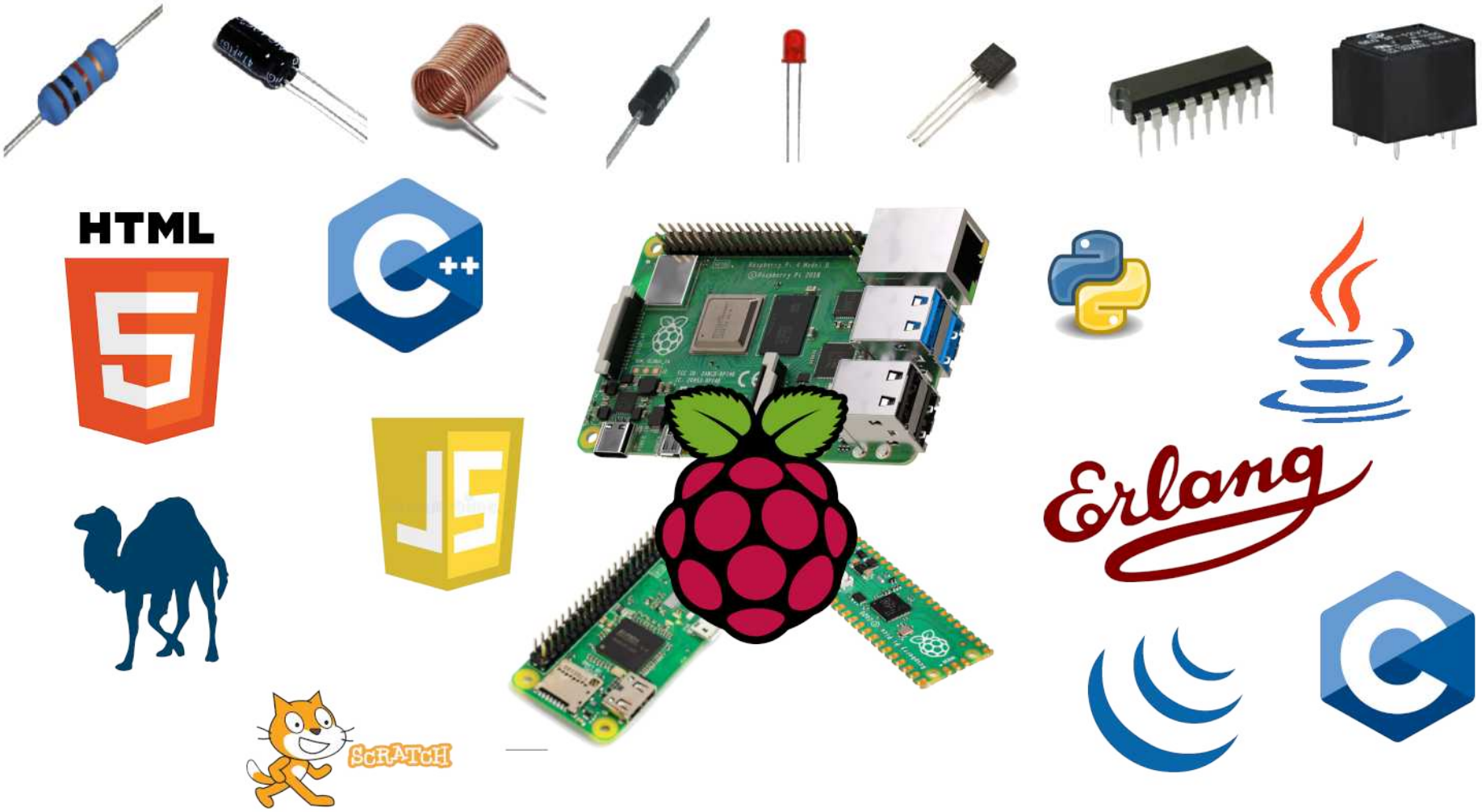
Raspberry Pi

Introduction to Raspberry Pi hardware



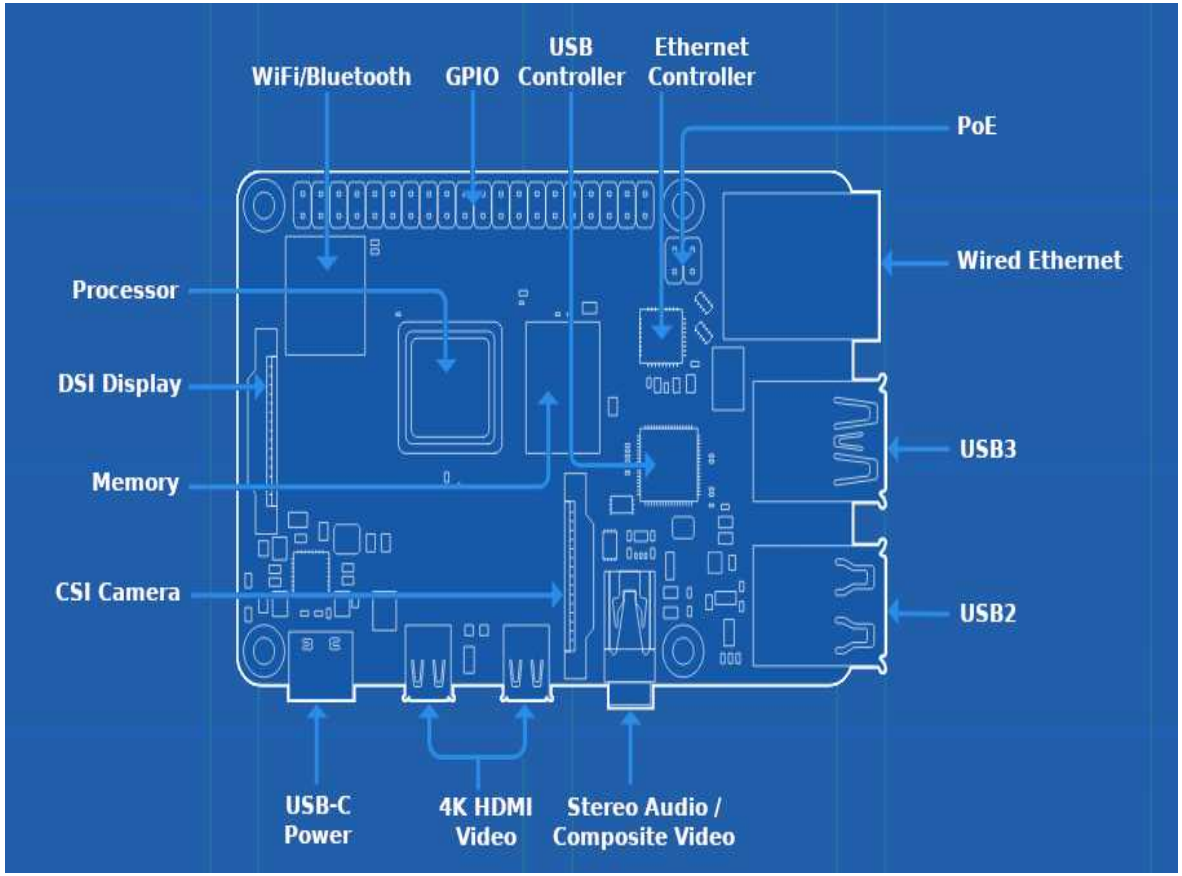
Subjects to cover

- What is a Raspberry Pi?
- What is an SBC?
- Types of Raspberry Pi
- Raspberry Pi HATs (Hardware Attached on Top)
- What is Raspberry Pi used for
- What can the Raspberry Pi do
- Inputs & Outputs (GPIO)
- Digital IO. What about Analog IO?
- Communications
- Why Raspberry Pi?
- Should I use Raspberry Pi or should I use Arduino?

What is a Raspberry Pi?

- A low cost SBC (Single Board Computer).
- The first model was developed by The Raspberry Pi Foundation in the UK and released February 2012.
- It runs various distributions of Linux. It's main supporting OS is Pi OS (formally Raspbian) and the OS is open source.
- It provides GPIO for connecting to the outside world using digital IO.
- A software and hardware development/experimentation platform that does not require an additional PC.
- It has many interface (HAT) boards, displays and sensors available from a large number of suppliers.

What is an SBC?



- A completely functional computer on a single circuit board.
- Including microprocessor, memory and IO (input/Output).
- Commonly used as demonstration and development systems for education or for use as embedded computer controllers.
- Many portable computers, such as laptops integrate all of their functions within a single circuit board, unlike desktop computers.

Main types: Raspberry Pi Zero WH

- Smallest and cheapest version of Raspberry Pi computer with WiFi and Bluetooth and GPIO headers pre soldered.
- Single core 1 GHz CPU, 512 MB memory, mini HDMI, SPI, I2C, WiFi, Bluetooth, 40 pin GPIO, camera, microSD.
- Retail ~ £14 September 2021.

Main types: Raspberry Pi 3B+

- Released 14th March 2018.
- Current workhorse for demonstration, education, experimentation and embedded computer control.
- 4 core 64bit 1.4 GHz CPU, 1 GB memory, full HDMI, SPI, I2C, 300 Mbit Ethernet, WiFi, Bluetooth, 4xUSB2, 40 pin GPIO, display, camera, analog audio and composite video out, microSD.
- Retail ~ £34 September 2021.

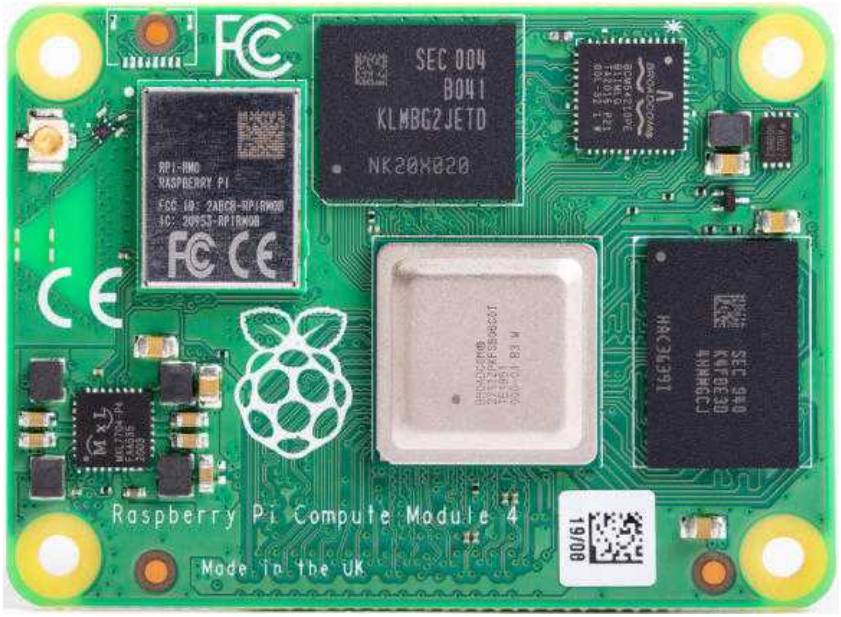
Main types:
Raspberry Pi 3 Model A+

- Released 15th November 2018.
- Smaller version of 3B+ with less memory.
- 4 core 64bit 1.4 GHz CPU, 512 GB memory, full HDMI, SPI, I2C, WiFi, Bluetooth, 1xUSB2, 40 pin GPIO, display, camera, analog audio and composite video out, microSD.
- Retail ~ £24 September 2021.

Main types: Raspberry Pi 4B

- 1, 2 and 4 GB versions released 24th June 2019. 8 GB version released 28th May 2020.
- Smaller version of 3B+ with less memory.
- 4 core 64bit 1.5 GHz CPU, 1, 2, 4 or 8 GB memory, 2x micro HDMI, SPI, I2C, Gigabit Ethernet, WiFi, Bluetooth, 2xUSB3, 2x USB2, 40 pin GPIO, display, camera, analog audio and composite video out, microSD.
- Retail ~ £54 for 1, 2 and 4 GB, £74 for 8 GB as of September 2021.

Main types:
RPi Compute Module 4



- Released 29th October 2020.
- Connection-less model for integration in embedded systems.
- 4 core 64bit 1.5 GHz CPU, 1, 2, 4 or 8 GB memory, SPI, I2C, optional WiFi/Bluetooth, 1x USB2, 26 pin GPIO, dual display, 1x PCIe Gen2, microSD.
- Retail ~ £30 as of September 2021.

Main types: Raspberry Pi 400

- Released 2nd November 2020.
- Raspberry Pi 4 integrated within a keyboard with improved CPU clock speed and all ports accessible.
- 4 core 64bit 1.8 GHz CPU, 4 GB memory, 2x micro HDMI, SPI, I2C, Gigabit Ethernet, WiFi, Bluetooth, 2xUSB3, 1x USB2, 40 pin GPIO, microSD.
- Retail ~ £67 as of September 2021.

Main types: Raspberry Pi Pico

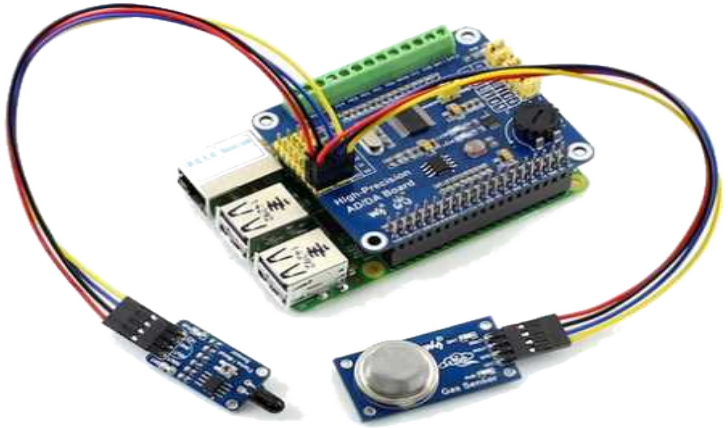
- Released 21st January 2021.
- Not a computer but a micro-controller similar to an Arduino Nano.
- 2 core 133 MHz CPU, 264 KB memory, micro USB, 2x SPI, I2C, 26 pin GPIO.
- Retail ~ £3.60 headerless and £6 with pre soldered headers, as of September 2021.

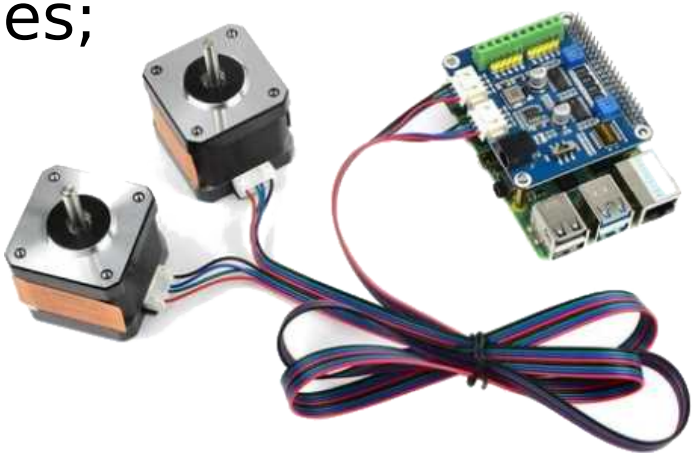
Comparison (excluding Pico)

	Rpi 400	Rpi Compute Module 4	Rpi 4B 8GB	Rpi 4B 1,2,4GB	Rpi 3 Model A+	Rpi 3B+	Rpi Zero WH
Released	02/11/20	19/10/20	28/05/20	24/06/19	15/11/18	14/03/18	12/01/18
Price	£67.00	£30.00	£74.00	£54.00	£24.00	£34.00	£14.00
SOC Type	BCM2711	BCM2711	BCM2711	BCM2711	BCM2837B0	BCM2837B0	BCM2835
Core Type	Cortex-A72 64bit	Cortex-A72 64bit	Cortex-A72 64bit	Cortex-A72 64bit	Cortex-A53 64bit	Cortex-A53 64bit	ARM1176JZF-S
Cores	4	4	4	4	4	4	1
GPU	VideoCore VI	VideoCore VI	VideoCore VI	VideoCore VI	VideoCore VI	VideoCore VI	VideoCore VI
CPU Clock	1.8 GHz	1.5 GHz	1.5 GHz	1.5 GHz	1.4 GHz	1.4 GHz	1 GHz
Memory	4 GB DDR4	1,2,4,8 GB DDR4	8GB DDR4	1,2,4,8 GB DDR4	512 MB DDR2	1 GB DDR2	512 MB
USB	2xUSB3,1xUSB2		2xUSB3,2xUSB2	2xUSB3,2xUSB2	1xUSB2	4xUSB2	1xmicroOTG
Ethernet	Gigabit		Gigabit	Gigabit		Gigabit over USB	
HDMI port	2xmicroHDMI		2xmicroHDMI	2xmicroHDMI	Full HDMI	Full HDMI	miniHDMI
Analog Video out			available	available	available	available	via unpopulated pin
Analog Audio out			3.5mm jack	3.5mm jack	3.5mm jack	3.5mm jack	HDMI audio
SPI	available	available	available	available	available	available	available
I2C	available	available	available	available	available	available	available
GPIO	40 pins	40 pins	40 pins	40 pins	40 pins	40 pins	40 pins
Camera			available	available	available	available	available
SD/MMC	microSD		microSD	microSD	microSD	microSD	microSD
WiFi	2.4 GHz, 5 GHz 802.11 b/g/n/ac	2.4 GHz, 5 GHz 802.11 b/g/n/ac	2.4 GHz, 5 GHz 802.11 b/g/n/ac	2.4 GHz, 5 GHz 802.11 b/g/n/ac	2.4 GHz, 5 GHz 802.11 b/g/n/ac	2.4 GHz, 5 GHz 802.11 b/g/n/ac	802.11n
Bluetooth	5	5	5	5	4.2 BLE	4.2 BLE	4.1 BLE

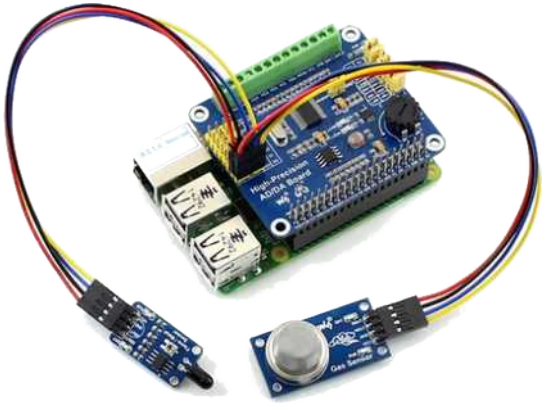
Raspberry Pi HATs (Hardware Attached on Top)

- HATs plug into the Raspberry Pi and provide:
  - Additional functionality;
    - Analog Inputs
    - Additional USB ports
    - Real time clock
    - Power over ethernet (PoE)
  - Connection to real world devices;
    - Motors
    - Servos
    - Stepper motors
    - High current outputs

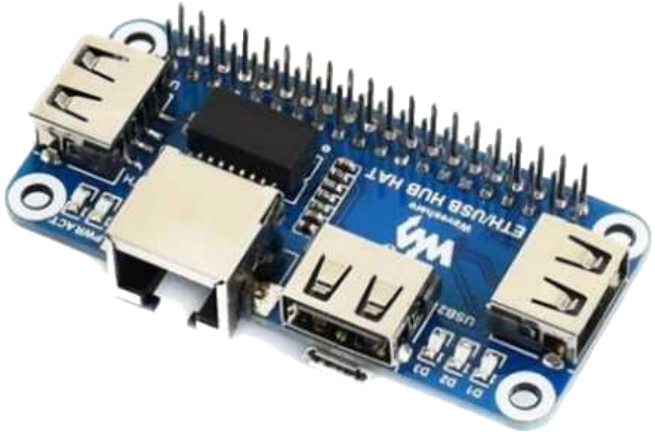




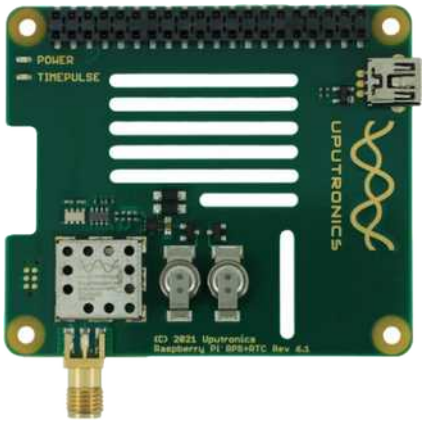
Raspberry Pi HAT examples



8x 24bit 30 ksps + 2x 16bit ADC



3x USB2.0 + 1x 10/100 Mbps Ethernet



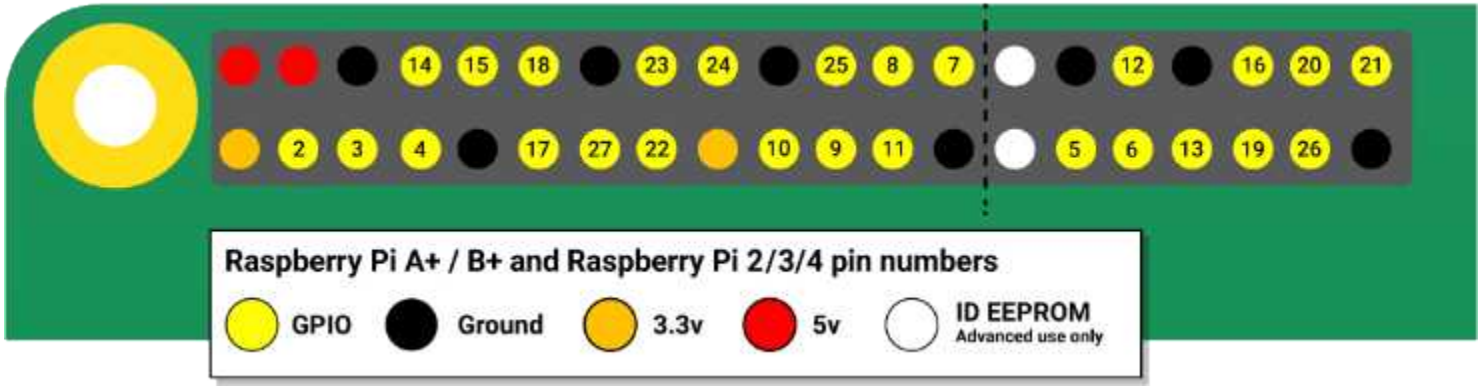
multi GNSS GPS receiver and hardware RTC

5V @ 4A PoE (Power over Ethernet)

Raspberry Pi, what can they do?

- Digital inputs:
  - Read pushbuttons
  - Read logic level sensors
- Digital and Analogue (PWM) outputs:
  - LEDs
  - Motors
  - Servos
  - Stepper motors
  - High current outputs

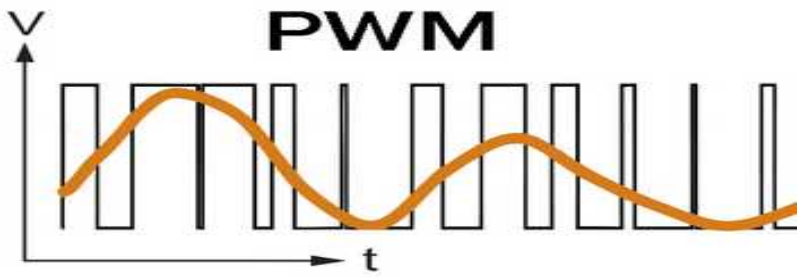
Raspberry Pi
GPIO (General Purpose Input / Output)



- 2x 5V
- 2x 3.3V
- 8x GND
- 26x software programmable digial input of output (max current 16mA)
- 2x ID EEPROM pins for advanced use only

Analog IO

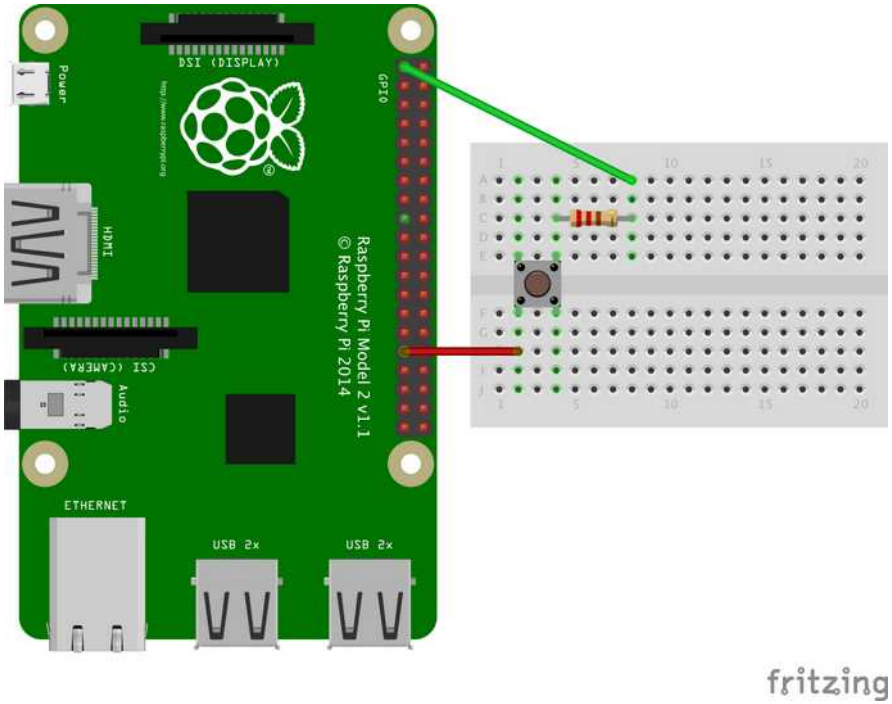
- Analogue input:
  - Use an appropriate HAT
  - Use an appropriate IC, such as the MCP3008 ADC
- Analogue output:
  - Use an appropriate IC, such as the MCP4725
  - Use PWM (Pulse Width Modulation) where a duty cycle is used to simulate an analog voltage level



Digital IO

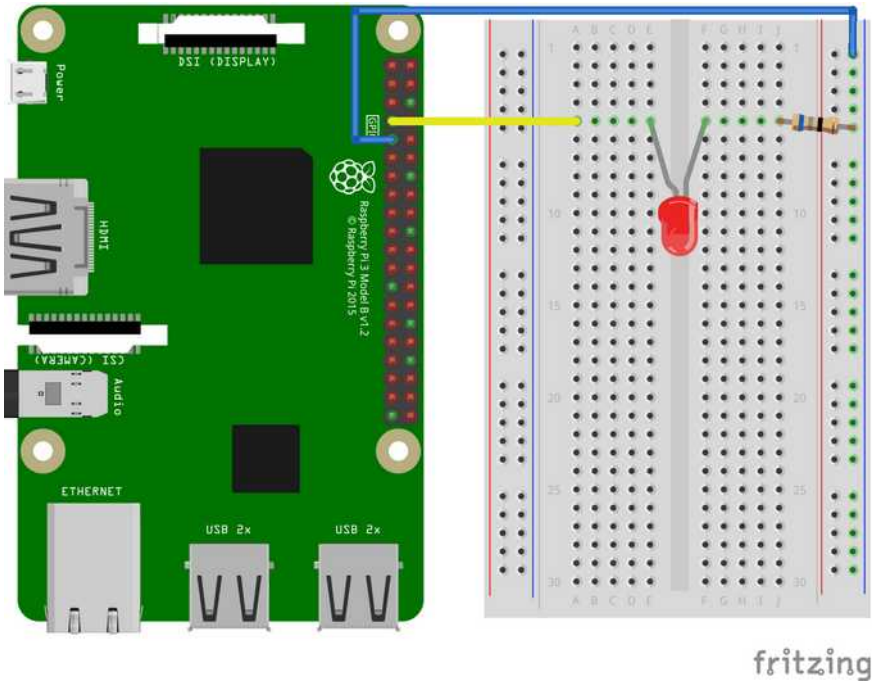
- Digital input:
  - 26 of the 40 GPIO pins can be configured as input
  - When a GPIO pin is configured as input it can receive either a HI or LO signal
  - The input signal must be 3.3V or lower
- Digital output:
  - As above the same 26 GPIO pins can be configured as output
  - When a GPIO pin is configured as output it produces either a HI or LO signal
  - A LO signal will be near GND
  - A HI signal will be near 3.3V but no higher

Digital Input: simple push button



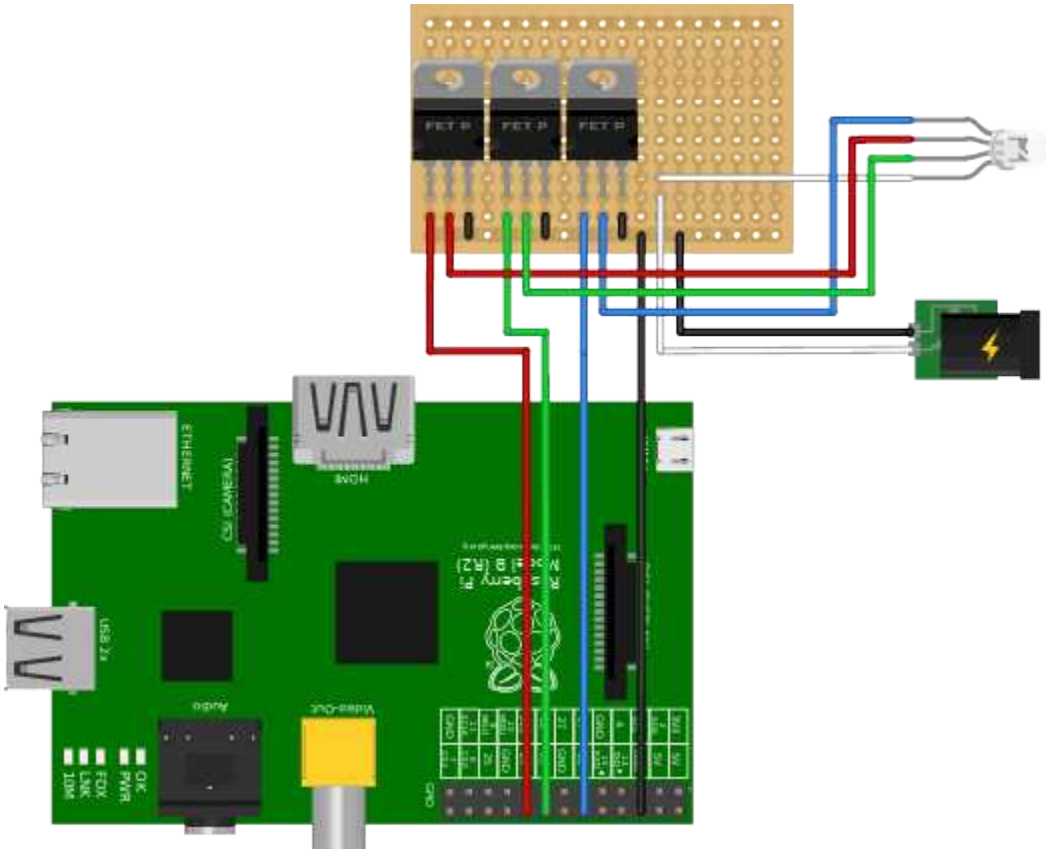
- Current limiting resistor is the only requirement.
- If pull up/down is required, this can be requested in software and a 50k internal resistor will be internally connected between the GPIO pin and 3.3V or GND respectively.

Digital Output: LEDs

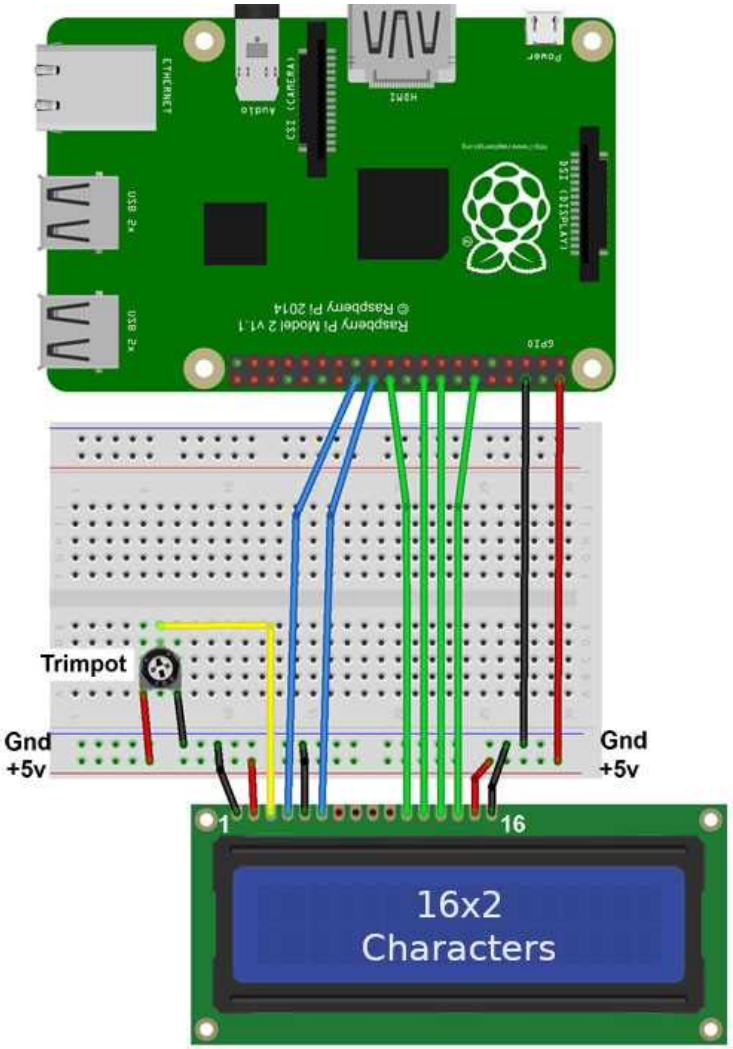


- Current limiting resistor is the only requirement.

Analog Output:
Using PWM from digital pins to drive an RGB LED



LCD Display IO



Communications methods

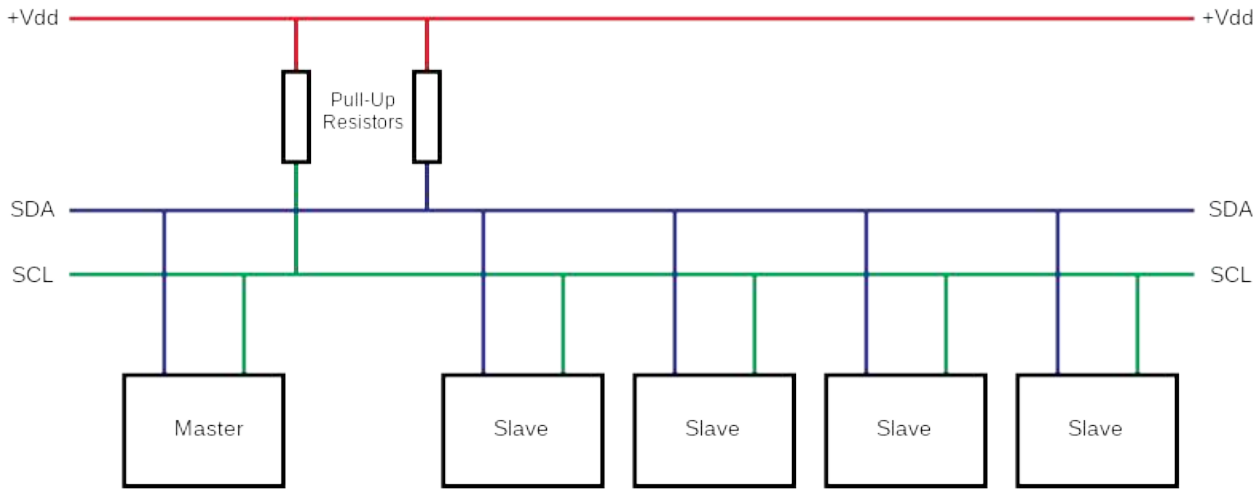
- Universal Asynchronous Receiver/Transmitter (UART)
  - Serial communications, to PC.
- Serial Peripheral Interface (SPI)
  - A master – slave model where there is a single master and multiple slave devices
- Inter-Integrated Circuit (I^2C)
  - Multiple master and multiple slave devices.
  - Used extensively to connect displays, sensors etc to Raspberry Pi.

Specific GPIO pins used for the various communications methods

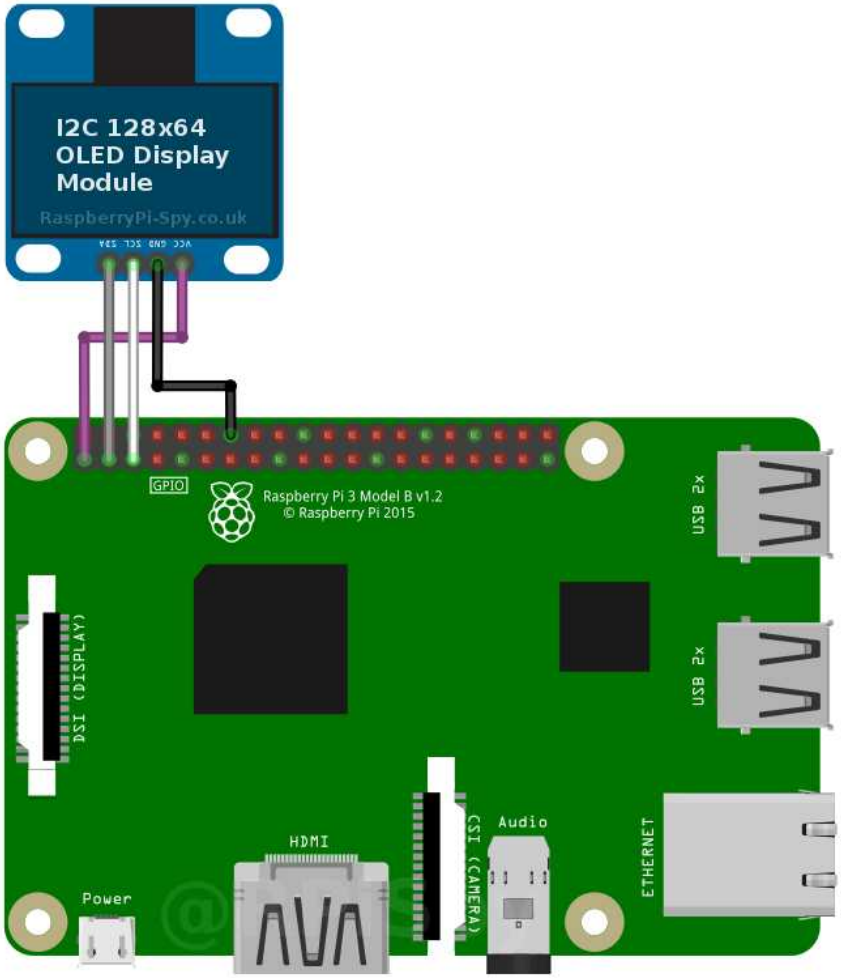
- GPIO pins 14 and 15 are used by UART.
- GPIO pins 2 and 3 are used for I2C.
- GPIO pins 9, 10 and 11 are used by SPI.
- GPIO pins 7 and 8 can also be used for SPI chip select but usually so can any GPIO pin.
- If these communications methods are not required then these pins can be used as general GPIO pins.

I²C communications

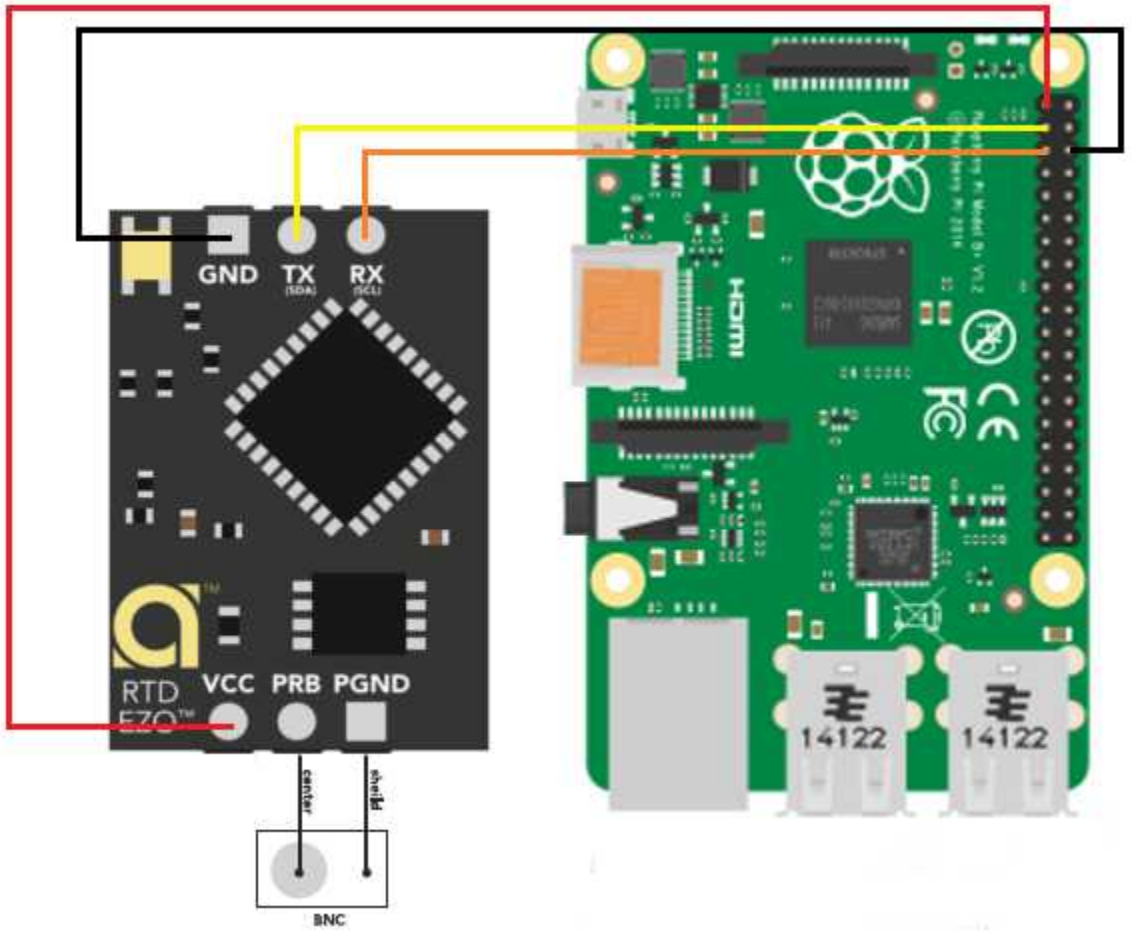
- Inter-Integrated Circuit (I²C)
  - Multiple master and multiple slave devices.
  - Used extensively to connect displays, sensors etc to Raspberry Pi.



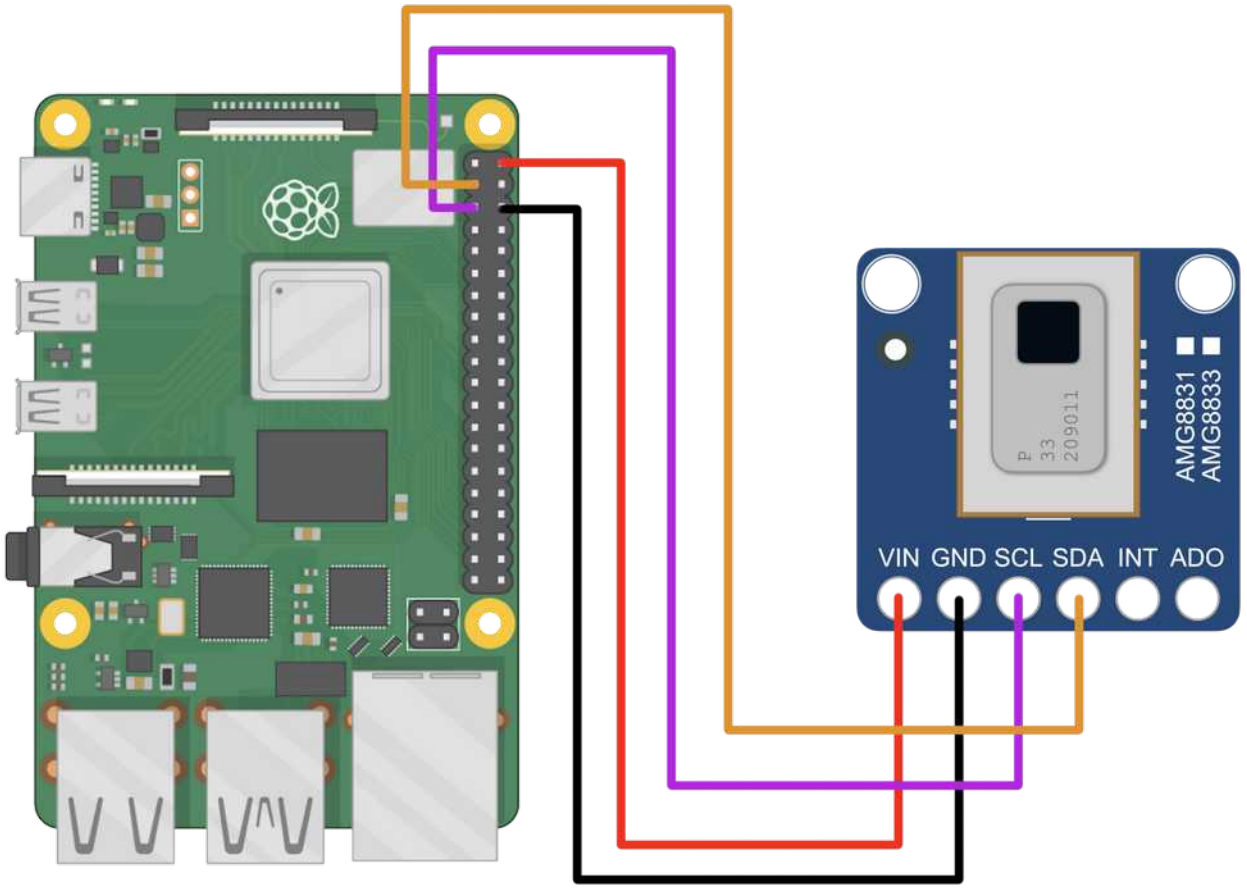
OLED Display: I²C example



Temperature sensor: I²C example



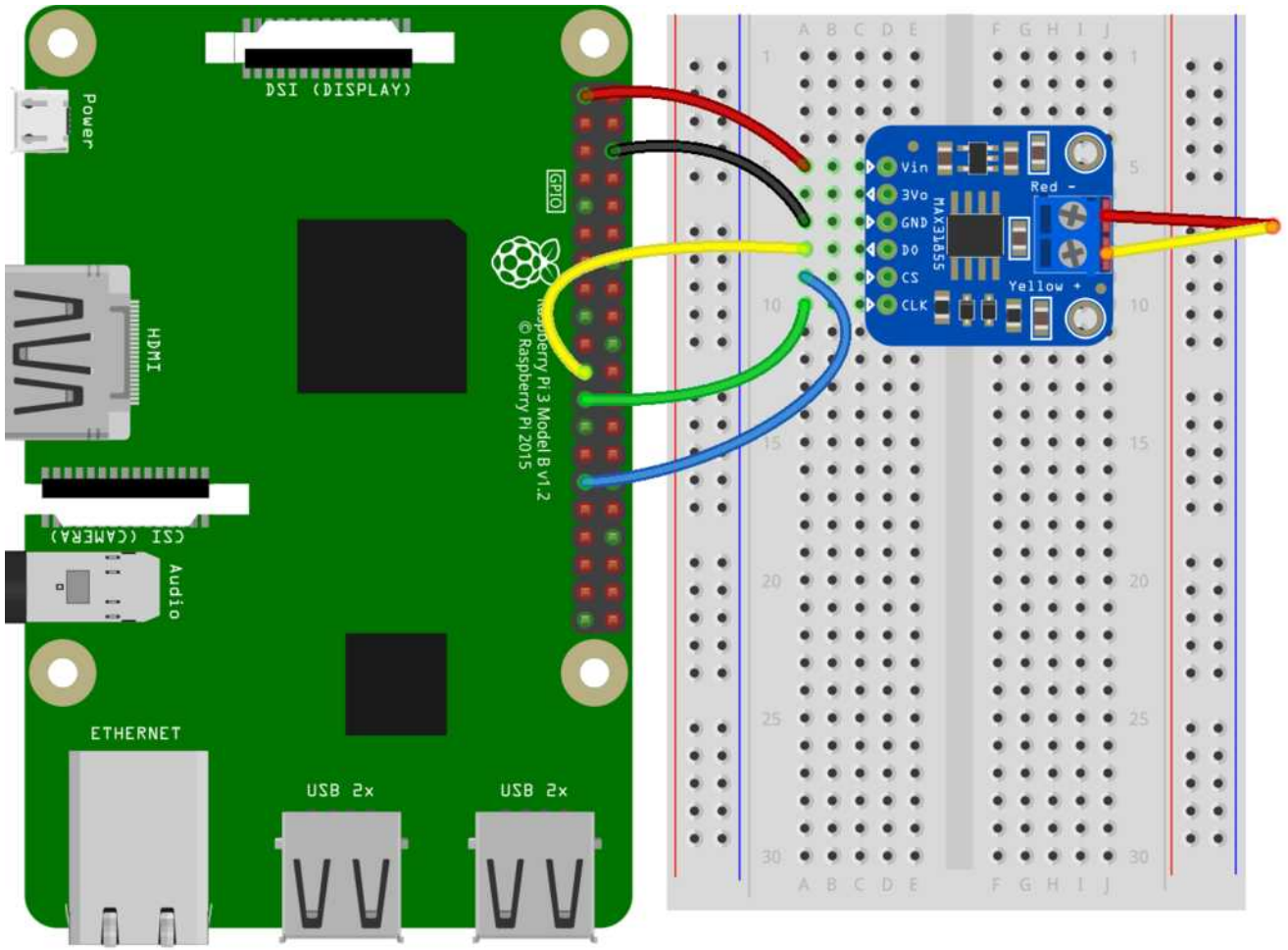
GPS sensor: I²C example



Raspberry Pi 4 Model B

AMG8833 Infrared Array

Thermocouple sensor: SPI example



So, why Raspberry Pi?

- The Raspberry Pi operates in the open source ecosystem: it runs Linux (a variety of distributions), and its main supported operating system, Pi OS, is open source and runs a suite of open source software.
- The Raspberry Pi's schematics are regularly released as documentation, but the board is not open hardware.
- The Raspberry Pi is a computer that can interact with the Internet and/or local network devices as well as interface to the outside world with it’s integrated GPIO.
- Development and experimentation can be performed directly using the Raspberry Pi without the need for an additional computer.
- The Raspberry Pi can work with digital signals and analog with appropriate HAT or ADC IC.
- The Raspberry Pi Foundation provides extensive documentation and the community is extremely active.
- Programming the Raspberry Pi to interact with GPIO devices is easy using the Python programming language – possibly the subject of a future talk!

Should I use Raspberry Pi or should I use Arduino?

- Not competing platforms.
- Both designed to be easy to use teaching tools. Raspberry Pi developed by Upton in the UK, Arduino developed by Banzi in Italy.
- Raspberry Pi out performs any micro-controller in terms of computing ability.
- Arduino’s simplicity makes it much better suited to pure hardware projects.
- Due to it’s simplicity the Arduino is much hard to break, damage or “go wrong” than the Raspberry Pi when it comes to running hobby projects.
- There is no definitive answer to the above question: use both projects based on your own knowledge and understanding and suitability to individual projects.
- Demonstrations and workshops to follow to improve understanding and knowledge of any interested members.