João Gameiro, 93097
Pedro Abreu, 93240

Arquiteturas para Sistemas Embutidos

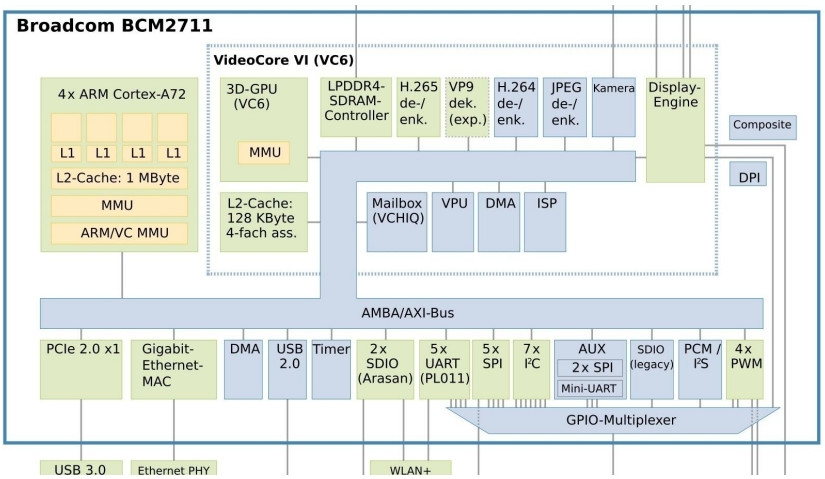
Aula5

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 2177

Broadcom 2177 is the chip used in the Raspberry Pi 4 Model B

- **CPU:** Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5 GHz
- **GPU:** Broadcom VideoCore IV 32-bit SoC @ 0.5 G Hz
- Logic units are connected by AMBA(Advanced Multicontroller Bus Architecture)/AXI-BUS



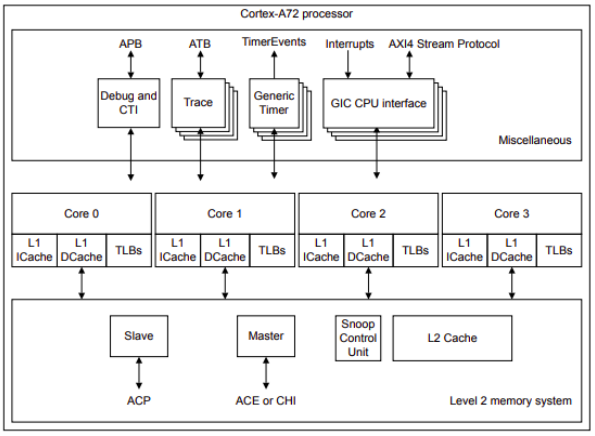
Broadcom's peripherals include:

- 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 & PWM
- PCM / I2S - APB providing improvements in audio streams
- DMA controller and I2C masters
- SPI masters - 2 SPI masters (SPI1 & SPI2)
- 6x UART - mini UART and five PL011 UART

ARM Cortex-A72 Processor

The Cortex-A72 is a high-performance, low-power processor that implements the ARMv8-A architecture. It contains a superscalar, variable-length, out-of-order pipeline. 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 and execution of integer operations.

The L1 memory system contains Instruction cache 48KB 3-way set-associative and data cache 32KB 2-way set-associative. The L2 memory system services L1 instruction and data cache misses from each processor and contains a L2 cache 512KB, 1MB, 2MB, or 4MB that is 16-way set-associative.



Additional hardware includes the Generic Timer that provides the ability to schedule events and trigger interrupts, the Generic Interrupt Controller (GIC) which is a CPU interface for supporting and managing interrupts and an Advanced SIMD and Floating-point unit that provides support for the ARMv8 Advanced SIMD and Floating-point execution.

The processor also includes logic to gather various statistics on the operation of the processor and memory system during runtime like the (PMU) Performance Monitor Unit that contains six counters to count any of the events available in the processor or the (ETM) Embedded Trace Macrocell which is a module that performs real-time instruction flow tracing based on the ARM specifications. There are also additional elements like the cross trigger channel interface (CTI) that enables the debug logic, and enables the ETM and PMU, to interact with each other and with other CoreSight components.

VideoCore IV 3D

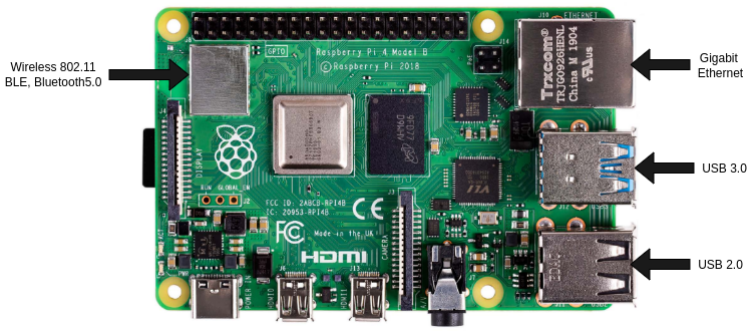
VideoCore IV 3D is a low-power mobile multimedia graphics processor Its architecture makes it flexible and efficient enough to decode (as well as encode) a number of multimedia codecs in software while maintaining low power usage. The hardware is self-contained and highly automated, requiring little processing bandwidth or real-time intervention from software drivers

The architecture is scalable, based around multiple specialist floating-point shading processors called QPUs (16-way SIMD processors)

Memory

1GB, 2GB or 4GB LPDDR4, that is a synchronous DRAM, optimized for low power consumption. It is targeted for mobile computers and devices such as mobile phones. Offers greater data transfer rates than previous versions and contains on-chip temperature sensors to control self-refresh rate. It is volatile. There is also support for an SD card, which is very useful since Raspberry has no internal storage, the SD card can be used to load operating systems 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 and 2 × USB 2.0 ports

Video & Sound Support

Contains a 2-lane MIPI DSI display port which defines a serial bus and a communication protocol between the host and the device which is the destination of the display content.

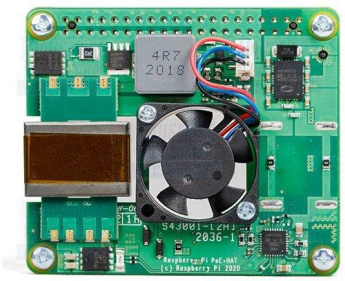
There is also a 2-lane MIPI CSI camera port which defines an interface between a camera and a host processor and supports 1080p, 4K, 8K, low power and low electromagnetic interference.

There are also two micro HDMI ports used to transmit audio/video from a source to an HDMI compatible device. Finally the board also contains a 4-pole stereo audio and composite video port.

Input Power

The Board can be powered one of several ways:

- 5V DC via USB-C connector,
- 5V DC via GPIO header with or without a HAT(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
    - A HAT (Hardware Attached on Top) connects to the GPIO and powers the board safely.
- Power Over Ethernet (HAT)
    - Using a PoE HAT (Raspberry Pi has 4 extra pins for PoE), that 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

The Raspberry pi supports OpenGL ES (oriented towards Embedded Systems), 3.0 graphics that are used for rendering 2D and 3D vector graphics, as well as the following codecs:

H.265 (High efficiency video coding) to decode 4Kp60 and H.264 (Advanced Video Coding) to decode 1080p60 and encode 1080p30.

Operating System and Desktop Kit

The Raspberry operating system is Raspberry Pi OS which is based on Debian. In order to use it, it is necessary to download the image and burn it on the SD card with Raspberry Pi Imager which is a program similar to Etcher or Rufus. Then boot Raspberry and finish installation. Besides Raspberry Pi OS, the board also supports many linux distributions and windows although the Raspberry Pi OS is the brand recommended.

The Desktop Kit is a full kit that comes with a minimal set of pieces to run the Raspberry Pi. It includes Raspberry Pi itself, a case, mouse, keyboard, 2 hdmi cables, power supply, beginners guide book, 16 Gb SD card. This kit costs around 300$.

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.

- 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 and to search if a 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, and with the latest versions of the VideoCore firmware. and installs 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.

Remote Access

Is possible to Access a Raspberry Pi remotely in 2 ways. Access terminal through ssh connection, is needed a ssh client on both ends. Over ssh is possible to do a secure copy (scp) in which is possible to share files and folders. It is possible to synchronize the folders so a desktop computer receives the content of a remote Pi folder in fixed time intervals. If we want access to a remote graphical environment we can use VNC, for that the remote Pi must have a VNC Server and have a VNC Client in Desktop computer. This software comes in the Raspberry Pi version with recommended software.

Applications

Used to Learn programming skills in Home automation environments or industrial applications, in Edge computing or to implement kubernetes clusters, and many more.

I2C and I2C usage

Raspberry Pi I2C interfaces allow for two-wire communication with a variety of external devices. I2C is a multi-drop bus that means multiple devices can be connected to these same two pins in which each device has its own unique I2C address. Pi as I2C interfaces:

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

An example of finding I2C device and program it in python

- 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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