



# NVIDIA Jetson Nano

## Arquiteturas para Sistemas Embutidos

João Gameiro, 93097  
Pedro Abreu, 93240

Turma TP1  
Grupo 3

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universidade  
de aveiro

# What is NVIDIA Jetson Nano

- NVIDIA Jetson Nano™ Developer Kit 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.



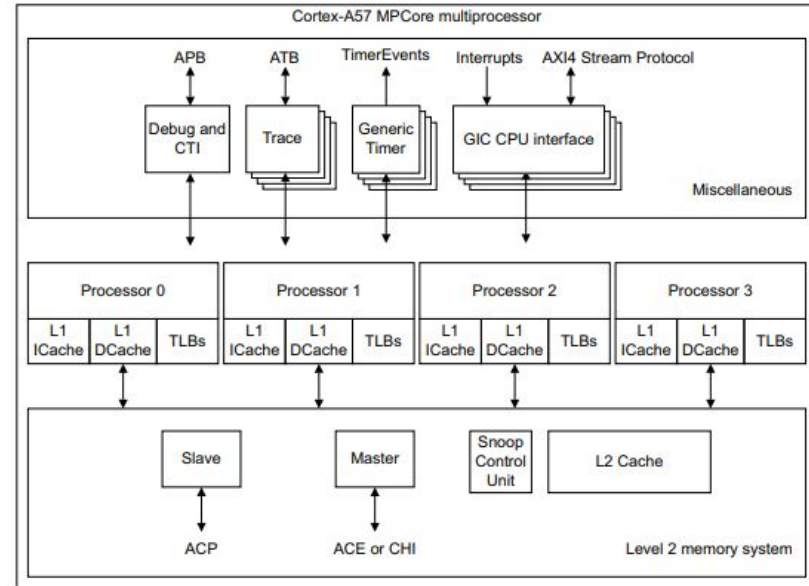
# ARM Cortex-A57 Processor

- The Cortex-A57 MPCore processor is a high-performance, low-power processor that implements the ARMv8 architecture.
- It has one to four processors in a single multiprocessor device, or MPCore device, with L1 and L2 cache subsystems.
- Superscalar, variable-length, out-of-order pipeline



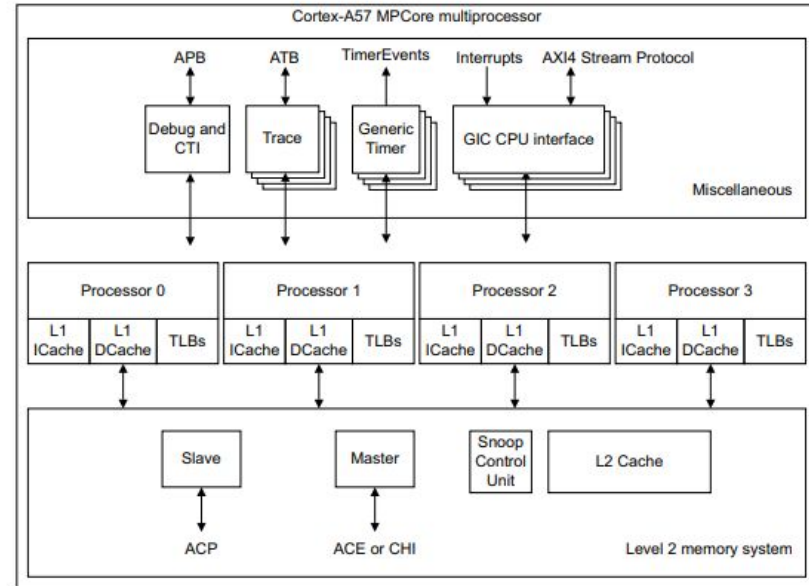
# ARM Cortex-A57 Processor

- Dynamic branch prediction with Branch Target Buffer (BTB) and Global History Buffer (GHB) RAMs, a return stack, and an indirect predictor.
- Instruction sets supported include A32, T32 and A64.
- Supports execution states AArch32 and AArch64



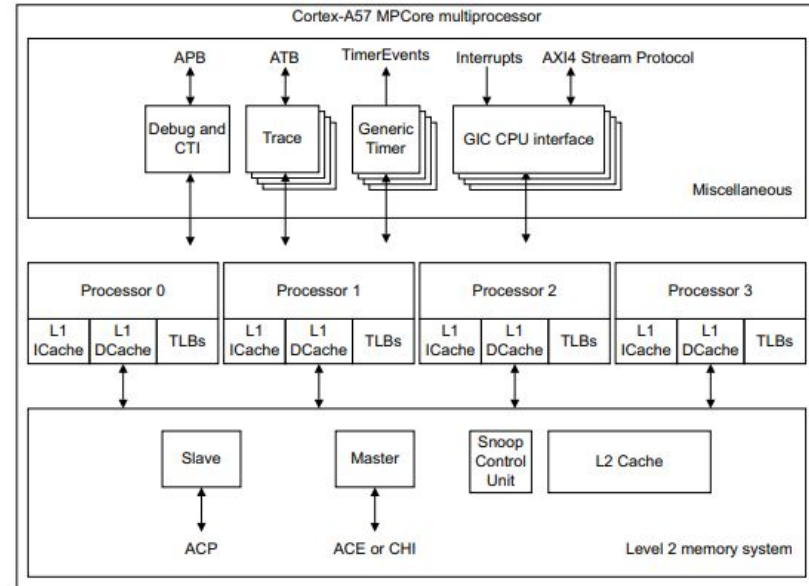
# ARM Cortex-A57 Processor

- Contains the following functional units
  - Instruction Fetch
  - Instruction Decode
  - Instruction Dispatch
  - Integer Execute
  - Advanced SIMD and Floating-Point unit
- Load/Store Units
  - Data cache of 32KB, 2-way set-associative
  - 32-entry fully-associative L1 data TLB with native support for 4KB, 64KB, and 1MB page sizes



# ARM Cortex-A57 Processor

- L2 Memory System
  - Services the L1 instruction and data caches misses
  - L2 cache 512KB, 1MB or 2MB, 16-way set-associative cache
  - Duplicate copy of L1 data cache Tag RAMs from each processor
  - Automatic hardware prefetcher
- L1 Memory System
  - Instruction cache 48KB 3-way set-associative
  - Data cache 32KB 2-way set-associative
  - Both with LRU replacement policy



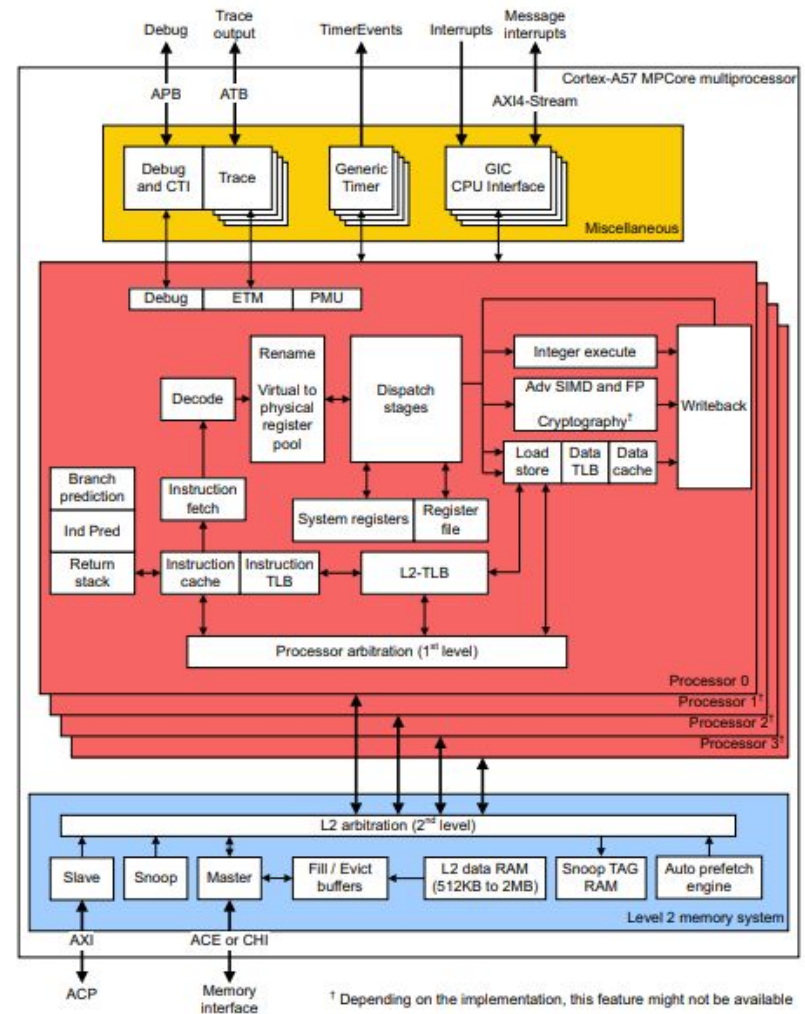


# ARM Cortex-A57 Processor

- 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
- The **ETM (Embedded Trace Macrocell)** is a module that performs real-time instruction flow tracing based on the ARM specifications
- **PMU Performance Monitor Unit** to gather statistics about the operation of the processor and memory system during runtime

# ARM Cortex-A57 Processor

- There is also the possibility for an additional cryptography engine that's not included in the A75 Processor
- However FP and Advanced SIMD units provide support for the cryptographic operations of the engine







## ARM Cortex-A57 vs ARM Cortex-A72

	Cortex-A57	Cortex-A72
Year of Release	2013	2015
Pipeline	Superscalar, Out-of-order pipeline	Superscalar, Out-of-Order pipeline
InstructionCache	48K	48K
DataCache	32K	32K
CPU Architecture	Armv8	Armv8
DMIPS/MHz	4.6	5.4
Applications	Digital TV wired and wireless network system	High-end digital TV, car driving system

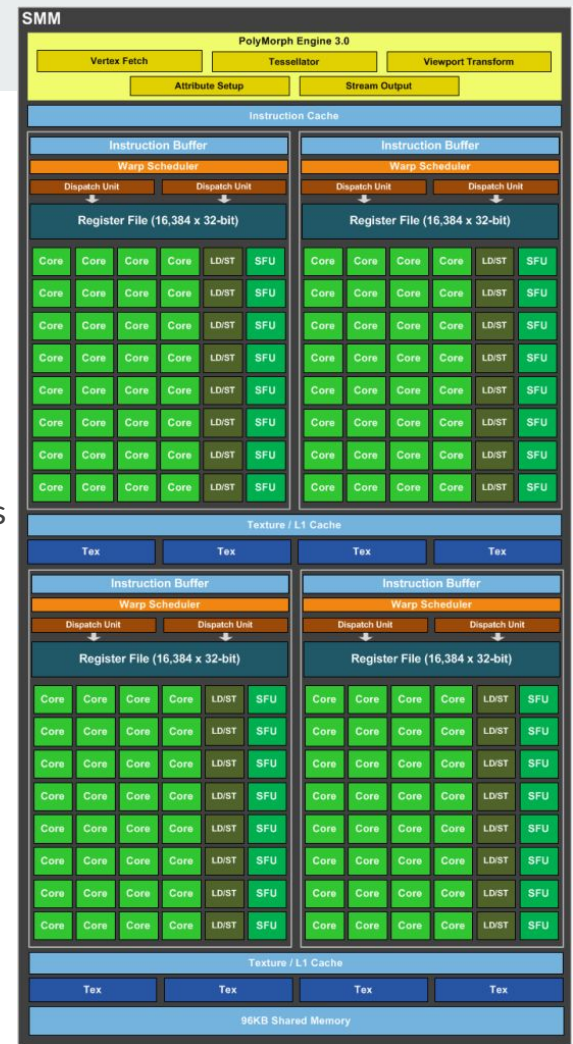


## GPU - NVIDIA Maxwell

- The NVIDIA Maxwell GPU is a dedicated hardware block for rasterization, shading, texturing, and computation, of graphics processing.
- Maxwell is NVIDIA's next-generation architecture for CUDA compute applications and introduces an all-new design for the Streaming Multiprocessor (SM) that dramatically improves energy efficiency.
- Improvements to control logic partitioning, workload balancing, clock-gating granularity, compiler-based scheduling, number of instructions issued per clock cycle, and many other enhancements

# GPU - NVIDIA Maxwell

- SMM (Streaming Maxwell Multiprocessor)
  - Quadrant-based design with four 32-core processing blocks
  - Each contains a dedicated warp scheduler capable of dispatching two instructions per clock.
  - Each block also contains its execution units and register files, as well as independent instruction buffers.
  - SFU units to handle transcendental and graphics interpolation instructions



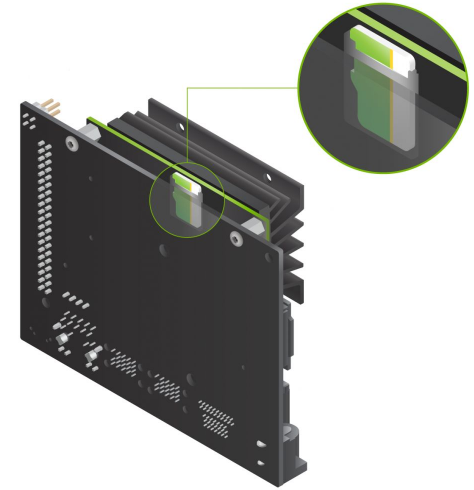


# Peripherals

- I2C - supports communication with multiple I<sup>2</sup>C Devices
- SPI - In master or slave mode, duplex synchronous and serial communication
- UART - controller provides serial data synchronization and data conversion
- PWM, USB and PCIe controllers
- I2S - transport streaming audio data between system memory and an audio codec
  - Supports PCM which is a standard method used to digitize audio (particularly voice) patterns for transmission over digital communication channels

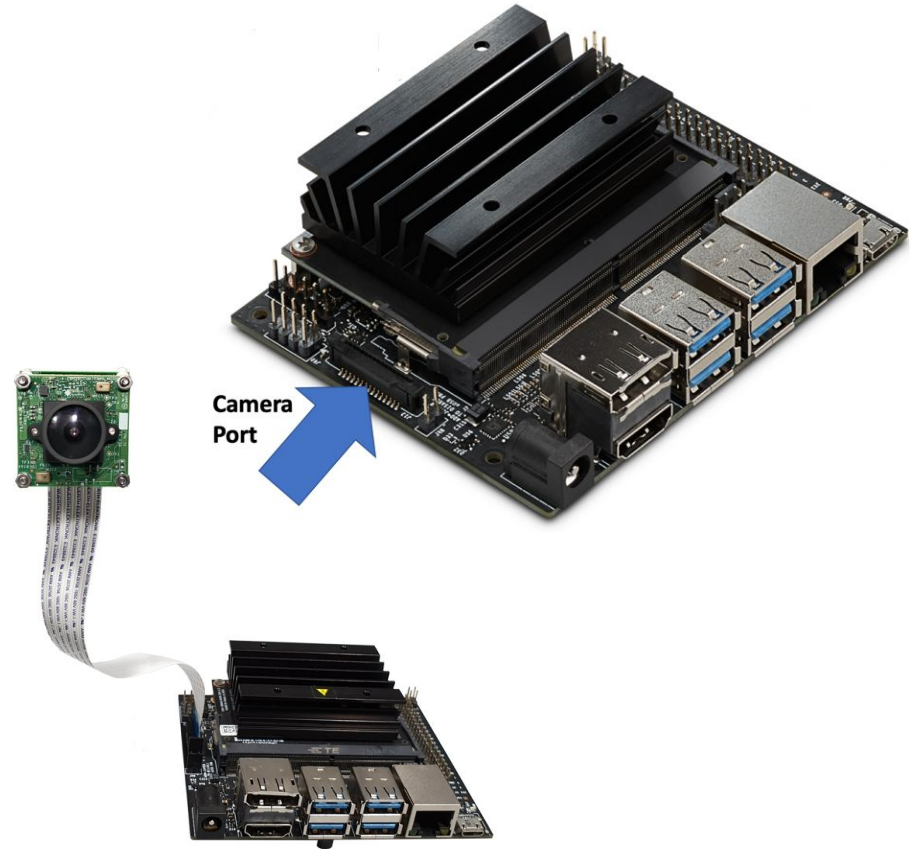
# Memory

- LPDDR4 4 GB, 64 bit
  - Low-Power Double Data Rate, Volatile Memory
  - Low power consumption
  - Targeted for mobile computers and devices such as mobile phones
  - Offers greater data transfer rates than previous versions
- SD Card Support
  - Since there is no internal storage in Jetson Nano, there is support for an SD card, for loading operating system and data storage



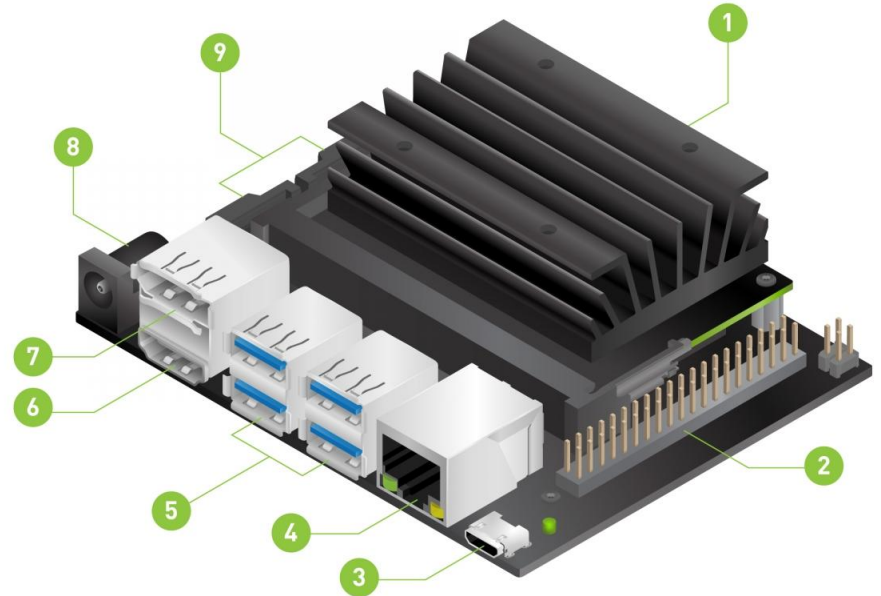
## Camera & Display

- MIPI CSI-2 DPHY lanes
  - Implements a Camera Serial Interface receiver which receives data from an external camera module with CSI transmitter
  - Supports 1080p, 4K, 8K, low power, low electromagnetic interference



## Camera & Display

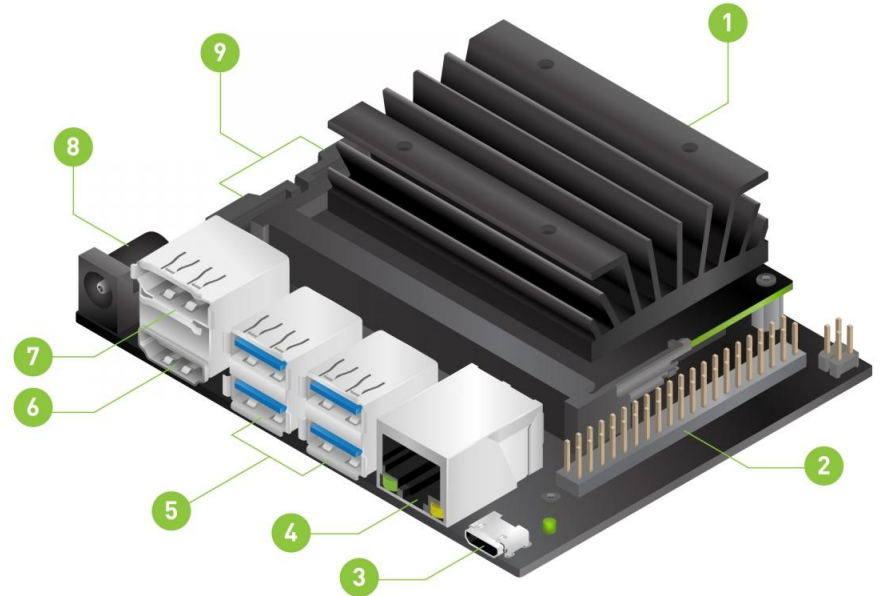
- HDMI output port
  - Transmit audio/video from a source to an HDMI compatible device (monitor, video, projector, etc)
- DisplayPort connector
  - Also used to transmit audio/video from source



- 6 HDMI output port
- 7 DisplayPort connector

# Connectivity

- 1 Gigabit Ethernet Port
  - Transmission technology based on the Ethernet protocol
  - 1 billion bits per second (1 Gigabit)
- 4 x USB3.0 ports
  - Higher transfer rates than USB 2.0
  - Power consumption of 900 mA



4 Gigabit Ethernet port

5 USB 3.0 ports (x4)



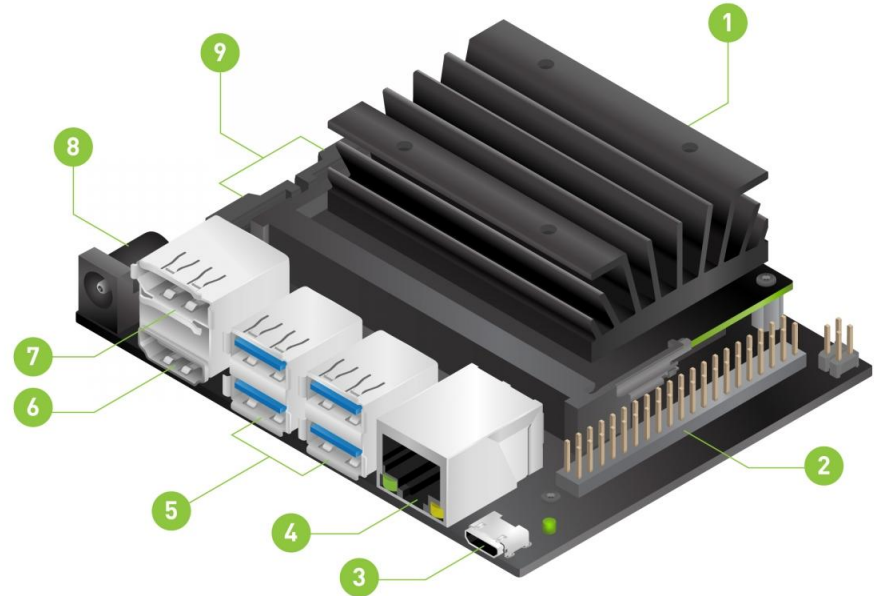
# Connectivity

- NVIDIA Jetson Nano does not contain a WIFI/Bluetooth module
  - However there is a M.2 Key E connector located under the board
  - M.2 is a specification for internal expansion cards on PC mainboards and notebook computers.
  - M.2 Key E is directed to wireless cards
- So for a wireless module is necessary to install a wireless a network card
  - Necessary to have the card itself
  - Antennas for wireless communication
  - M2 Key E Connector



# Power

- Via the Micro-USB connector (5 V power)
- DC Barrel jack (5 V power)
  - Electrical connector to supply direct current



**3** Micro-USB port for 5V power input, or for Device Mode

**8** DC Barrel jack for 5V power input

# Power

- PoE (Power Over Ethernet)
  - PoE Splitter that splits “power” from “data” coming from an ethernet cable
  - DC barrel jack for power
- Power can also be supplied via GPIO (in the 5V pins)
  - Connect GPIO 5V pins to a 5V source and feed energy directly to the board
  - Can be dangerous because there is no regulation
  - A HAT can be used
- PoE HAT
  - The Jetson contains 4 additional pins for PoE

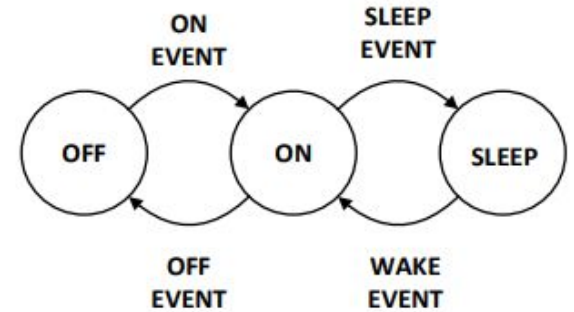




# Power Management

- Jetson contains mechanisms and modules to implement a tiered structure of power and clock gating in a complex environment that optimizes power consumption
- **Power Management Controller (PMC)**
  - Provides an interface to an external power managers and controls voltage transitions for the SoC
- **Real Time Clock (RTC)**
  - Maintains the ability to wake the system based on either a timer event or an external trigger
- **Clock and Power Gating**
  - The SoC aggressively employs clock and power gating to power-off modules which are idle
- **Dynamic Voltage and Frequency Scaling (DVFS)**
  - Raises voltages and clock frequencies when demand requires, lowers them when less is sufficient, and removes them when none is needed

# Power Management



- The Jetson module operates in three main power modes:
  - **OFF** - System is not powered, therefore the Jetson is not operation
  - **ON** - Jetson module is fully functional and operates normally
  - **SLEEP** - allows the Jetson module to quickly resume to an operational state without performing a full boot sequence. Operates in low power with enough circuitry powered to allow the device to resume and re-enter the ON state
- Jetson can enter both in OFF and SLEEP modes if internal temperature exceeds a certain limit unsafe value



# Video Encode/Decode

- Supports two codecs for video codification
  - H.265 (HEVC - High Efficiency Video Coding )
  - H.264 (AVC - Advanced Video Coding)
- H.265 is allows for further reduced file size, and therefore reduced required bandwidth
- Video Decoding formats
  - 4K @ 60 | 2x 4K @ 30 | 8x 1080p @ 30 | 18x 720p @ 30
- Video Encoding formats
  - 4K @ 30 | 4x 1080p @ 30 | 9x 720p @ 30

# GPIO

- 40 Pin Header
  - 2 x 3.3 V Power
  - 2 x 5 V Power
  - GND
  - I2S
  - SPI
  - UART
  - CAM
  - PWM

Sysfs	Name	Pin	Pin	Name	Sysfs
	3.3V DC	1	2	5V DC	
	I2C_2_SDA	3	4	5V DC	
	I2C_2_SCL	5	6	GND	
gpio216	AUDIO_MCLK	7	8	UART_2_TX	
	GND	9	10	UART_2_RX	
gpio50	UART_2_RTS	11	12	I2S_4_CLK	gpio79
gpio14	SPI_2_SCK	13	14	GND	
gpio194	LCD_TE	15	16	SPI_2_CS1	gpio232
	3.3V DC	17	18	SPI_2_CS0	gpio15
gpio16	SPI_1_MOSI	19	20	GND	
gpio17	SPI_1_MISO	21	22	SPI_2_MISO	gpio13
gpio18	SPI_1_SCK	23	24	SPI_2_CS0	gpio19
	GND	25	26	SPI_2_CS1	gpio20
	IC2_1_SDA	27	28	I2C_1_SCL	
gpio149	CAM_AF_EN	29	30	GND	
gpio200	GPIO_PZO	31	32	LCD_BL_PWM	gpio168
gpio38	GPIO_PE6	33	34	GND	
gpio76	I2S_4_LRCK	35	36	UART_2_CTS	gpio51
gpio12	SPI_2_MOSI	37	38	I2S_4_SDIN	gpio77
	GND	39	40	I2S_4_SDOUT	gpio78



# NVIDIA jetPack

Provides a full development environment for hardware-accelerated AI-at-the-edge development. [8]

It includes:

- Ubuntu desktop environment
- Set of libraries for acceleration of GPU computing, multimedia, graphics, and computer vision
- Samples and documentation
- Developer Tools





# OS image

NVIDIA Jetson Linux 34.1 with:

- Linux Kernel 5.10
- UEFI based bootloader
- Ubuntu 20.04 based root file system
- NVIDIA drivers
- necessary firmwares
- toolchain



# Libraries

- **TensorRT** and **cuDNN** for high-performance deep learning applications
- **CUDA** for GPU accelerated applications across multiple domains
- **NVIDIA Container Runtime** for containerized GPU accelerated applications
- **Multimédia API** provides low level APIs for flexible application development
- **VPI** and **OpenCV** for visual computing applications



# Samples

Demonstrating use of JetPack components

JetPack component	Sample locations on reference filesystem
TensorRT	/usr/src/tensorrt/samples/
cuDNN	/usr/src/cudnn_samples_<version>/
CUDA	/usr/local/cuda-<version>/samples/
MM API	/usr/src/jetson_multimedia_api
OpenCV	/usr/share/opencv4/samples/
VPI	/opt/nvidia/vpi/samples/



# Developer Tools

Tools for application development and debugging:

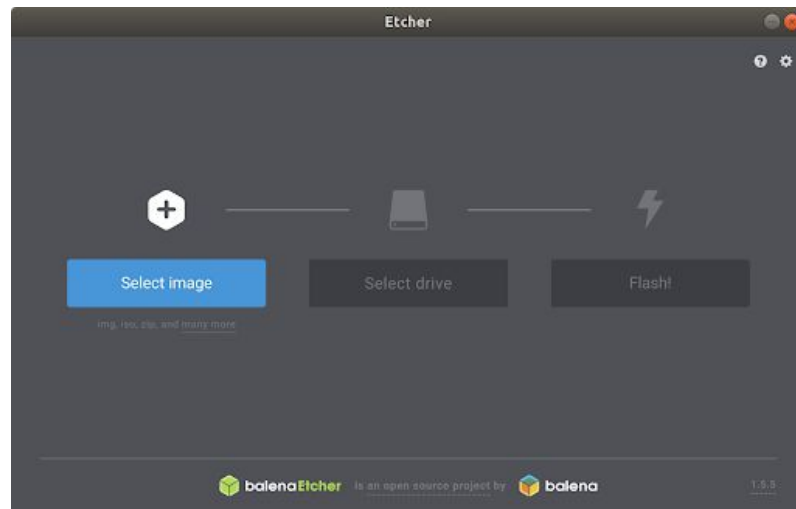
- **Nsight Eclipse Edition** extension in Eclipse for development of GPU accelerated applications
- **CUDA-GDB** for application debugging
- **CUDA-MEMCHECK** for debugging application memory errors

Tools for application profiling and optimization:

- **Nsight Systems** and **nvprof** for application profiling across GPU and CPU.
- **Nsight Graphics** for graphics application debugging and profiling

# Install OS

- burn JetPack SDK image to usb pen using etcher [11]
- after first boot:
  - finish installation
- boot:
  - display monitor
  - headless mode
  - also possible to use VNC





# Support for Upgrades

Updating software using **APT (Advanced Packaging Tool)**

- **sudo apt update** - updates that list of software packages
- **sudo apt upgrade** - upgrade those packages
- **APT** also allows to install and uninstall specific packages



## Support for Remote Access

- Access command line with SSH
  - Graphical desktop with VNC
  - SCP or FTP to transfer files
- 
- Being Jetson Nano capable of supporting Unix distributions, the majority of the traditional ways to access remotely a device are possible
    - All that is necessary is that the tools that allow remote access are installed,



## Jetson nano 2G Developer kit

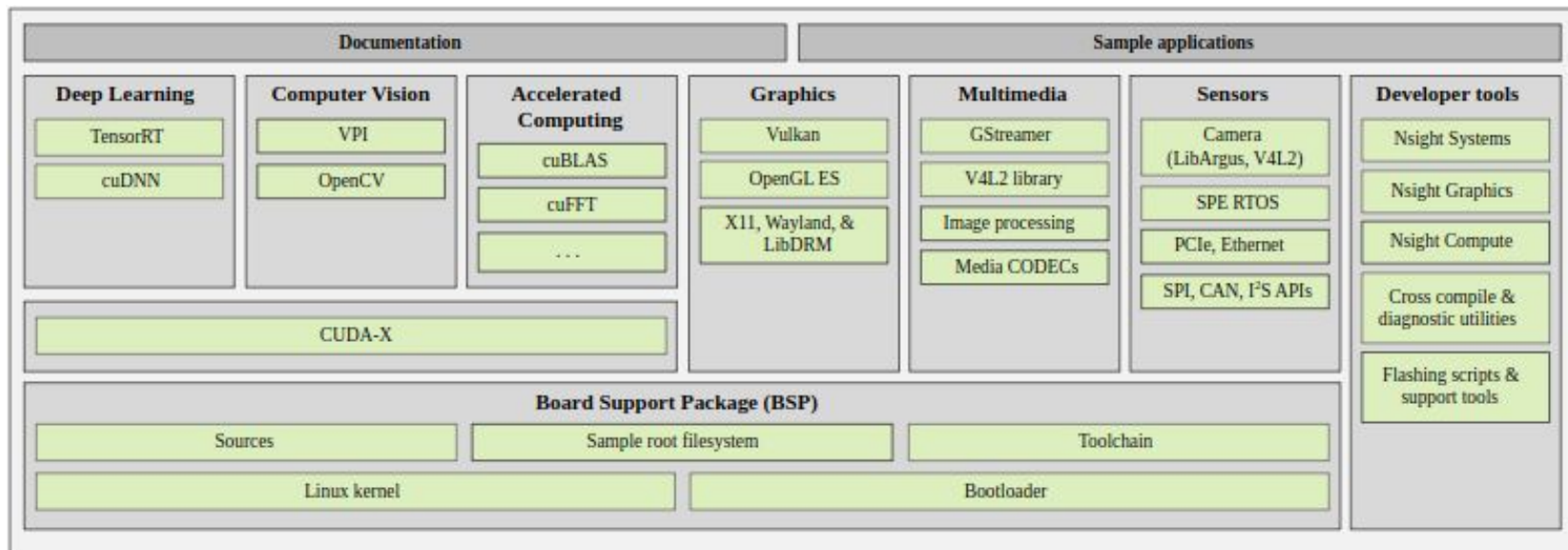
- NVIDIA Jetson module and reference carrier board
- Quick Start / Support Guide
- 802.11ac wireless adapter and extension cable

it doesn't include:

- microSD Card
- USB keyboard and mouse
- HDMI display
- USB-C power supply (5V=3A)

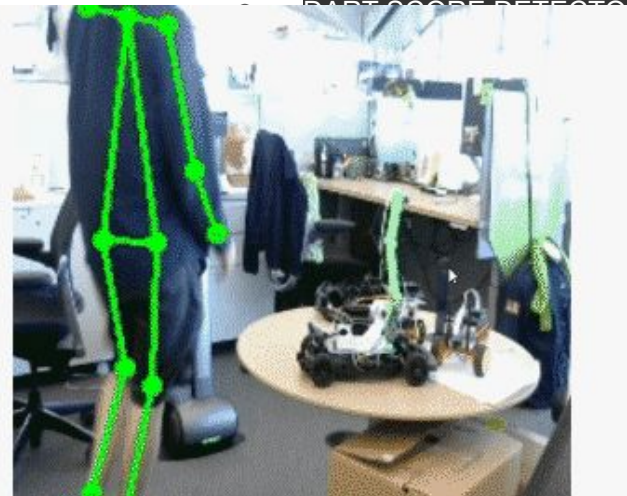
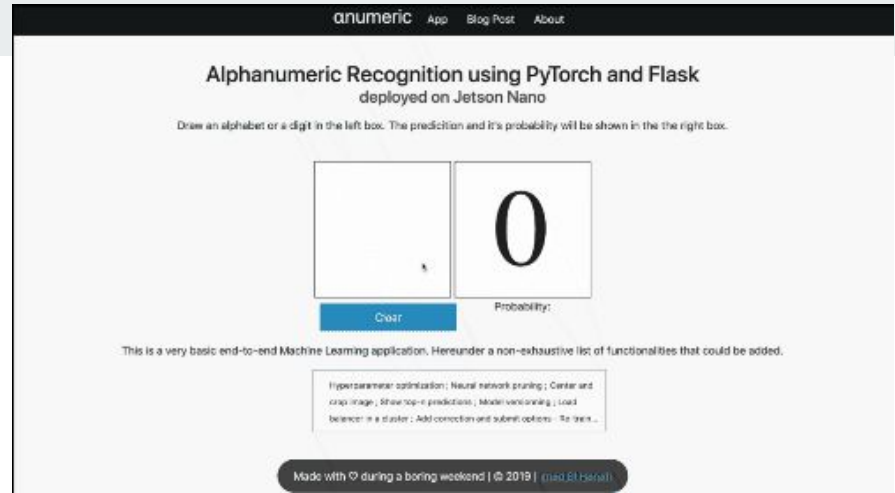


# Software Architecture



# Community Projects

- AI whiteboard
- real-time human pose estimation
- handwriting ml classifier
- dart score detector
- many more [9]





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