

# Arquiteturas para Sistemas Embutidos

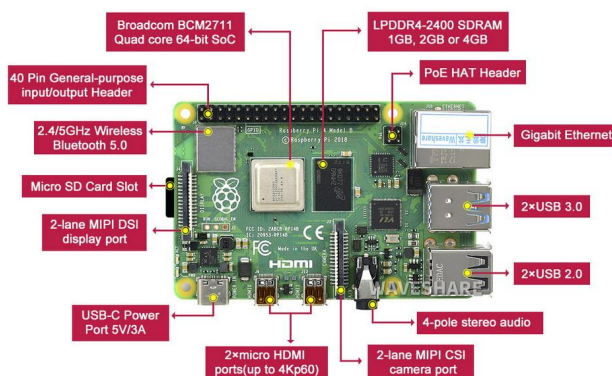
## Aula2

### Raspberry Pi 4

Raspberry Pi is a small single board computer. By connecting peripherals like Keyboard, mouse, display to the Raspberry Pi, it will act as a mini personal computer. Raspberry Pi is slower than laptop or desktop but is still a computer which can provide all the expected features or abilities, at a low power consumption. The Raspberry Pi runs Linux and its main operating system (Pi OS) is open source.

Raspberry Pi is more than computer as it provides access to the on-chip hardware i.e. GPIOs (general purpose I/O) for developing an application. By accessing GPIO, we can connect devices like LED, motors, sensors, etc and can control them too.

Raspberry Pi 4 is the latest version of the Raspberry Pi low cost computer. It offers ground-breaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+, while retaining backwards compatibility and similar power consumption. For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems.



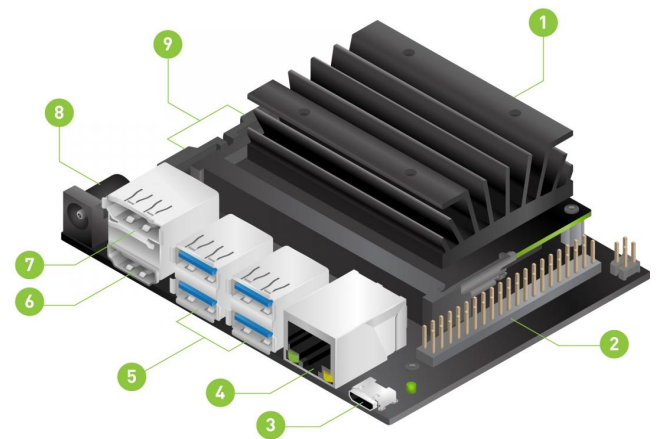
#### Specifications:

- **Processor:** Broadcom BCM2711, quad-core Cortex-A72 (ARM v8), 64-bit SoC @ 1.5GHz
- **Memory:** 1GB, 2GB or 4GB LPDDR4 (depending on model)

- **Connectivity:**
- **Gigabit Ethernet:**
  - 2 × USB 3.0 ports, 2 × USB 2.0 ports;
  - 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless;
  - LAN, Bluetooth 5.0, BLE
- **General Purpose Input/Output:** Standard 40-pin GPIO header
- SD card support
- **Voice & Video Support:**
  - 2 × micro HDMI ports (up to 4Kp60 supported)
  - 2-lane MIPI DSI display port
  - 2-lane MIPI CSI camera port
  - 4-pole stereo audio and composite video port
- **Multimedia:**
  - H.265 (4Kp60 decode)
  - H.264 (1080p60 decode, 1080p30 encode);
  - OpenGL ES, 3.0 graphics
- **Power:** USB-C

## Nvidia Jetson Nano

NVIDIA Jetson Nano is a small, powerful computer that lets you run multiple neural networks in parallel for applications like image classification, object detection, segmentation, and speech processing. Jetson is a low-power system and is designed for accelerating machine learning applications. The Jetson Nano uses a microSD card as a boot device and for main storage. It's important to have a card that's fast and large enough for your projects; the minimum recommended is a 32 GB UHS-1 card. NVIDIA GPU support (CUDA, VisionWorks, OpenCV)



- |   |                                     |
|---|-------------------------------------|
| 1 microSD card slot for main storage                    | 5 USB 3.0 ports (x4)                |
| 2 40-pin expansion header                               | 6 HDMI output port                  |
| 3 Micro-USB port for 5V power input, or for Device Mode | 7 DisplayPort connector             |
| 4 Gigabit Ethernet port                                 | 8 DC Barrel jack for 5V power input |
|   | 9 MIPI CSI-2 camera connectors      |

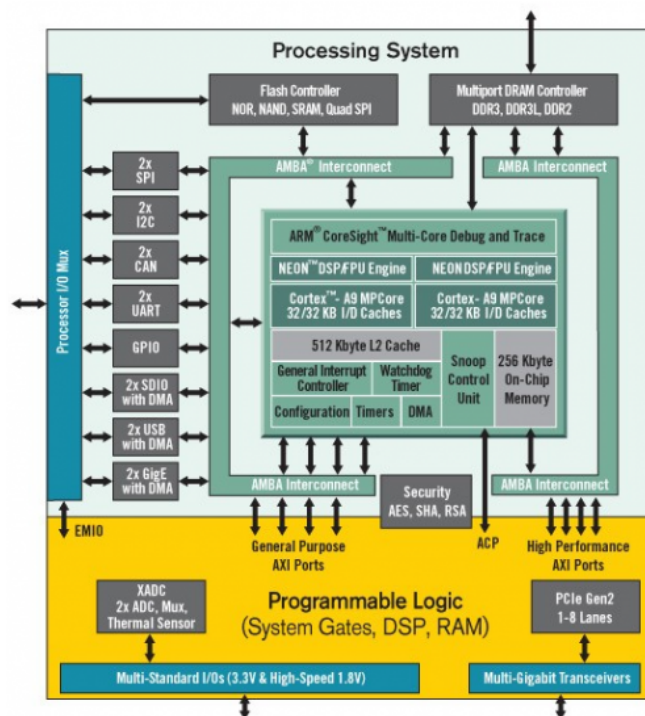
### Specifications:

- **Processor:**
  - Quad-core ARM A57 @ 1.43 GHz
- **Memory:**
  - 4 GB 64-bit LPDDR4 25.6 GB/s
- **Storage:**
  - microSD

- **GPU:**
  - 128-core Maxwell
- **Power:**
  - Either Micro-USB or DC power supply
- **Camera:**
  - 2x MIPI CSI-2 DPHY lanes
- **Video Encode:**
  - 4K @ 30 | 4x 1080p @ 30 | 9x 720p @ 30 (H.264/H.265)
- **Video Decode:**
  - 4K @ 60 | 2x 4K @ 30 | 8x 1080p @ 30 | 18x 720p @ 30 (H.264/H.265)
- **Connectivity:**
  - Gigabit Ethernet(physical), M.2 Key E(wireless card(wi-fi/bluetooth))
- **Display:**
  - HDMI and display port
- **USB:**
  - 4x USB 3.0, USB 2.0 Micro-B
- **GPIO:**
  - 40-pin expansion header, includes:
    - power pins
    - programmable interface signal pins

## Digilent Zybo Z7 (Xilinx Zynq 7000)

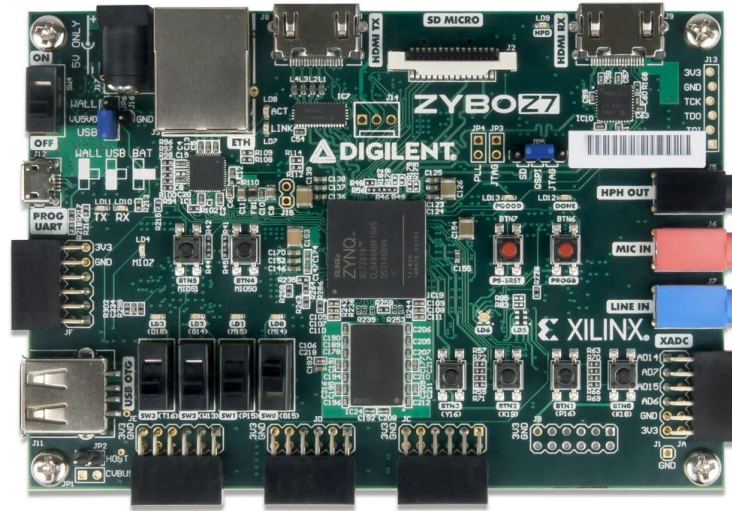
Xilinx SoCs are processor-centric platforms that offer software, hardware and I/O programmability in a single chip. The Zynq 7000 SoC family integrates the software programmability of an ARM-based processor with the hardware programmability of an FPGA, enabling key analytics and hardware acceleration while integrating CPU, DSP, ASSP, and mixed signal functionality on a single device.



The PL is nearly identical to a Xilinx 7-series Artix FPGA, except that it contains several dedicated ports and buses that tightly couple it to the PS.

The PS consists of many components, including the Application Processing Unit (APU, which includes 2 Cortex-A9 processors), Advanced Microcontroller Bus Architecture (AMBA) Interconnect, DDR3 Memory controller, and various peripheral controllers with their inputs and outputs.

The Zybo Z7 is a feature-rich, ready-to-use embedded software and digital circuit development board built around the Xilinx Zynq-7000 family.



### Specifications:

- **Processor:**
  - 667MHz dual-core ARM Cortex-A9 processor
  - Low-bandwidth peripheral controller: SPI, UART, CAN, I2C
- **Memory:**
  - 1 GB DDR3L with 32-bit bus @ 1066 MHz
  - 16 MB Quad-SPI Flash with factory programmed 128-bit random number and 48-bit globally unique EUI-48/64™ compatible identifier
  - microSD slot
- **Power:** Power from USB or any 5V external power source
- **Audio and Video:**
  - HDMI sink port (input) with CEC (Zybo Z7-20) and without CEC (Zybo Z7-10)
  - HDMI source port (output) with CEC
  - Audio codec with stereo headphone, stereo line-in, and microphone jacks
- **USB and Ethernet:**
  - Gigabit Ethernet PHY
  - USB-JTAG Programming circuitry
  - USB-UART bridge
  - USB 2.0 OTG PHY (supports host only)
- **Switches, Push-buttons, and LEDs**
  - 6 push-buttons
  - 4 slide switches
  - 5 LEDs, 2 RGB LEDs

## Overall comparison between architectures

	Raspberry Pi 4	Nvidia Jetson Nano	Xilinx Zynq 7000
<b>Applications</b>	Build hardware projects, implementing Kubernetes clusters and edge computing or in industrial applications.	Run multiple neural networks in parallel for applications like image classification, object detection, segmentation, and speech processing.	Industrial IoT applications such as motor control, small cell base stations, multi camera drivers assistance systems, machine vision for industrial automation, medical endoscopy, and 4K2K Ultra-HDTV.
<b>Processor</b>	Quad-core ARM Cortex-A72, 1.5GHz Arch: Armv8-A	Quad-core ARM A57, 1.43 GHz Arch: Armv8-A	Dual-core ARM Cortex-A9, 667MHz (0.667GHz) Arch: Armv7-A
<b>Memory</b>	1 GB, 2GB or 4GB 64-bit LPDDR4 Supports 1.1V	4 GB 64-bit LPDDR4 Supports 1.1V	1 GB 32-bit DDR3L Supports 1,2 V
<b>SD card slot</b>	contains	contains	contains
<b>Power</b>	USB-C	Either Micro-USB or DC power supply	USB or any 5V external power source
<b>USB</b>	2 × USB 3.0 ports, 2 × USB 2.0 ports	4x USB 3.0, USB 2.0 Micro-B	USB-JTAG Programming circuitry USB-UART bridge USB 2.0 OTG PHY (supports host only)
<b>Ethernet</b>	Gigabit Ethernet PHY Bluetooth 5.0, BLE, 2.4 GHz and 5.0 GHz IEEE 802.11	Gigabit Ethernet PHY Slot for Bluetooth or Wifi	Gigabit Ethernet PHY
<b>Cost</b>	Around 35 \$	Around 109\$	Around 249 \$

**1. What is the current market share of 8, 16, 32 and 64 bit architectures for embedded systems? What are the preferred application domains for each one?**

In 2019, the market share was 10%-8 bits, 11%-16 bits, 61%-32 bits and 15%-64 bits.

8-bit are used for control, sensing, and IoT.

16 or 32 bit are used in networking protocols and communication software stacks.

64-bit are used in scientific and digital media applications.

<https://blog.techdesign.com/selecting-microcontrollers-8-bit-32-bit-mcu/>

[https://www.embedded.com/wp-content/uploads/2019/11/EETimes\\_Embedded\\_2019\\_Embedded\\_Markets\\_Study.pdf](https://www.embedded.com/wp-content/uploads/2019/11/EETimes_Embedded_2019_Embedded_Markets_Study.pdf)

<https://pvs-studio.com/en/blog/posts/k0002/>

**2. What are the top 5 programming languages used in embedded systems development and the respective preferred application domains?**

C C++ Python Java Rust. C and C++ in compilers, operating systems and their tools. Python, machine learning, analyzing data and network programming. Java, android, backend servers and distributed applications. Rust, data processing and system programming.

<https://www.kdnuggets.com/2021/05/top-programming-languages.html>

<https://www.allaboutcircuits.com/news/programming-languages-for-embedded-systems-101-background-and-resources/>