Raspberry Pi 4 Model B

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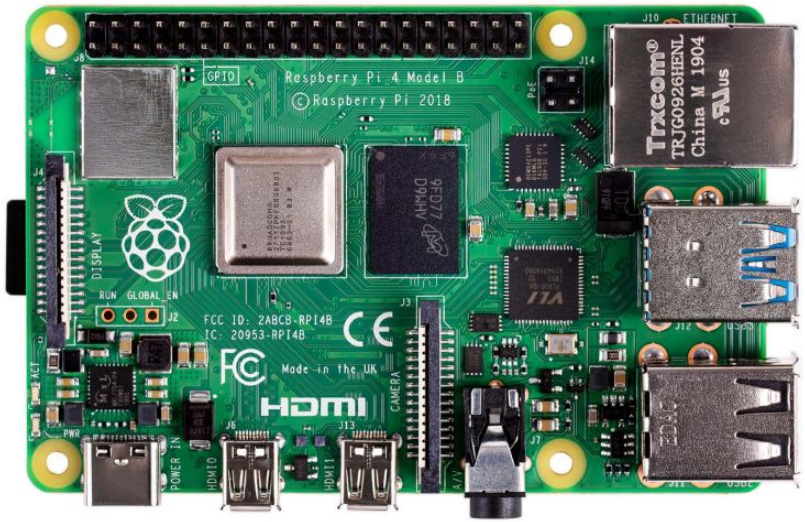
What is Raspberry Pi 4 Model B

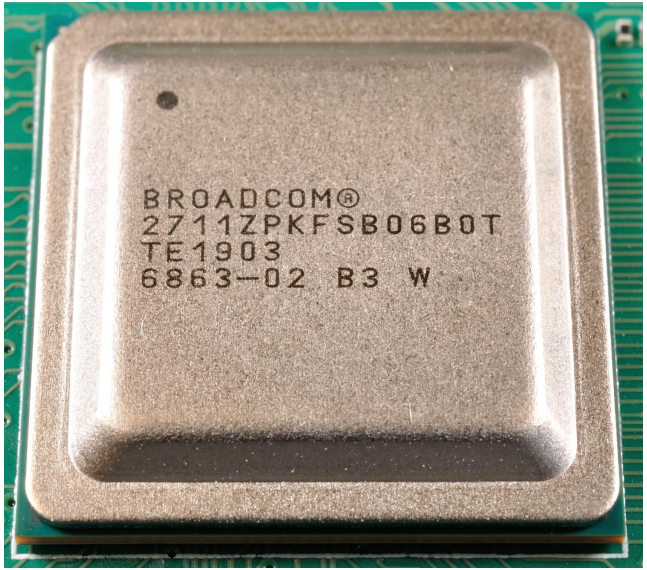
- Raspberry Pi is the name of a series of single board computers. They provide access to the on-chip hardware i.e. GPIOs (general purpose I/O) for developing an applications.

- Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers.
- It offers groundbreaking increases in processor speed, multimedia performance, memory, and connectivity compared to prior-generations.

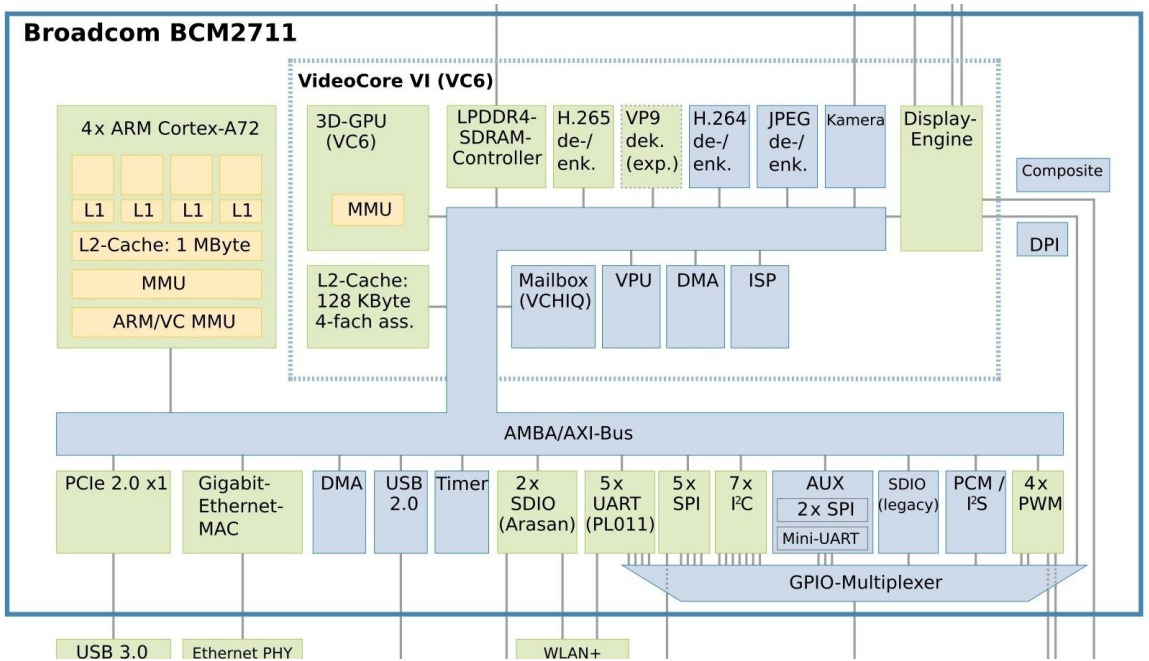


BroadCom 2711

- Chip used in the Raspberry Pi 4 Model B
  - **CPU:** Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5 GHz
  - **GPU:** VideoCore IV 32-bit SoC @ 0.5 GHz
  - Uses heat spreading technology that allows for better thermal management



Broadcom 2711

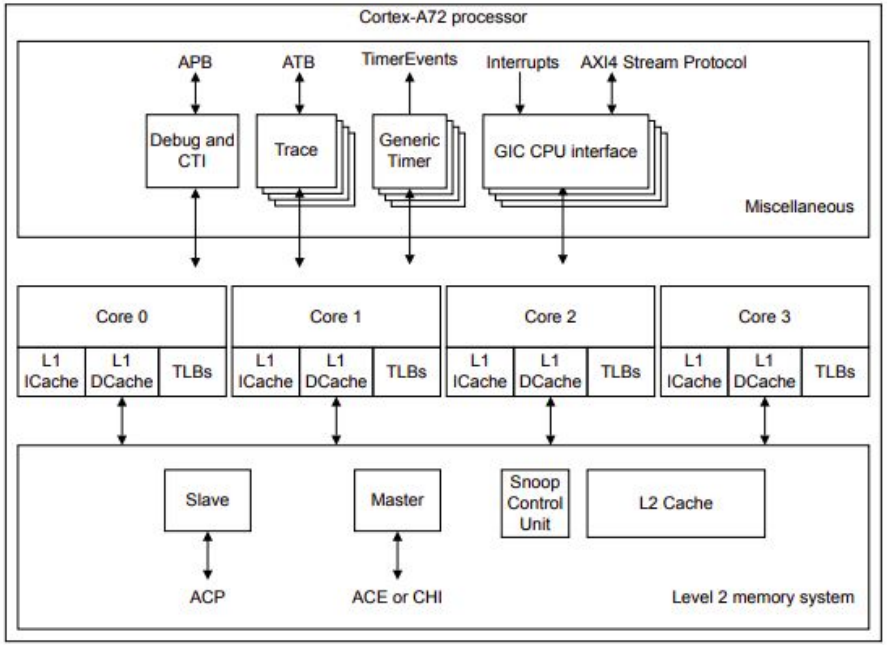


ARM Cortex-A72 Processor

- The Cortex-A72 processor is a high-performance, low-power processor that implements the ARMv8-A architecture.
- It has one to four cores in a single processor device with L1 and L2 cache subsystems.
- Superscalar, variable-length, out-of-order pipeline
- ARMv8 Architecture
  - Supports A32, A64 and T32 instruction sets
  - Supports execution states AArch32 and AArch64

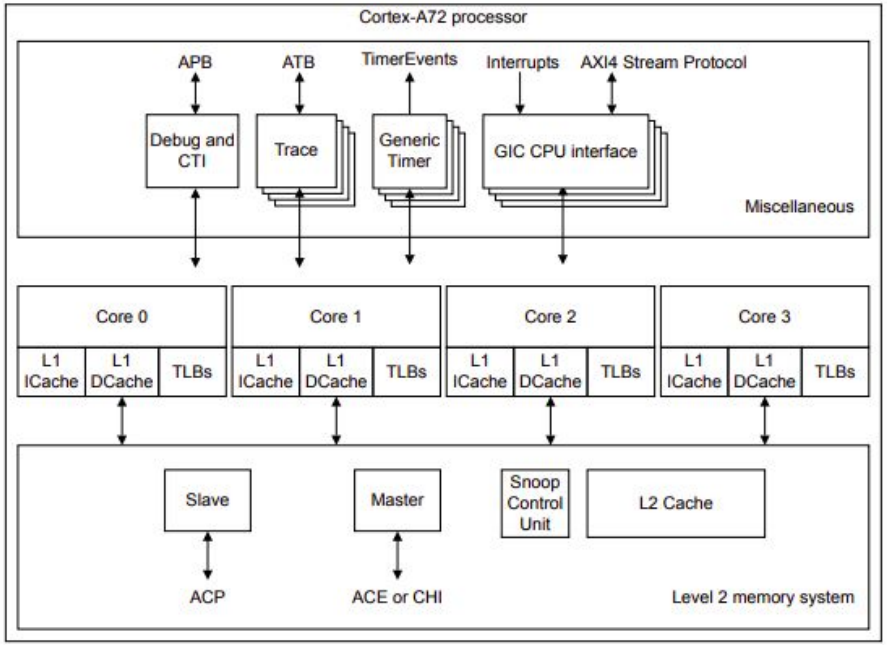
ARM Cortex-A72 Processor

- It supports dynamic and static branch prediction.
- Performs register renaming to facilitate out-of-order execution
- Contains units for
  - Instruction fetch
  - Instruction decode
  - Instruction dispatch
  - Execution of integer operations



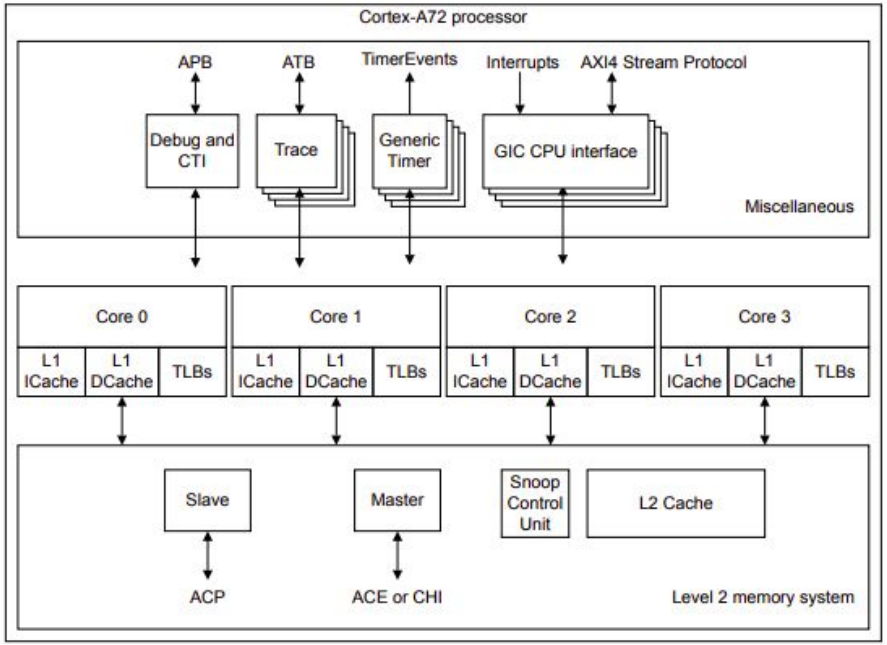
ARM Cortex-A72 Processor

- Instruction Fetch fetches instructions from L1 instruction cache and delivers up to three instructions per cycle to the instruction decode unit
- The instruction dispatch unit controls when the decoded instructions are dispatched to the execution pipelines
- Integer execution unit
  - Two pipelined ALUs
  - Multiply pipelined ALU
  - Iteractive integer divide hardware
  - Result forwarding and comparator logic



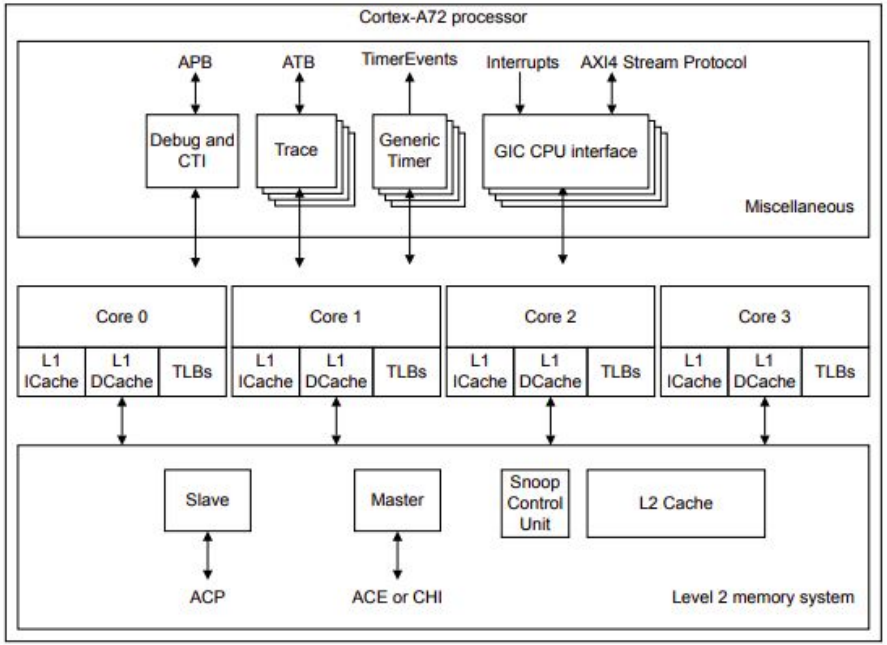
ARM Cortex-A72 Processor

- Load/Store Unit contains
  - L1 data cache that is a 32KB 2-way set-associative cache
  - 32-entry fully-associative L1 data TLB with native support for 4KB, 64KB, and 1MB page sizes
  - Automatic hardware prefetcher that generates prefetches targeting the L1 Data cache and the L2 cache



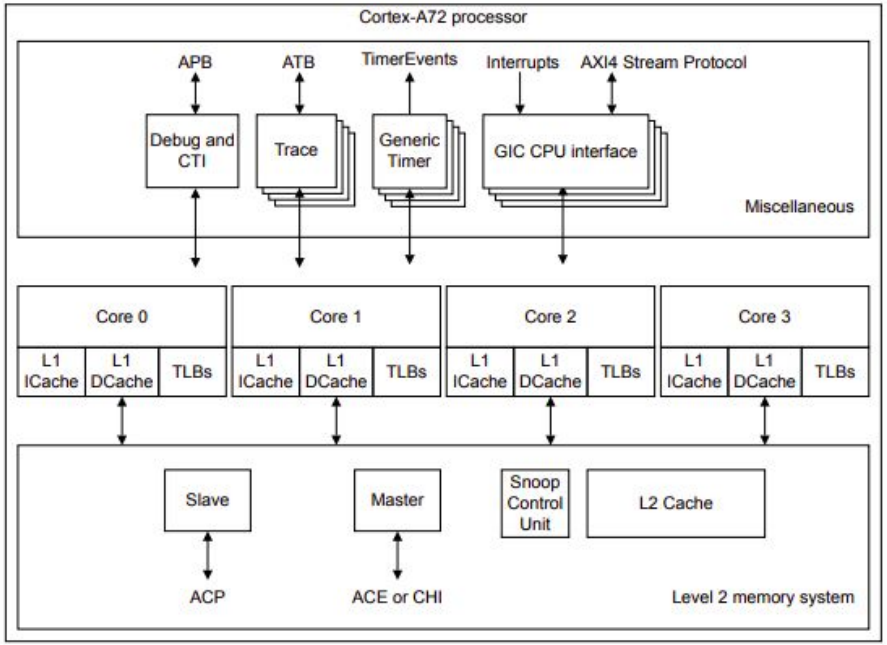
ARM Cortex-A72 Processor

- L1 memory system
  - Instruction cache 48KB 3-way set-associative
  - Data cache 32KB 2-way set-associative
  - Both with LRU replacement policy
  - Hardware prefetcher that generates prefetches targeting both the data and the instruction caches



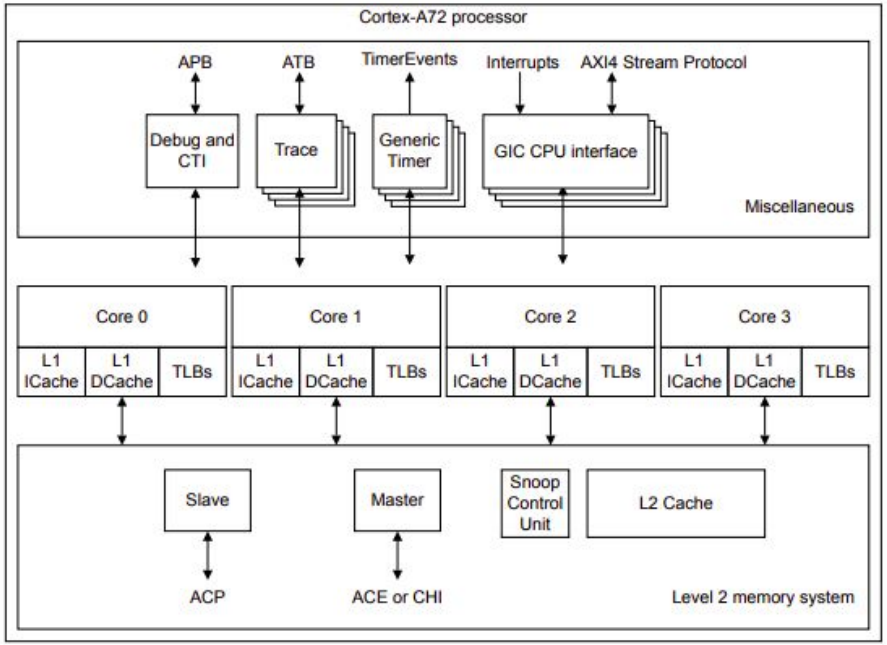
ARM Cortex-A72 Processor

- L2 memory system services L1 instruction and data cache misses from each processor
  - L2 cache 512KB, 1MB, 2MB, or 4MB
  - 16-way set-associative cache
  - Duplicate copy of L1 data cache Tag RAMs from each processor
  - Automatic hardware prefetcher with programmable instruction fetch distance
  - Supports Error Correction Code



ARM Cortex-A72 Processor

- The **Generic Timer** provides the ability to schedule events and trigger interrupts.
- **Generic Interrupt Controller (GIC)** CPU interface for supporting and managing interrupts.
- **Advanced SIMD and Floating-point unit** provides support for the ARMv8 Advanced SIMD and Floating-point execution

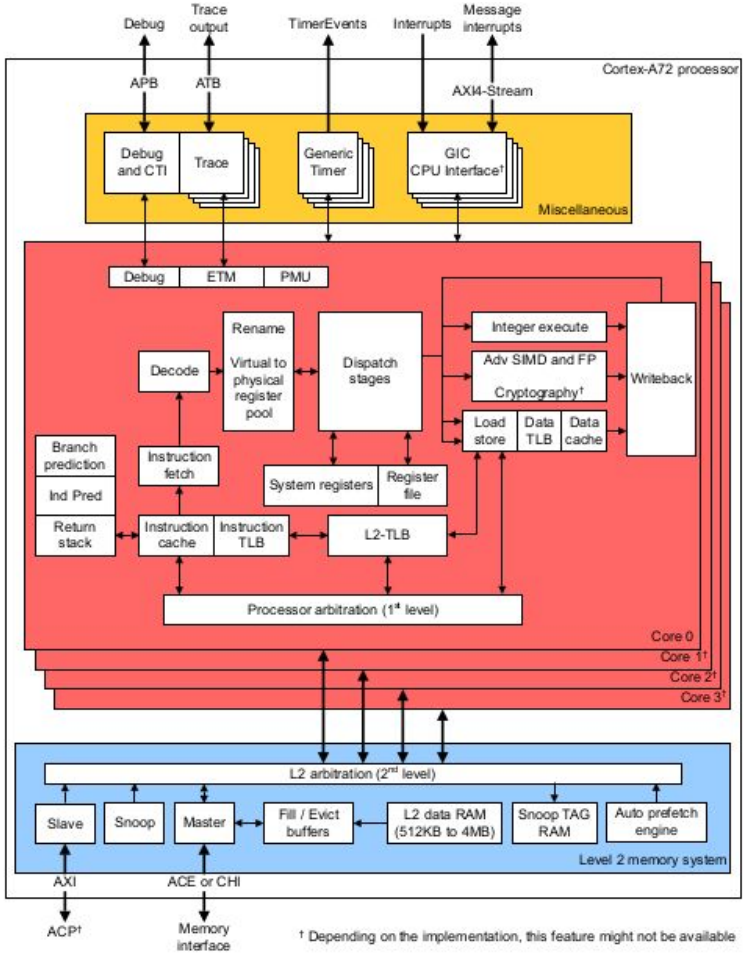


ARM Cortex-A72 Processor

- The processor includes logic to gather various statistics on the operation of the processor and memory system during runtime
  - **PMU Performance Monitor Unit**
  - The PMU six counters to count any of the events available in the processor.
- The **ETM (Embedded Trace Macrocell)** is a module that performs real-time instruction flow tracing based on the ARM specifications
- The Cortex-A72 has a single external cross trigger channel interface (**CTI**)
  - Enables the debug logic, ETM, and PMU, to interact with each other and with other CoreSight components
  - We can configure the CTI to generate an interrupt when the ETM trigger event occurs.

ARM Cortex-A72 Processor

- There is also the possibility for an additional cryptography engine that's not included in the A72 Processor
- However FP and Advanced SIMD units provide support for the cryptographic operations of the engine



VideoCore IV 3D

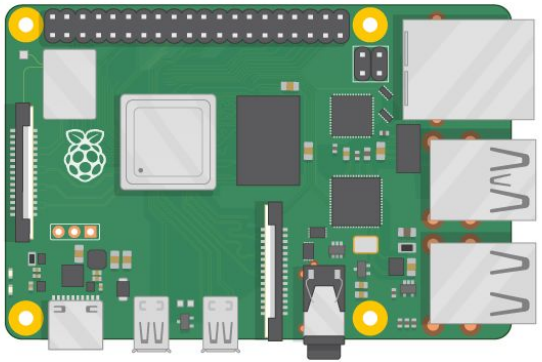
- VideoCore IV 3D is a low-power mobile multimedia graphics processor
- Its architecture makes it flexible and efficient enough to decode (as well as encode) a number of multimedia codecs in software while maintaining low power usage.
- Architecture is scalable, based around multiple specialist floating-point shading processors called QPUs (16-way SIMD processors)
- The hardware is self-contained and highly automated, requiring little processing bandwidth or real-time intervention from software drivers

BCM2711 Peripherals

- Timers - 4 32-bit timer channels and a single 64-bit free running counter
- Interrupt controller
- GPIO - 58 GPIO lines split into 3 banks. All pins have at least 2 functions
- USB
- PCM / I2S - APB providing improvements in audio streams
- DMA controller
- I2C masters
- SPI masters - 2 SPI masters (SPI1 & SPI2)
- PWM
- 6x UART - mini UART and five PL011 UART

Memory

- 1GB, 2GB or 4GB LPDDR4
  - Synchronous DRAM
  - Low power consumption
  - Targeted for mobile computers and devices such as mobile phones
  - Offers greater data transfer rates than previous versions
  - On-chip temperature sensor to control self-refresh rate
  - Volatile
- Support for SD Card
  - There is no internal storage in Raspberry Pi
  - Micro SD card slot for loading operating system and data storage



Connectivity

- 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless
- Bluetooth 5.0, BLE
- Gigabit Ethernet
- 2 × USB 3.0 ports
  - Faster than USB 2.0
  - Power consumption of 900 mA
- 2 × USB 2.0 ports
  - Power consumption of 500 mA
  - Less expensive than USB 3.0

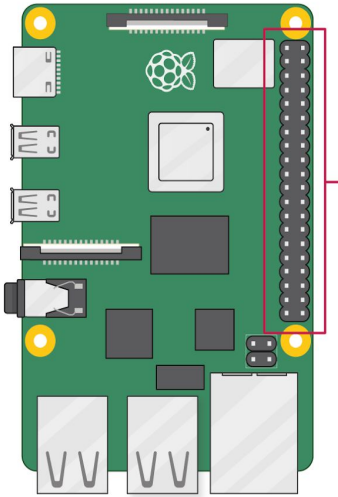
GPIO

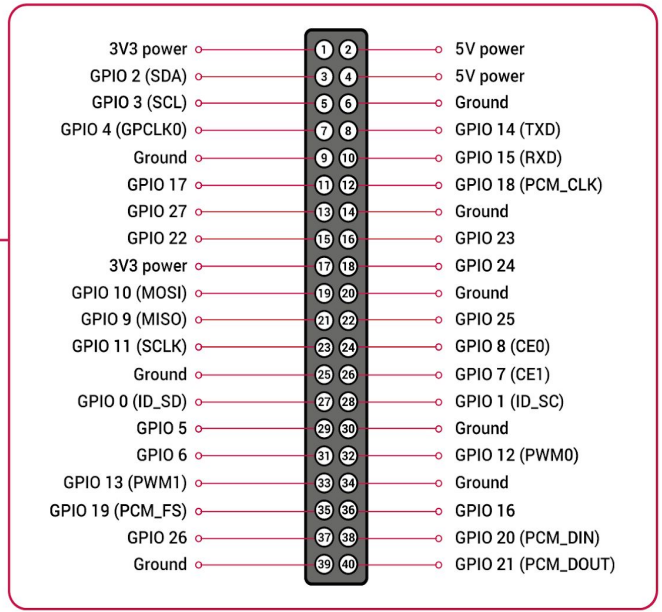
40 Pin GPIO Header

- GND pins are unconfigurable

Supports:

- PWM
- SPI
- I2C
- PCM
- UART
- DPI
- JTAG



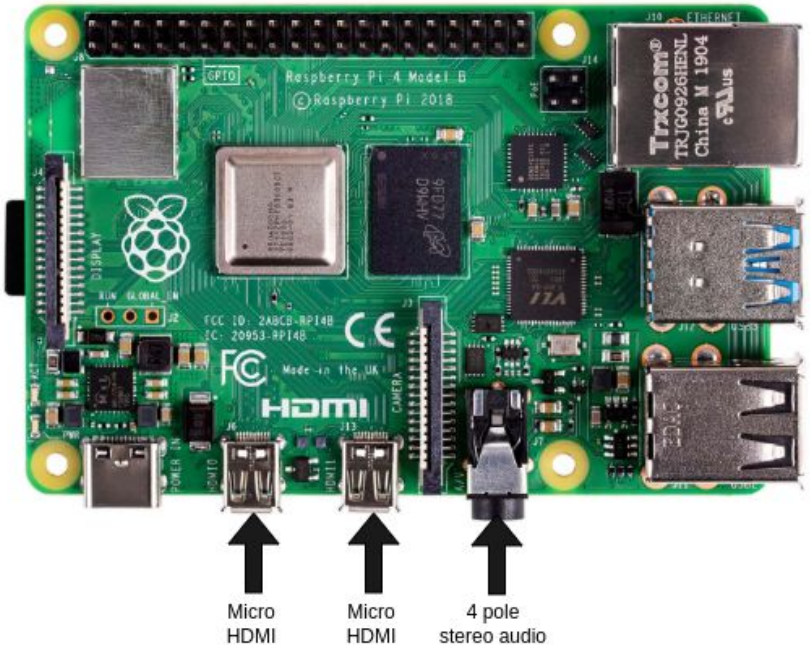


Video & Sound Support

- 2-lane MIPI DSI display port
  - Defines a serial bus and a communication protocol between the host and the device which is the destination of the display content.
  - Can operate at very low power and produces very low electromagnetic interference
  - Supports high resolutions and color depths without increasing the number of required data lines
- 2-lane MIPI CSI camera port
  - Defines an interface between a camera and a host processor
  - Supports 1080p, 4K, 8K, low power, low electromagnetic interference

Video & Sound Support

- 2 × micro HDMI ports
  - Transmit audio/video from a source to an HDMI compatible device (monitor, video projector, etc)
- 4-pole stereo audio and composite video port
  - 4 pole: right and left channel, ground and composite video
  - audiovisual applications like Television and media peripherals



Input Power

- 5V DC via USB-C connector (minimum 3A)
- 5V DC via GPIO header (minimum 3A)
  - Connect GPIO 5V pins to a 5V source and feed energy directly to the board
  - It is also needed to connect the ground of that source to a GND GPIO
  - More dangerous because there is no regulation or fuse protection on the GPIO against over-voltage or current spikes
- Via GPIO header but with a HAT
  - Hardware Attached on Top that connects to the GPIO and allows to power the board

Input Power

- Power Over Ethernet (HAT)
  - Using a PoE HAT (Raspberry Pi has 4 extra pins for PoE)
  - Contains a fan to cool the board
  - However if using a PoE HAT, access to the GPIOs is lost
- Power Over Ethernet (Splitter)
  - Device that splits “power” from ”data” coming from an ethernet cable
  - USB power connector and Ethernet connector (for data)

Multimedia

- OpenGL ES, 3.0 graphics
  - Used for rendering 2D and 3D vector graphics
  - Directed for Embedded Systems
- H.265
  - High efficiency video coding
  - Decode 4Kp60
- H.264
  - Advanced Video Coding
  - Decode 1080p60 and encode 1080p30

Desktop Kit

- Raspberry Pi 4 Model B (2GB, 4GB or 8GB version)
- Raspberry Pi Keyboard & Mouse
- 2 × micro HDMI to Standard HDMI (A/M) 1m Cables
- Raspberry Pi 15.3W USB-C Power Supply
- Raspberry Pi 4 Case
- Official Raspberry Pi Beginner's Guide (English language)
- 16GB with Raspberry Pi OS microSD card
- ~300 $

Operating System

- Raspberry Pi OS (Debian based)
  - downloadable on official website
- Download Raspberry Pi Imager
- Burn OS image to SD card
- Boot device and install Raspberry Pi OS

- Also supports many linux distributions and windows

Programming Languages

Languages pre-installed on Raspberry Pi OS

- Python 2.7.13 and 3.5.3
- C/C++ (gcc 6.3.0)
- Scratch

However since Raspberry Pi is based off Debian, it supports almost every programming language, compiler or interpreter.

Support for Upgrades

Like any computer, single-board computers need to be regularly updated, because many times software contains bugs or vulnerabilities that can be exploited.

Since Raspberry Pi is based on Debian, updating is done very similarly to how it's done in linux based distributions

Support for Upgrades

- Updating software using **APT (Advanced Packaging Tool)**
  - APT keeps a list of software sources on your Raspberry Pi in a file at **/etc/apt/sources.list**
  - **sudo apt update** updates that list of software packages
  - **sudo apt full-upgrade** to upgrade those packages
  - APT also allows to install and uninstall specific packages
  - APT also allows to search if a software package exists or not (in the **sources.list** file)
- Updating kernel and firmware with **rpi-update**
  - Downloads the latest pre-release version of the linux kernel, its matching modules, device tree files, along with the latest versions of the VideoCore firmware
  - Then install these files to relevant locations on the SD card, overwriting any previous versions.
  - It is advisable to take a backup of the system first because running rpi-update could result in a non-booting system
  - It is also possible to return to the previous stable release if after the update the device is bootable

Remote Access

- Access command line over SSH
- Share files over SCP
  - possible to copy a folder to a remote Pi
- Access graphical desktop with VNC
  - VNC Server
  - VNC Viewer
- Synchronize folder between computer and Pi with rsync

All this software comes with Raspberry Pi OS (with recommended software)

Applications

- Learning programming skills
- Home automation
  - Home alarm systems, video recording and motion sensors
  - Smart door systems, remote control devices
- Industrial applications
  - Industrial computers or controllers
- Edge computing
- Implementing kubernetes clusters
- ...

I2C

Raspberry Pi I2C interfaces allow for two-wire communication with a variety of external devices

I2C is a multi-drop bus, multiple devices can be connected to these same two pins. Each device has its own unique I2C address.

2 I2C interfaces:

- I2C0 - GPIO0 (Data) and GPIO1 (Clock) - commonly used with HAT EEPROM
- I2C1 - GPIO2 (Data) and GPIO3 (Clock)

I2C usage

- verify address of connected I2C peripheral for I2C1

  sudo apt-get install i2c-tools

  sudo i2cdetect -y 1

- Access I2C from python using smbus library

  import smbus

  DEVICE_BUS = 1

  DEVICE_ADDR = 0x15

  bus = smbus.SMBus(DEVICE_BUS)

  bus.write_byte_data(DEVICE_ADDR, 0x00, 0x01)

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