Controllers and Peripherals

Instructor: Deepak Gangadharan

Microcontroller

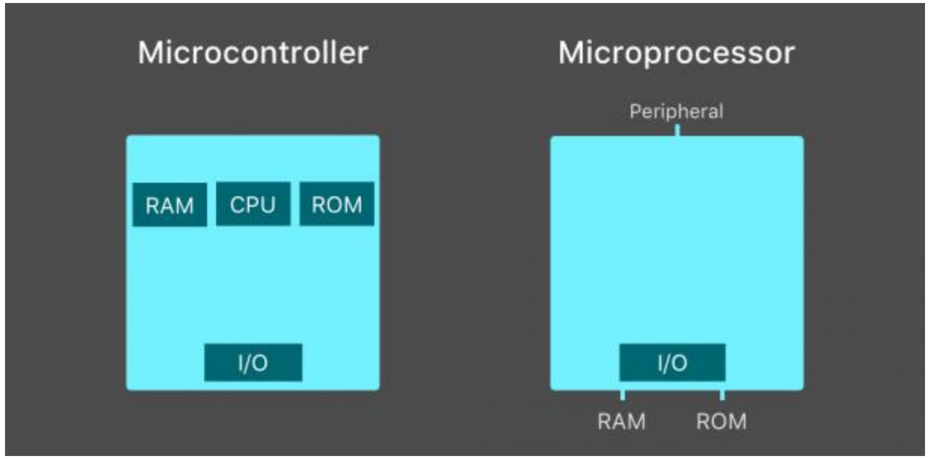
- A compact integrated circuit designed to govern a specific operation in an embedded system.
- Typically includes a processor, memory and input/output (I/O) peripherals on a single chip
- Most IoT applications have more than just a sensor added to a physical object and invariably comes with an internet connected microcontroller making it smart

Source: https://internetofthingsagenda.techtarget.com/definition/microcontroller

Source: https://electrobes.com/product/7782/

Comparison with conventional microprocessors

- Less expensive and use less power
- Have built in RAM, ROM or other peripherals on chip, while microprocessors have to interface with them through their pins
- Less computation power than a microprocessor
- Dedicated specifically to executing a task or a small set of tasks



Source: https://iiot-world.com/connected-industry/a-guide-for-selecting-the-right-microcontroller-for-your-iot-project/

Elements of a Microcontroller

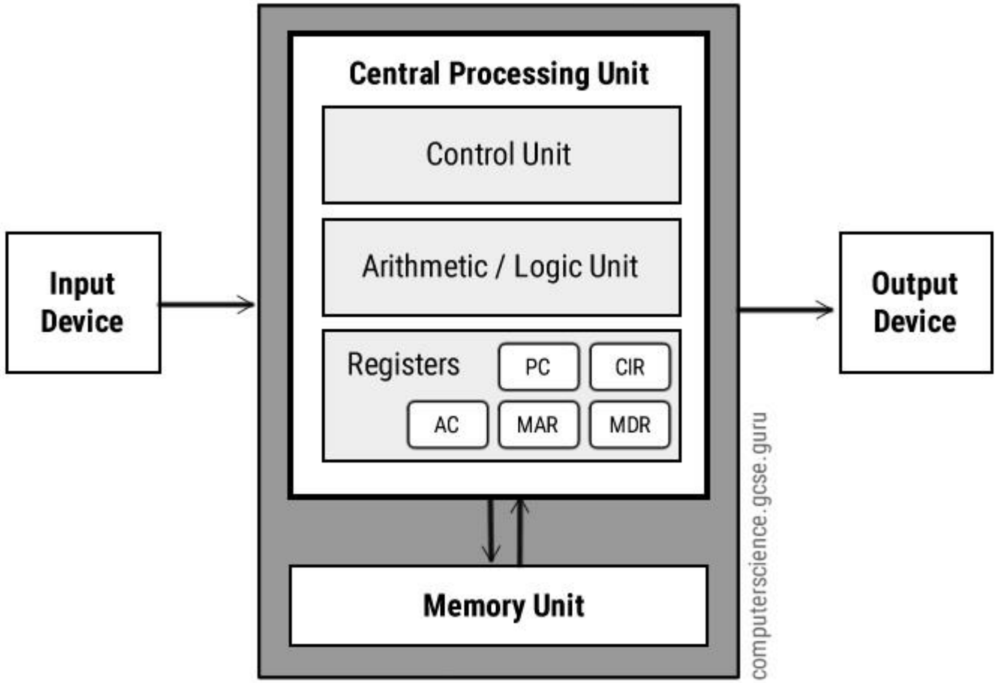
- **Processor (CPU)**
  - Processes and responds to various instructions that direct the microcontroller's function
  - Includes basic arithmetic, logic and I/O operations
  - Also performs transfer operations, which communicate commands to other components
- **Memory**
  - Program Memory – Stores the instructions that the CPU carries out and is non volatile
  - Data Memory – Temporary data storage, while instructions are executed. It is volatile

Elements of a Microcontroller

- **I/O Peripherals**
  - Interface for the processor to the outside world, for e.g., GPIOs, I2C, SPI, UART, timers, etc
  - The input ports receive information and send it to processor in binary format
  - The processor receives the data and sends necessary instructions to output devices

Processor Architecture

- Von Neumann Architecure
  - ➢Single shared memory for program and data
  - ➢Single bus for memory access
  - ➢An arithmetic unit
  - ➢Program control unit
  - ➢Operates fetching and execution cycles serially

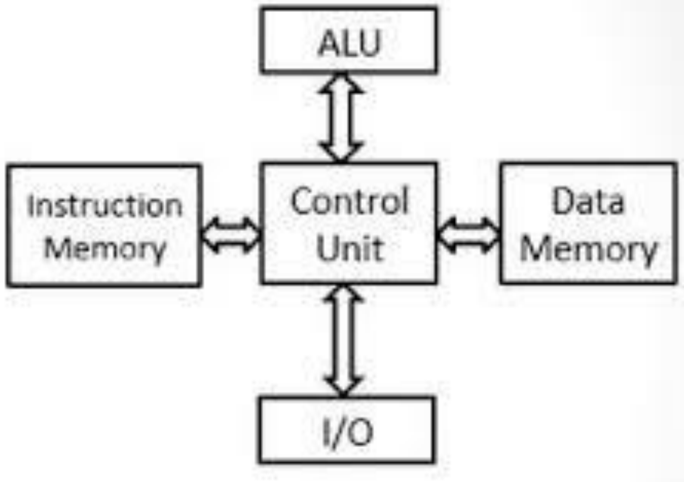


Source: https://www.computerscience.gcse.guru/theory/von-neumann-architecture

Processor Architecture

Source: https://www.thecrazyprogrammer.com/2019/02/difference-between-von-neumann-and-harvard-architecture.html

- Harvard Architecture
  - Two separate memory spaces for program code and data
  - Two corresponding address buses
  - Two data buses
  - Offers fetching and execution in parallel



Harvard Model

Supporting Elements

- **Analog to Digital Converter (ADC)**
  - ➢ Analog signals can be continuous and provide infinite number of different voltage values, while digital circuits work with binary values, i.e., a logic HIGH or a logic LOW
  - ➢ A circuit that converts analog signals to digital signals
  - ➢ Samples the analog voltage at an instant and produces the digital output code that represents the analog voltage
  - ➢ Sampling rate and bit resolution are important parameters
  - ➢ Works using the Sample, Hold, Quantize and Encoding stages
  - ➢ Allows processor to interface with external analog devices, such as sensors
- **Digital to Analog Converter (DAC)**
  - ➢ Performs the inverse function of ADC, i.e., converts outgoing signals from the processor to external analog components
- **System Bus**
  - ➢ A connecting wire/set of wires that links all the components of a microcontroller together

Microcontroller Features

- **Bits**
  - Microcontroller processor varies from simple 4-bit, 8-bit or 16-bit processors to more complex 32-bit or 64-bit processors
  - 4-8 bits used in remote controls and other constrained applications – not fit for IoT applications
  - 8-bit: Used in cost constrained applications. Can be used in IoT applications with an RTOS running a simple control loop
  - 16-bit: Not very common in IoT
  - 32-bit: Normally used in IoT applications unless cost constraints required 8-bit architecture
  - 64-bit: Reserved for high end systems
  - Impacts the speed at which they are able to perform non-trivial computations
- **Architecture**
  - Majority use ARM, MIPS or x86

Microcontroller Features

- **RAM**
  - Volatile fast-access memory
  - The more the better, but it comes with its cost
  - Can vary from 16 bytes on 8-bit MCUs to about 4.5 MB on 32 and 64-bit MCUs
- **Flash**
  - Non volatile memory, essential for offline storage
- **GPIO**
  - General purpose i/o pins used to connect sensors and actuators to the MCU
  - Number of pins may be a parameter for choosing a certain MCU for your IoT application
- **Connectivity**
  - Options how the microcontroller can connect to the internet, i.e., Wi-Fi, Ethernet or some other means.
  - Any IoT application requiring connected sensors will need this feature
- **Power Consumption**
  - Critical when the device has to rely on battery or other energy source like solar power
  - Gives an indication regarding how power hungry the microcontroller is

How to choose the microcontroller?

- Compatibility
  - ➢Does it support the sensors/actuators that you want to use
  - ➢Does it have enough input/output ports based on the sensors/actuators you use
- Architecture
  - ➢Is the architecture sophisticated to handle the complexity of your program
- Memory
  - ➢Does MCU come with enough RAM and Flash memory
  - ➢In case there is possibility of future updates, it is better to have extra memory
- Availability, Power and Cost
- Internet and other Communication Protocols
- Development Support

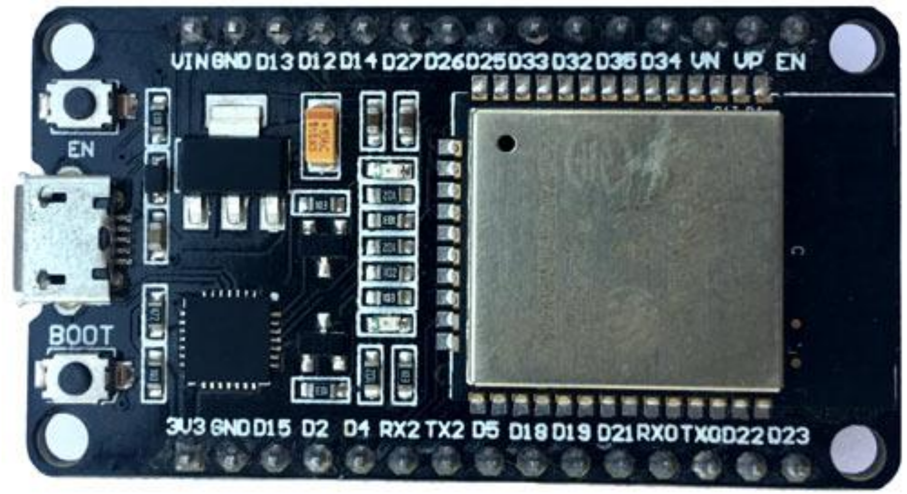
IoT Hardware Platforms

- Particle.io
  - ➢ Most comprehensive all in one IoT hardware platform that offers connectivity, device cloud and apps
  - ➢ All Particle's microcontroller boards are enabled to communicate over either Wi-Fi, cellular (2G/3G/LTE) or BLE
  - ➢ Their microcontrollers are controlled by a special OS, which enables easy integration of devices with particle's device cloud and apps
  - ➢ Open source boards with lot of support
  - ➢ OTA updates possible

Source: https://circuitdigest.com/article/top-hardware-platforms-for-internet-of-things-iot

IoT Hardware Platforms

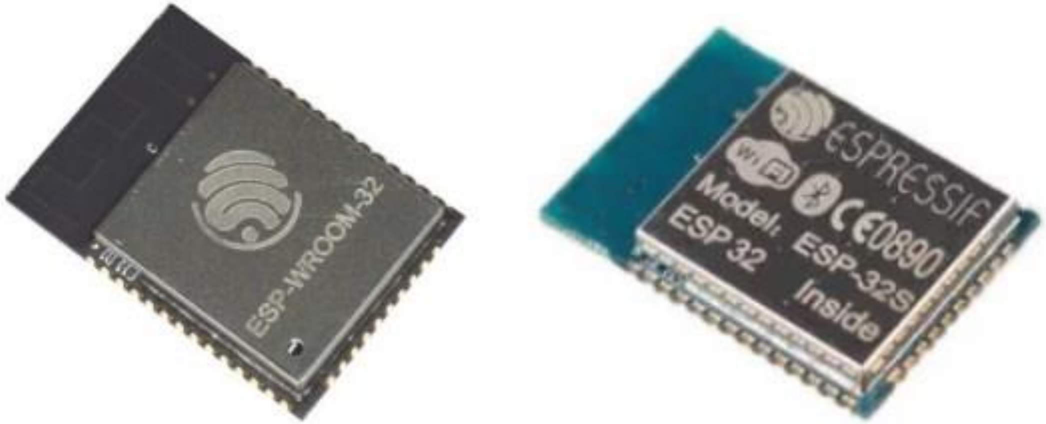
- Espressif ESP8266 Boards
  - ➢Low cost, low power and easy to use
  - ➢Initially used as a bridge to connect microcontrollers to wifi networks
  - ➢Can be used as either a WiFi module connected to other microcontrollers or used in standalone mode
  - ➢Small form factor


VIN GND D13 D12 D14 D27 D26 D25 D33 D32 D35 D34 VN VP EN
EN
BOOT
3V3 GND D15 D2 D4 RX2 TX2 D5 D18 D19 D21 RX0 TX0 D22 D23

Source: https://circuitdigest.com/article/top-hardware-platforms-for-internet-of-things-iot

IoT Hardware Platforms

- ESP32 – Main features
  - ➢ Tensilica LX6 dual core processor at 240 MHz
  - ➢520 Kb of SRAM memory
  - ➢WiFi 802.11 b/g/n connectivity with support for WEP, WPA/WPA2
  - ➢Bluetooth connectivity (classic and LE)
  - ➢32 I/O pins with built in peripherals
  - ➢Hardware acceleration for security algorithms



Source: http://www.lucadentella.it/en/2016/12/03/esp32-1-introduzione/

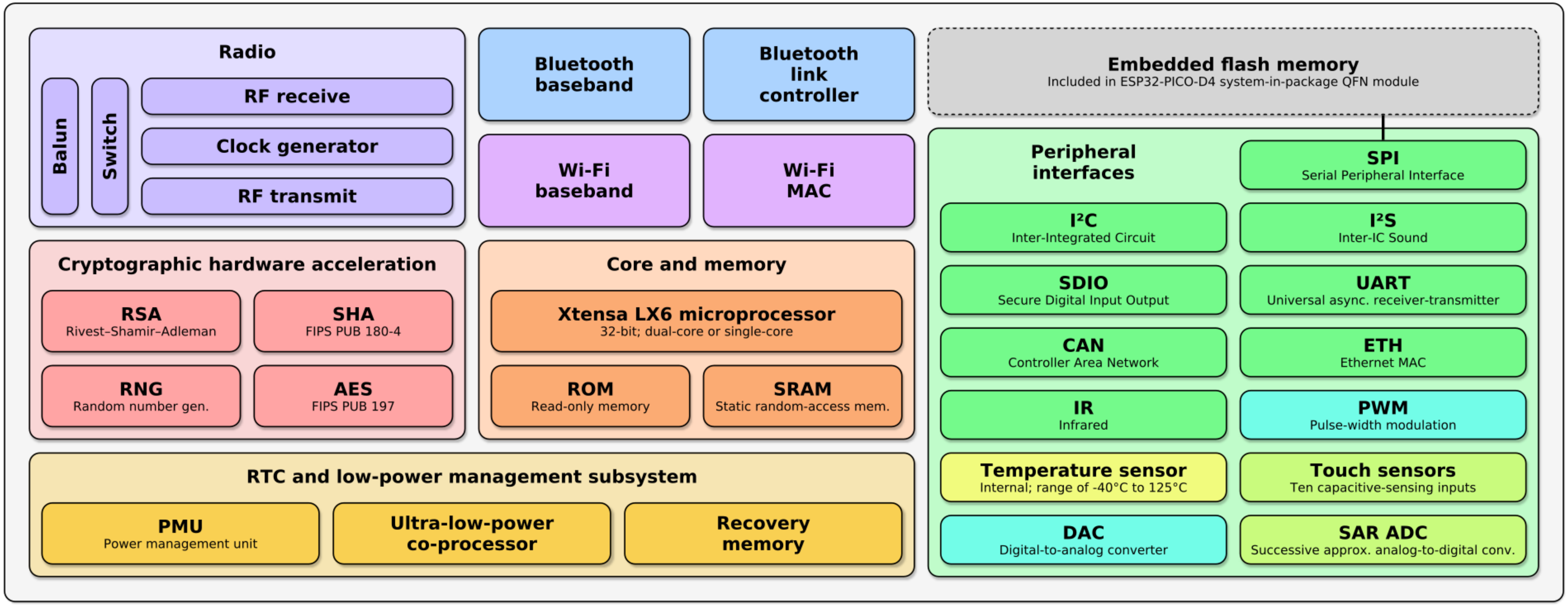
IoT Hardware Platforms

- Single board based computer and runs on Linux
- Different boards with extremely powerful processors (1.4 GHz 64-bit quad core processor in Pi 3 Model B+)

Raspberry Pi

ESP32 functional block diagram

Espressif ESP32 Wi-Fi & Bluetooth Microcontroller — Function Block Diagram



Radio

Balun

Switch

RF receive

Clock generator

RF transmit

Bluetooth baseband

Bluetooth link controller

Wi-Fi baseband

Wi-Fi MAC

Embedded flash memory
Included in ESP32-PICO-D4 system-in-package QFN module

Cryptographic hardware acceleration

RSA Rivest–Shamir–Adleman

SHA FIPS PUB 180-4

RNG Random number gen.

AES FIPS PUB 197

Core and memory

Xtensa LX6 microprocessor 32-bit; dual-core or single-core

ROM Read-only memory

SRAM Static random-access mem.

RTC and low-power management subsystem

PMU Power management unit

Ultra-low-power co-processor

Recovery memory

Peripheral interfaces

SPI Serial Peripheral Interface

I^2C Inter-Integrated Circuit

I^2S Inter-IC Sound

SDIO Secure Digital Input Output

UART Universal async. receiver-transmitter

CAN Controller Area Network

ETH Ethernet MAC

IR Infrared

PWM Pulse-width modulation

Temperature sensor Internal; range of -40°C to 125°C

Touch sensors Ten capacitive-sensing inputs

DAC Digital-to-analog converter

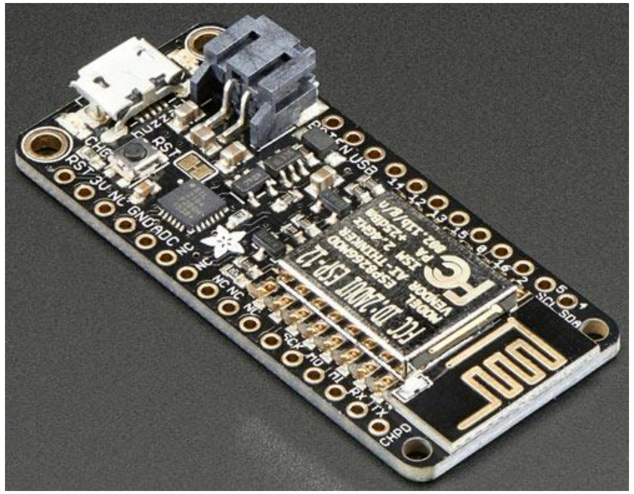
SAR ADC Successive approx. analog-to-digital conv.

IoT Hardware Platforms

- Intel IoT development boards
  - ➢Huge processing capabilities
  - ➢Most popular is Intel Edison
  - ➢Dual core, Dual threaded Intel Atom CPU at 500 MHz and a 32-bit Intel Quark microcontroller which runs at 100 Mhz

Source: https://circuitdigest.com/article/top-hardware-platforms-for-internet-of-things-iot

IoT Hardware Platforms



Adafruit Range of boards

Arduino IoT Product Line

Thank You