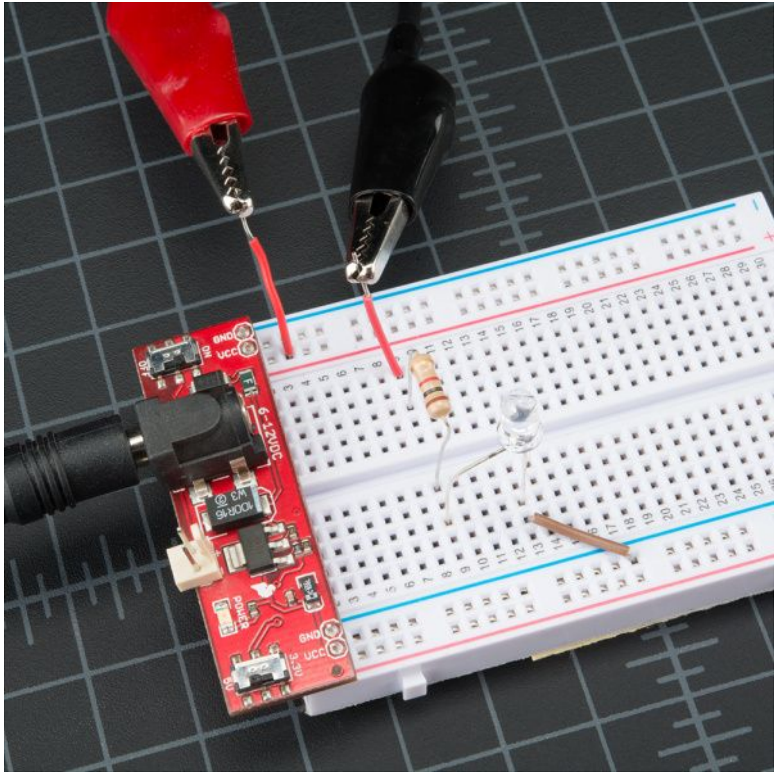
Measuring Voltage: in parallel



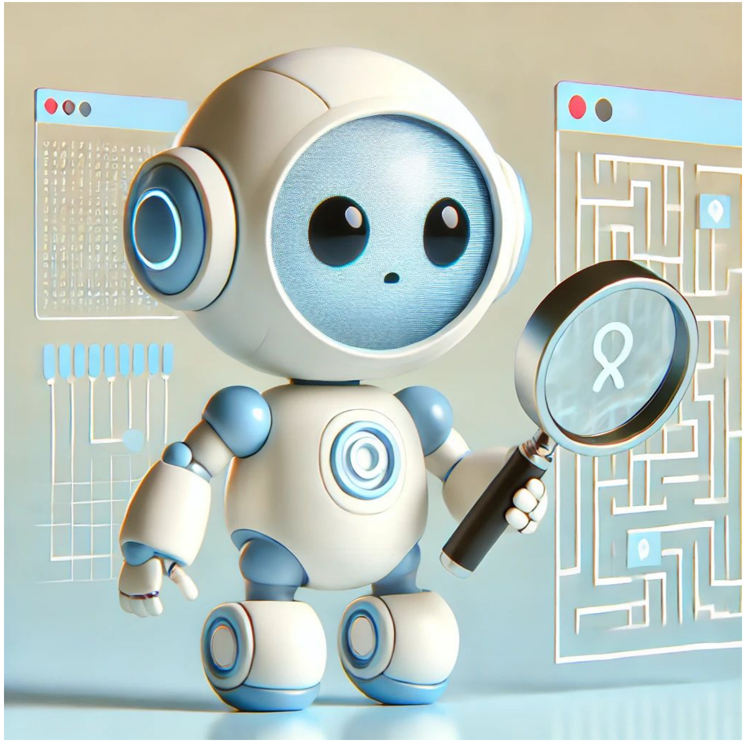



R1
220Ω
LED1
3.3v

Measuring Current: in series



Hands on Lab



MAYFLOWER
A.S.T.E.M.
ACADEMY

Blink LED – Components

- LED * 1
- Resistor 220Ω * 1
- Jumper Wires

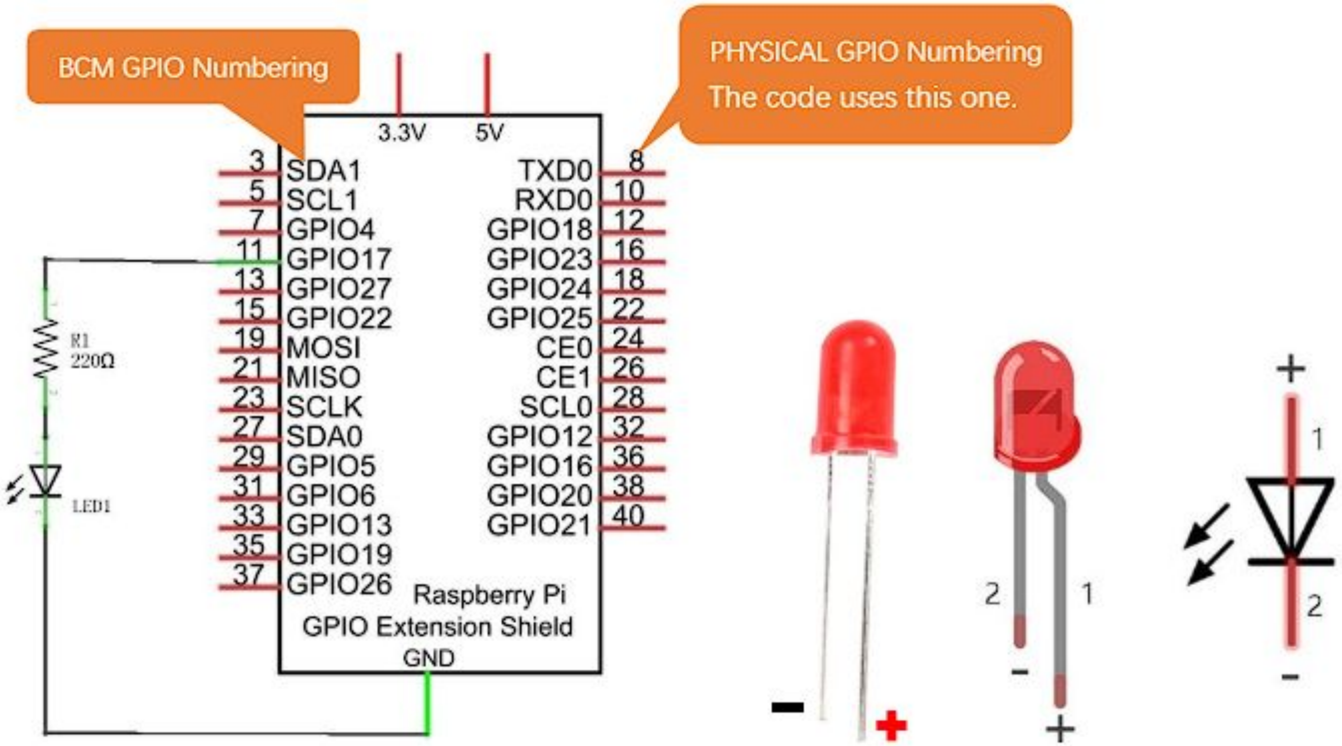
There are only three kind of resistors in this kit.

The one with 1 red ring is 10KΩ 

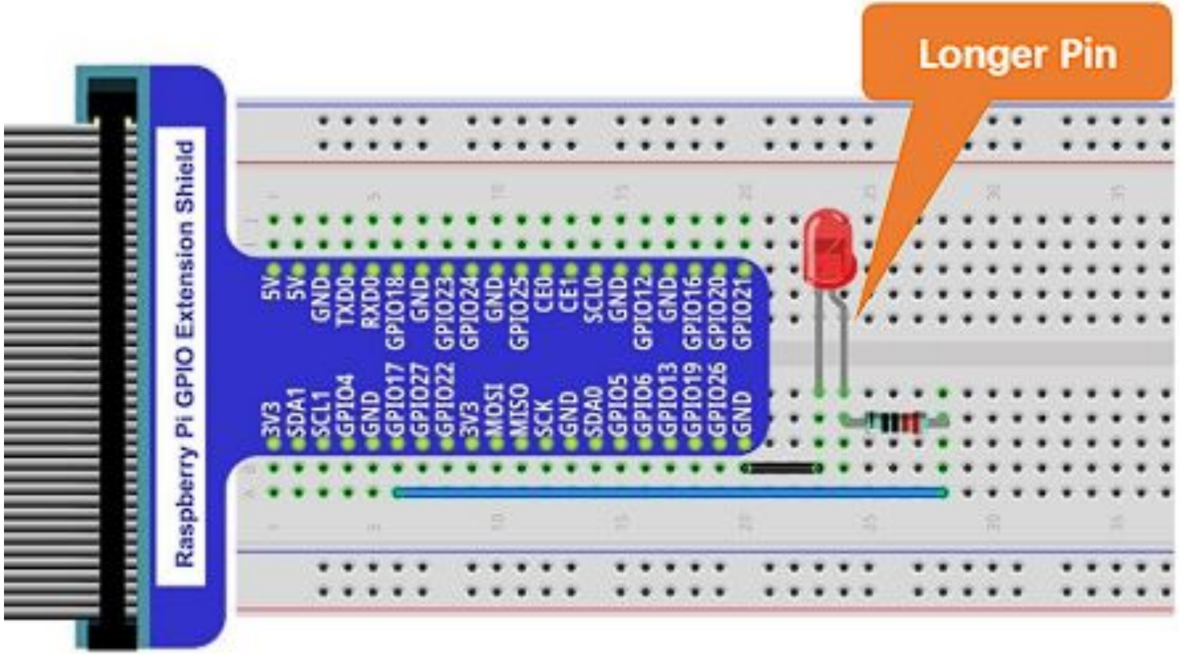
The one with 2 red rings is 220Ω 

The one with 0 red ring is 1KΩ 

Blink LED - Schematic diagram



Blink LED – Circuit



Traffic Light

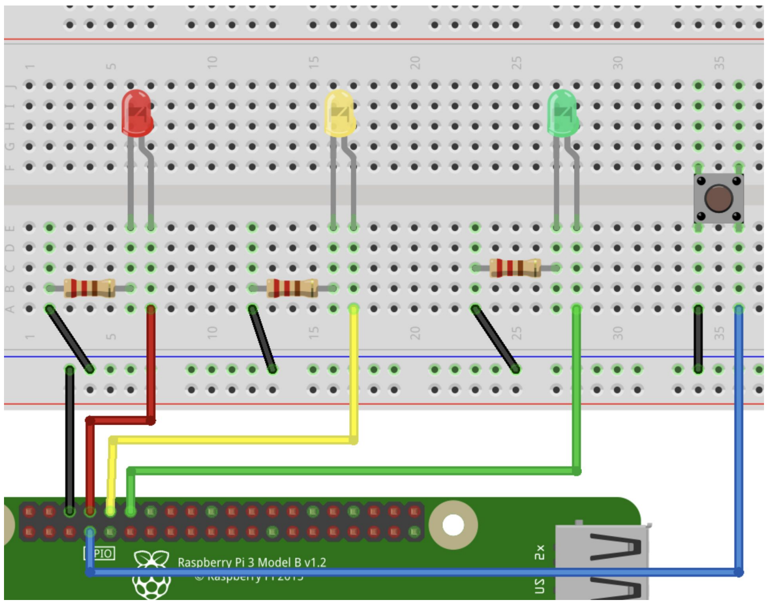
Questions for Circuit

1. What components do we use to simulate the lights in a traffic light?
2. What component can we use to limit the current passing through an LED to prevent it from burning out?
3. How should we arrange the LEDs and resistors on the breadboard?
4. How should the control code sequence the lights to mimic a real traffic light?
5. How can we improve the traffic light system?

Questions for Programming

1. What should the overall structure of the program be?
2. How can we handle the program exiting gracefully?
3. What variables do we need to declare for this program?
4. Should we define any functions in the program?
5. How can we implement the traffic light sequence in the code?
6. How can we control the timing of the lights changing?
7. How can we ensure that the cleanup code runs even if the program is interrupted?
8. How can we modify the code to include a pedestrian crossing light?

Example circuit



Example Pseudo Code

```
FUNCTION setup()
    INITIALIZE GPIO mode to BOARD
    DEFINE red_led_pin, yellow_led_pin, green_led_pin
    SET red_led_pin as OUTPUT
    SET yellow_led_pin as OUTPUT
    SET green_led_pin as OUTPUT
END FUNCTION
```

Example Pseudo Code

```
FUNCTION traffic_light()
    # Green Light Sequence
    TURN ON green_led_pin
    WAIT for 5 seconds
    TURN OFF green_led_pin

    # Yellow Light Sequence
    TURN ON yellow_led_pin
    WAIT for 2 seconds
    TURN OFF yellow_led_pin

# Red Light Sequence
    TURN ON red_led_pin
    WAIT for 7 seconds
    TURN OFF red_led_pin
END FUNCTION
```

Example Pseudo Code

```
FUNCTION loop()
    WHILE True
        CALL traffic_light()
    END WHILE
END FUNCTION
```

```
FUNCTION main()
    CALL setup()
    TRY
        CALL loop()
    EXCEPT KeyboardInterrupt
        CLEAN UP GPIO settings
    END TRY
END FUNCTION
```