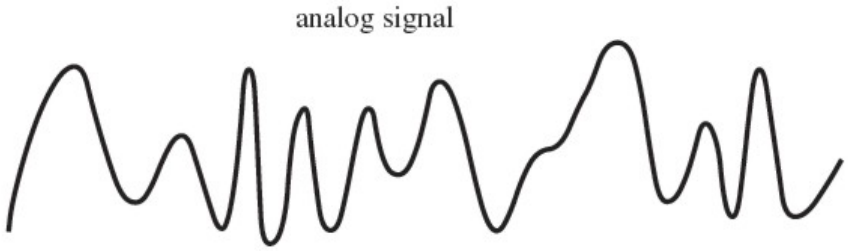
Controllers

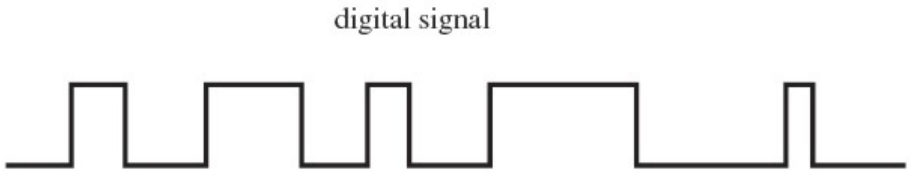
Analogue vs Digital Signals Reminder

For this lesson we are focusing on electrical signals which are split into two forms:

- Analogue signals are continuous and change smoothly over time

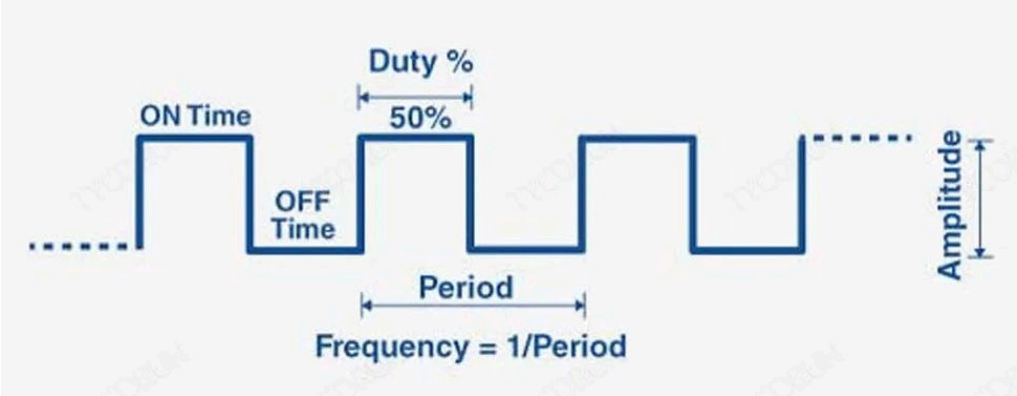


- Digital signals are discrete and therefore have set values which they change between



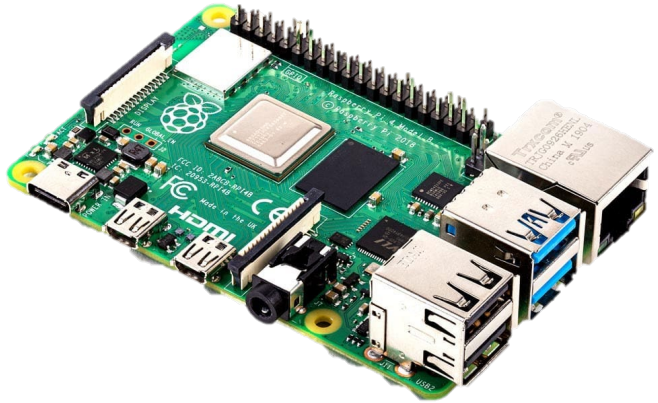
PWM Reminder

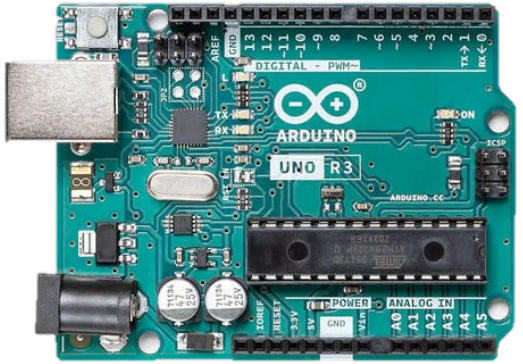
- A technique to control power by rapidly switching a signal between ON and OFF states.
- Simulates an analogue output using a digital signal
- Used for controlling motors, LEDs, and power regulation

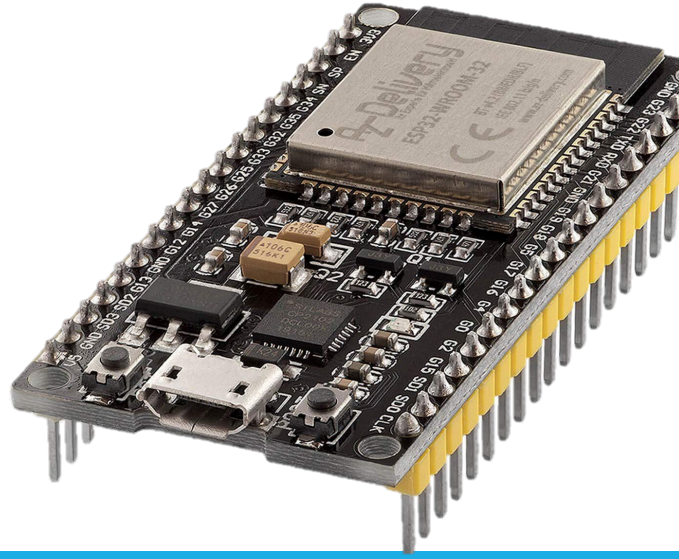


What are controllers?

- Controllers are objects that link to sensors and actuators
- They facilitate communication between sensors and actuators
- They allow us to perform calculations with sensor inputs

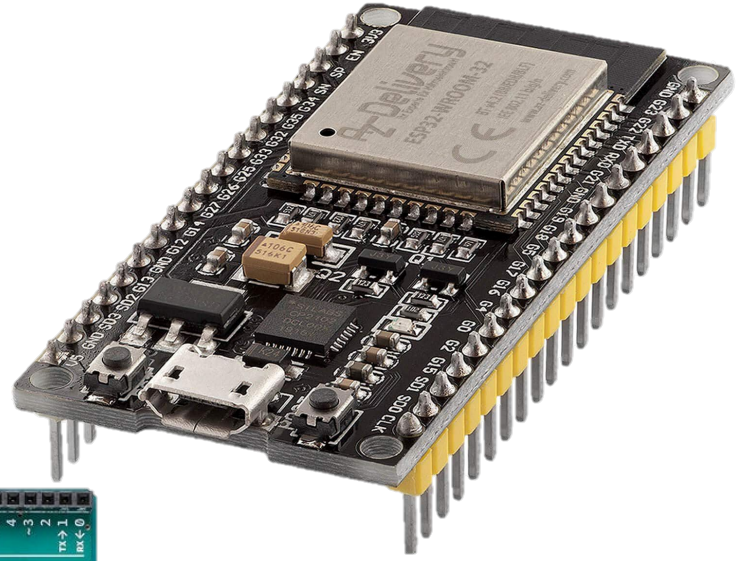


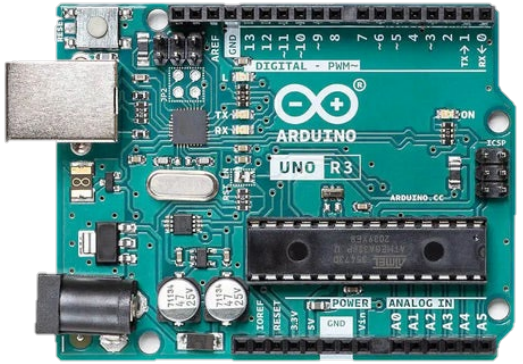




What are microcontrollers?

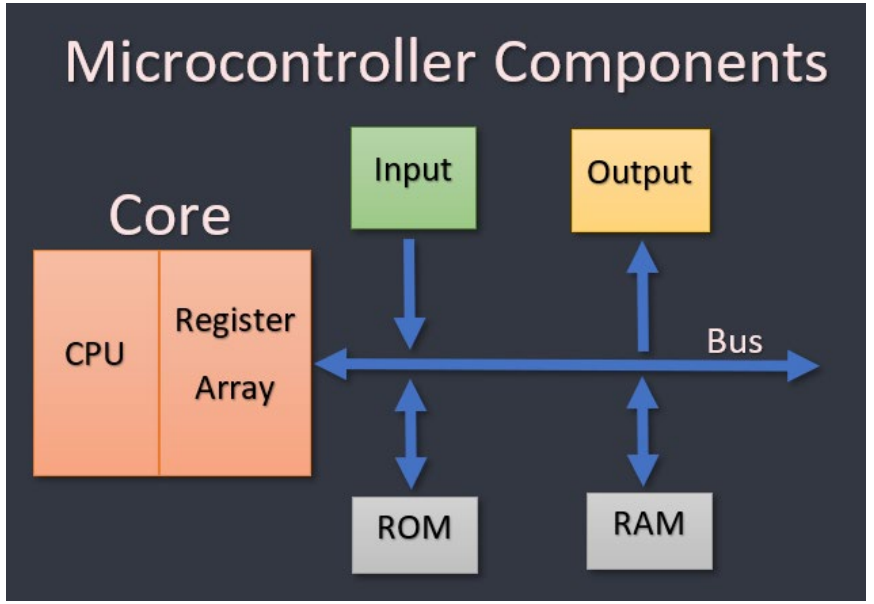
- Microcontrollers are small computers that act as controllers
- They differ from most regular computers as they are optimised for a specific task
- They often have lots of I/O (input/output) ports for communicating with lots of sensors and actuators





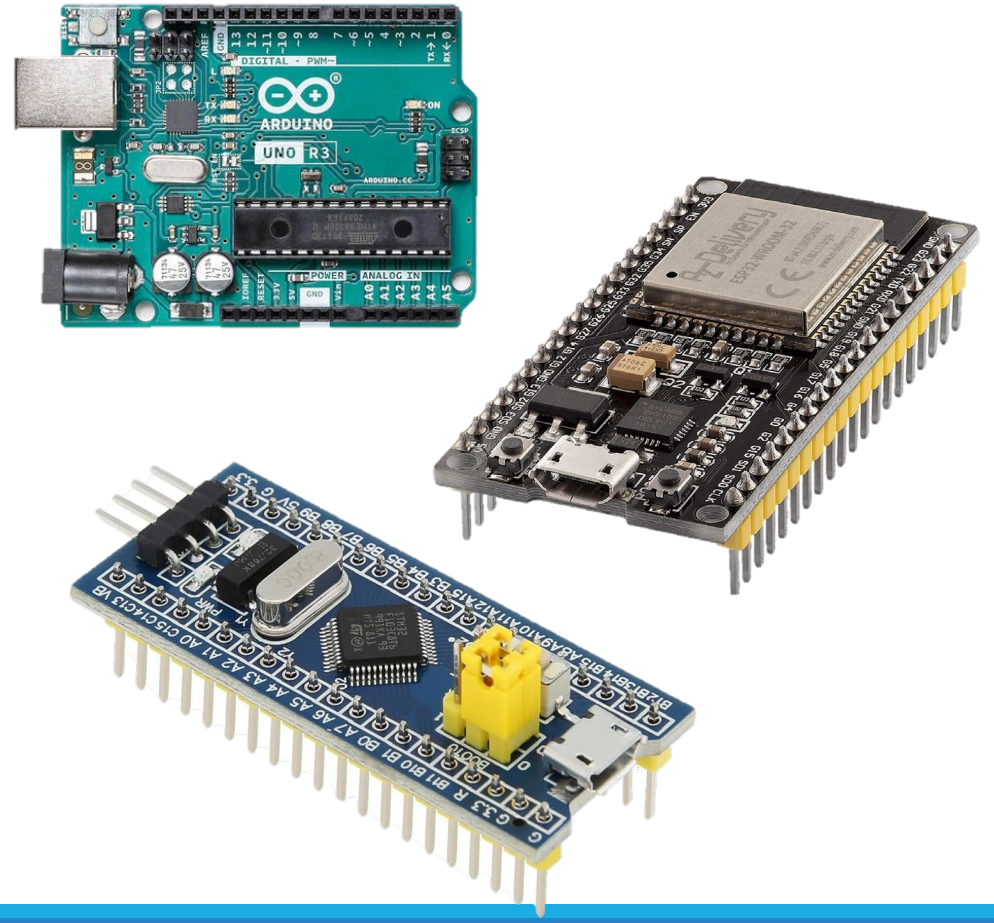
Components of a microcontroller

- Micro controllers are made of the following key components:
  - **Central Processing Unit (CPU):**
    - The brain of the microcontroller
    - Processes instructions and controls everything
  - **Memory:**
    - ROM (Read-Only Memory): Stores the program/code permanently.
    - RAM (Random Access Memory): Temporary memory for running tasks.
  - **I/O Pins:**
    - Connects to the actuators and sensors



Most Common Microcontrollers

- ATmega328P (Arduino Uno) – the most used microcontroller by both hobbyists and industry
- ESP32 – much more powerful than the ATmega328P includes built in Wi-Fi and Bluetooth capabilities
- STM32 – Used a lot for industrial and high-performance applications

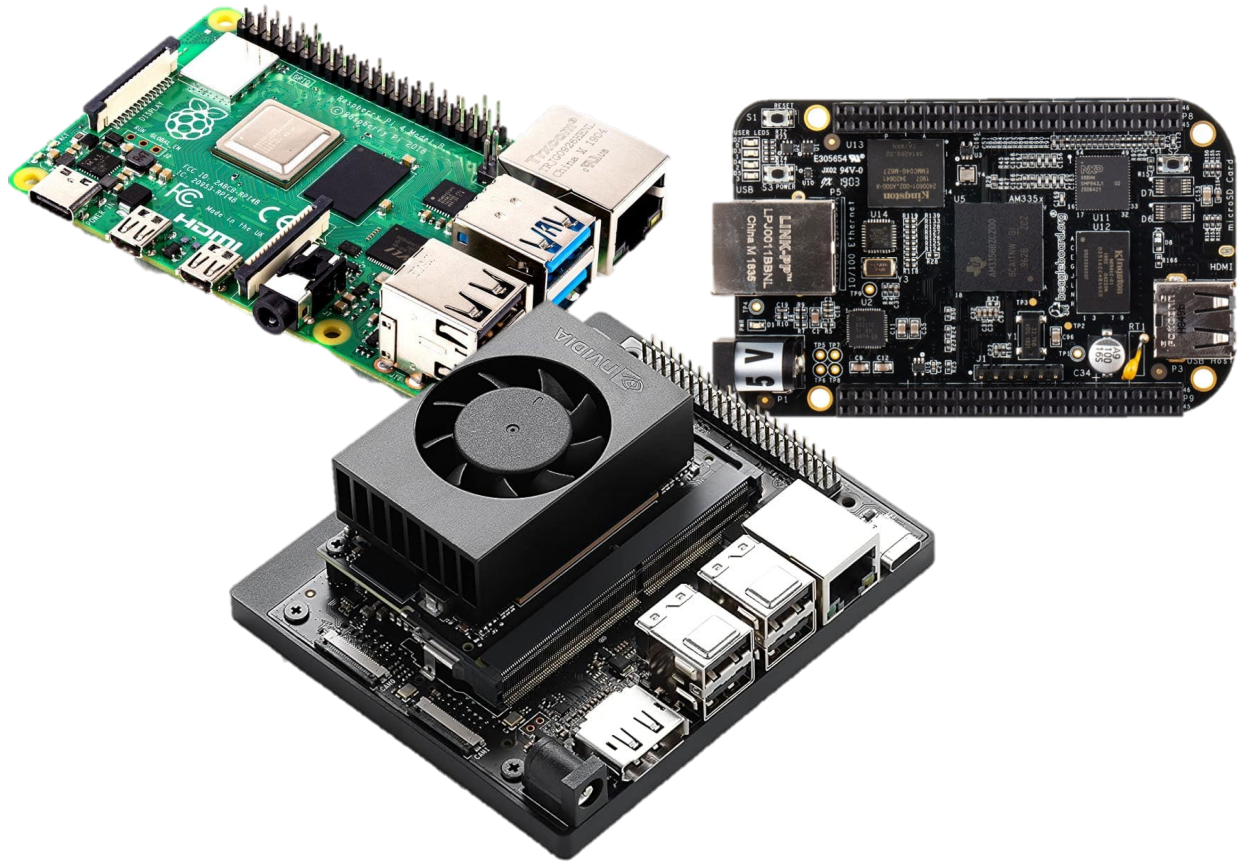


Picking a microcontroller

Microcontroller (price)	Clock Speed	Memory	Bit Size	GPIO Pins	Wifi/Bluetooth built-in	Power Usage	Use cases	Usability
ATmega328P (£22-£25)	16MHz	32KB Flash 2KB RAM	8-bit	23	No	Low Power (15 mA)	Low power or battery powered	Easiest
ESP32 (£7-£9)	Up to 240MHz	4MB Flash 520KB RAM	32-bit	34+	Yes	Higher Power (160 mA)	Anything that needs wireless	Moderate
STM32 (£30-£35)	Up to 72MHz	64-512KB Flash 20KB RAM	32-bit	37+	No	Middle Power (30-100mA)	Industrial control	Difficult

MicroComputers

- Microcomputers are miniaturised computers that are used for specific tasks
- They have a full OS allowing us to do much more complex tasks
- Most common are Raspberry Pi Series, BeagleBone Series and Jetson Nano
- They have higher power requirements than microcontrollers



Picking a MicroComputer

Microcontroller	Price	Power Consumption	Processing Power	GPIO Pins	Best for
Raspberry pi 4/5	£50-£100	Most Power Hungry	Medium Power	40 Pins	General purpose, all rounder
BeagleBone Black	£50-70	Least Power Hungry	Least Powerful	69 Pins	Industrial Control, Automation, Robotics
Jetson Nano	£80-£120	Medium Power Hungry	Most Powerful	40 Pins	AI, Machine Learning, Computer Vision

Microcontroller vs Microcomputers

- We need a microcomputer when we are doing anything which needs significant processing power
- For instance, if we wanted to detect an animal on a video feed, we would need a microcomputer as microcontrollers are not powerful enough