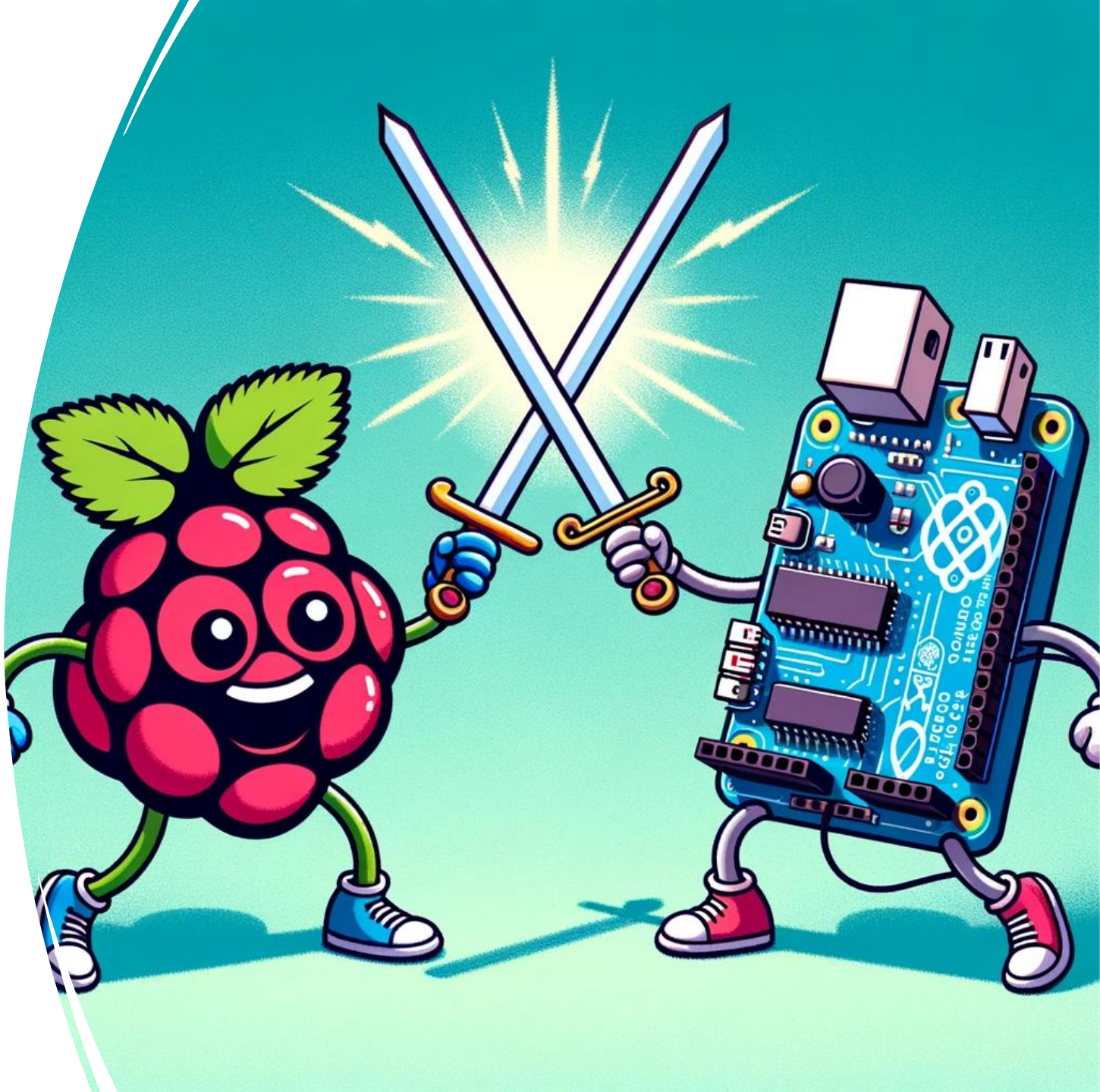
Single Board Computers

Frank Walsh

2025

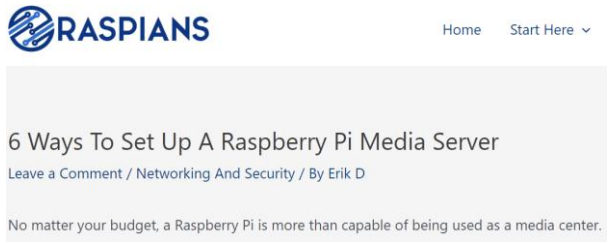


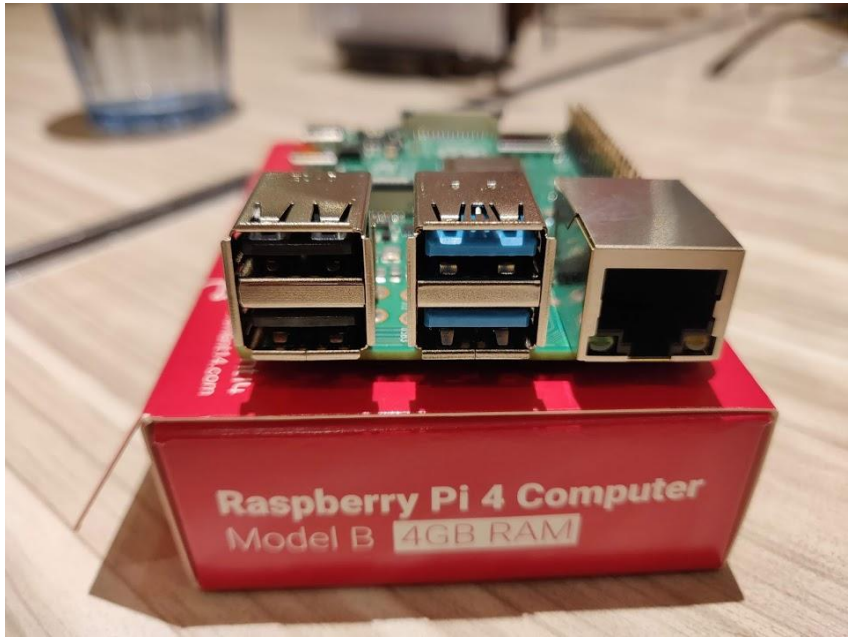
Single Board Computers (*and a little about µC!)*

- Single Board Computer – What
- Microcrontrollers
- Raspberry Pi(RPi) Introduction
- Getting Started with the RPi
- Conventional vs Headless+
- Connecting Hardware+ SenseHAT

What is a Single Board Computer(SBC)?

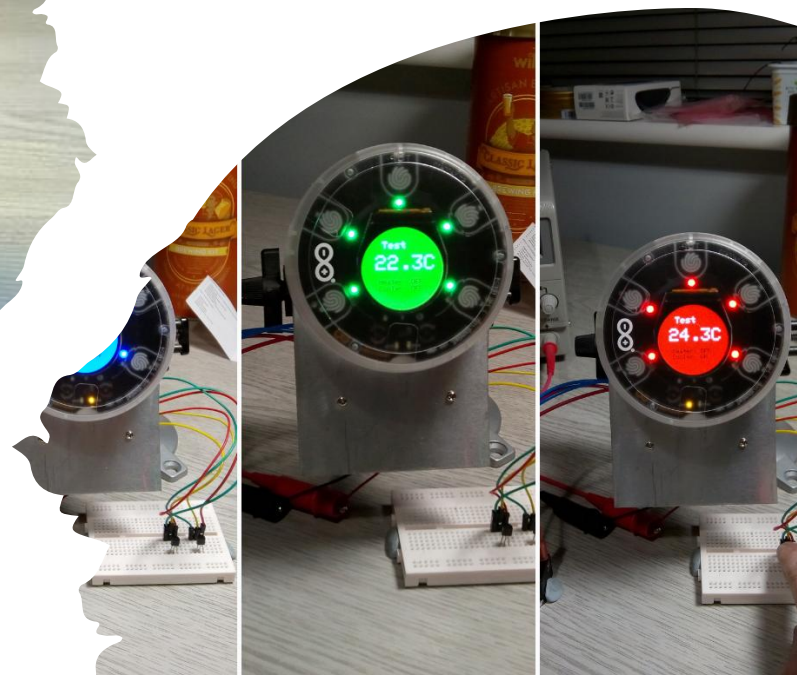
- A complete computer on a single board
  - CPU, RAM, storage, and I/O ports.
- Runs a full-fledged operating system
  - Linux distributions
- Capable of multitasking, web browsing, and running software applications.
- Examples: Rpi 4.





What is a Microcontroller?

- A compact computer on a single chip designed for specific operations in embedded systems.
- Contains a CPU, small RAM, storage, and operates without a full OS.
- Executes pre-programmed tasks, ideal for hardware interactions.
- Examples:
  - Washing machines (to control cycles)
  - Microwaves (to read buttons and run the timer)
  - Cars (to monitor engine sensors)
  - Toys and remote controls



SBCs vs. Microcontrollers Key Differences

Microcontrollers

- Designed for specific tasks — no operating system overhead
- Continuously loop, waiting for sensor input and responding instantly
- Can **guarantee predictable response times**
- Use **interrupts** to react immediately to events (e.g. triggered by a tilt sensor in a car)

Single-Board Computers (SBCs)

- Run full operating systems (e.g. Linux)
- Handle many tasks via scheduling and background processes
- **Response times vary** — not suitable for strict real-time control

Summary:

Microcontrollers can operate in *real-time*
SBCs generally **cannot**

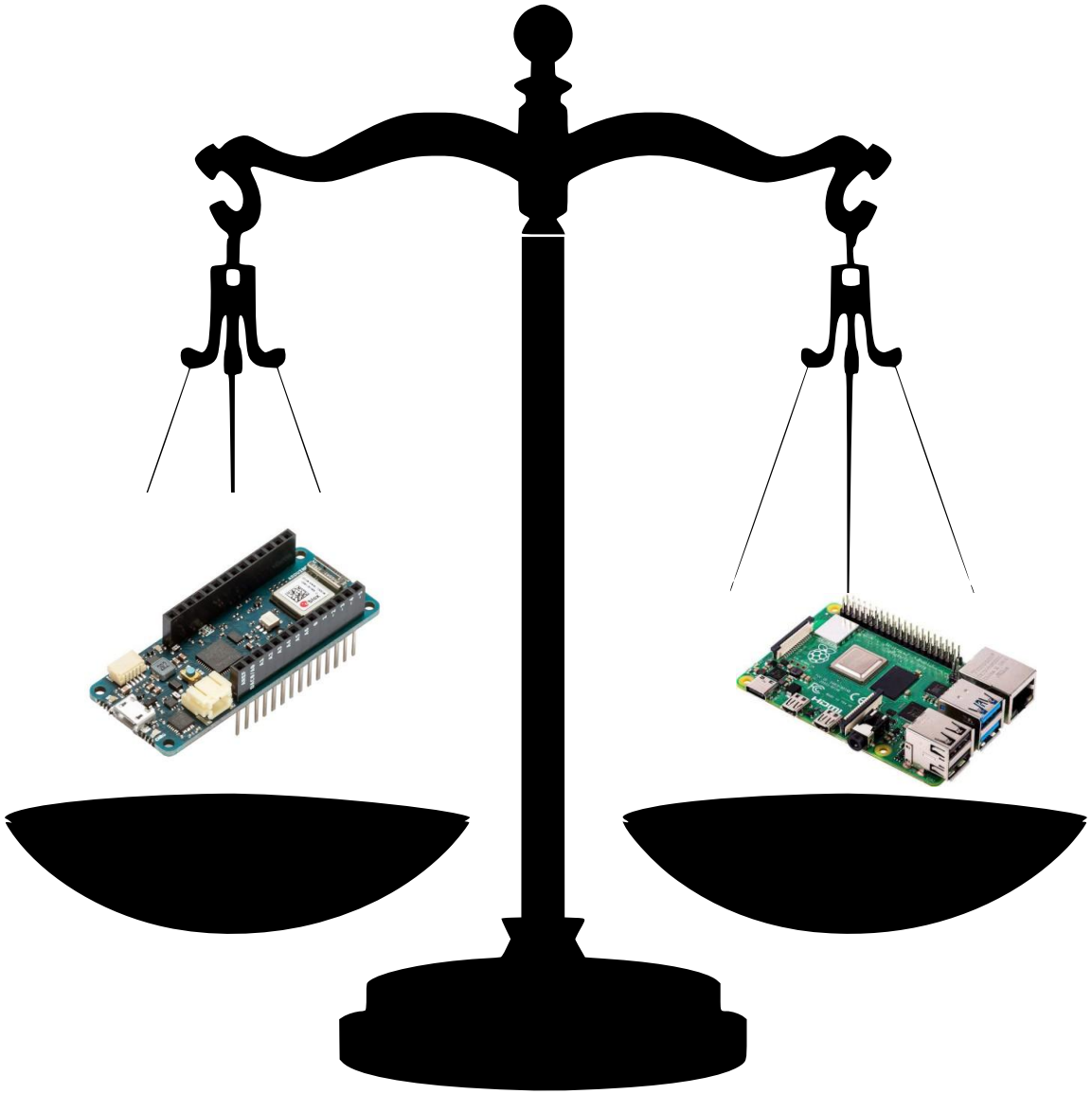
SBCs vs. Microcontrollers Key Differences

- **Power Consumption:** Microcontrollers is more energy-efficient than Raspberry Pi.
- **Complexity:** Raspberry Pi can handle intricate,complex tasks due to its robust CPU architecture, memory resources and OS.
- **Boot Time:** Microcontrollers start nearly instantly, while Raspberry Pi requires boot-up time(like your laptop).
- **Cost:** Microcontrollers are generally cheaper than SBCs.

- **Development:** Raspberry Pi offers a typical Operating System and desktop-like environment, whereas Microconrollers requires external coding and uploading.

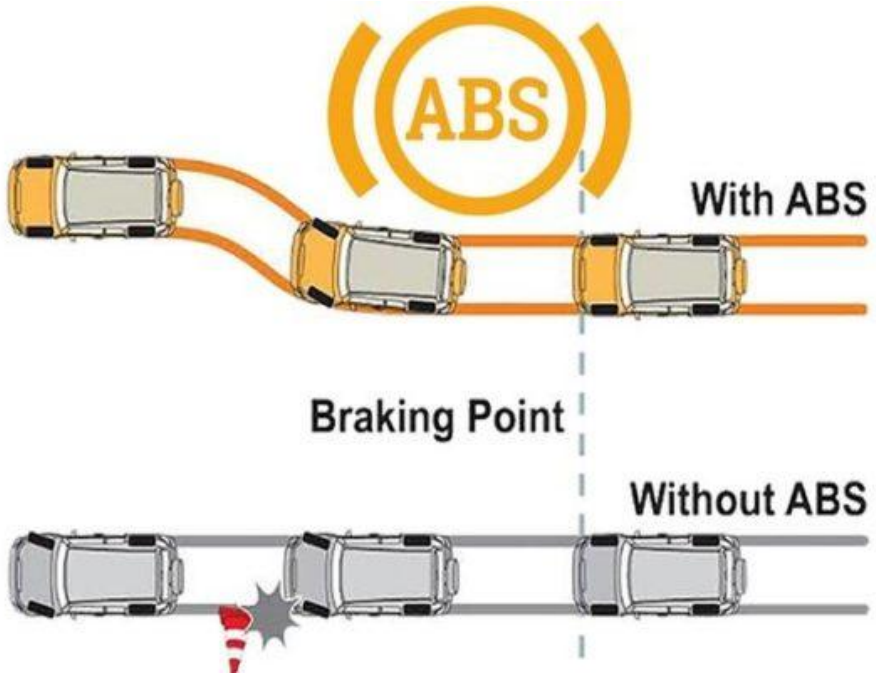
Which one???

- **Task Simplicity:**
  - Use Microcontroller for simpler, hardware-focused tasks.
  - Use Raspberry Pi for complex tasks or when a full OS is beneficial (e.g. image processing, DB I/O).
- **Power Constraints:** For battery-operated or energy-efficient systems, Microcontroller is often a better choice.
- **Integration:** Raspberry Pi is ideal for projects that need internet connectivity, computation & processing, or integration with complex software.
- **Budget:** Consider cost implications, especially for large scale or commercial projects.



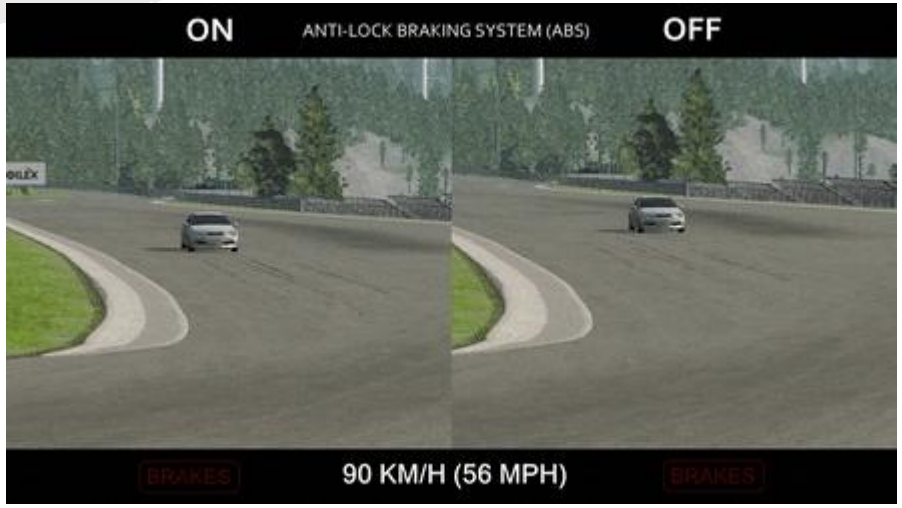
Example Use Case1: ABS

- **Anti-lock Braking System (ABS)**
  - ABS is a safety anti-skid braking system that prevents the wheels from “locking up” during braking, which helps the driver maintain control.
- **How it works:**
  - Wheel Speed Sensors constantly measure the speed of each wheel and send this data to the ABS controller.
  - ABS Controller processes the wheel speed data and determines if a wheel is about to lock up.
  - If the ABS Controller detects a wheel is about to lock, it decreases the pressure to the brake until the wheel starts moving again.
- **Safety Critical System: Has to Work Always, Has to be Reliable, Has to be Fast, Can’t be waiting around for processor timeslot**



Example Use Case1: ABS

- The ABS controller needs to operate in real-time.
- When a driver steps on the brake pedal, the ABS must instantly assess and react to wheel slip conditions to prevent skids
- A delay in processing could reduce the effectiveness of the ABS, leading to potential accidents.
- **Microcontroller** is the best option here and are used extensively in the automotive industry where safety, performance, and reliability are critical.(Incorporated into ECUs(electronic control units)



Example Use Case2: Licence Plate Recognition (LPR)

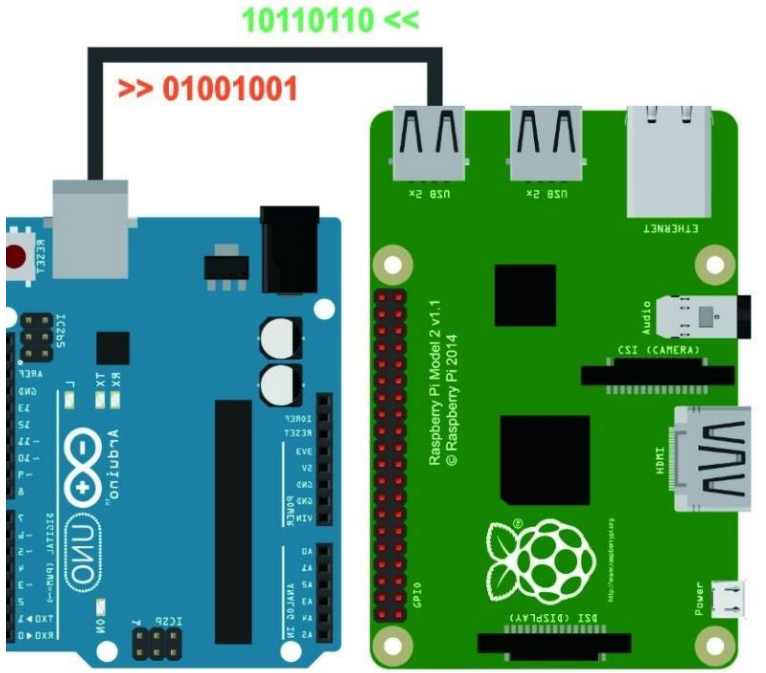
- LPR systems automate the process of identifying a vehicle's license plate to manage access, billing, security….
- **Capture:** Cameras take images of vehicles' as they come and go.
- **Image Processing:** The system processes these images to enhance clarity, adjust lighting, and prepare the image for plate extraction.
- **Plate Extraction:** Program identify the rectangular region of the image containing the license plate.
- **Optical Character Recognition:** The system then processes this extracted portion to recognise and read the characters on the license plate.
- **Database:** The licence plate number is used to query/update a DB

Example Use Case2: Licence Plate Recognition (LPR)

- A lot of computationally expensive processing here (image processing). May need a lot of CPU power and memory.
- Short period to acquire, process and recognise licence plate is acceptable.
- Quick, but not exact real-time processing, is OK.
- Nobody will be hurt if it fails – not safety critical.
- A networked/connected **Single Board Computer** connected to Camera is a viable option here.

Can you use both together?

- Yep! If you want
- Why?
  - Microcontrollers are reliable, real-time and interface well with sensors (analog/digital sensors)
  - OS on computer have a lot of processing power/software to work on data but can crash and have security vulnerabilities like any computer.
  - Use Microcontroller to interface/control sensors and actuators
  - Use SBC to process data/connect to other networks and services.



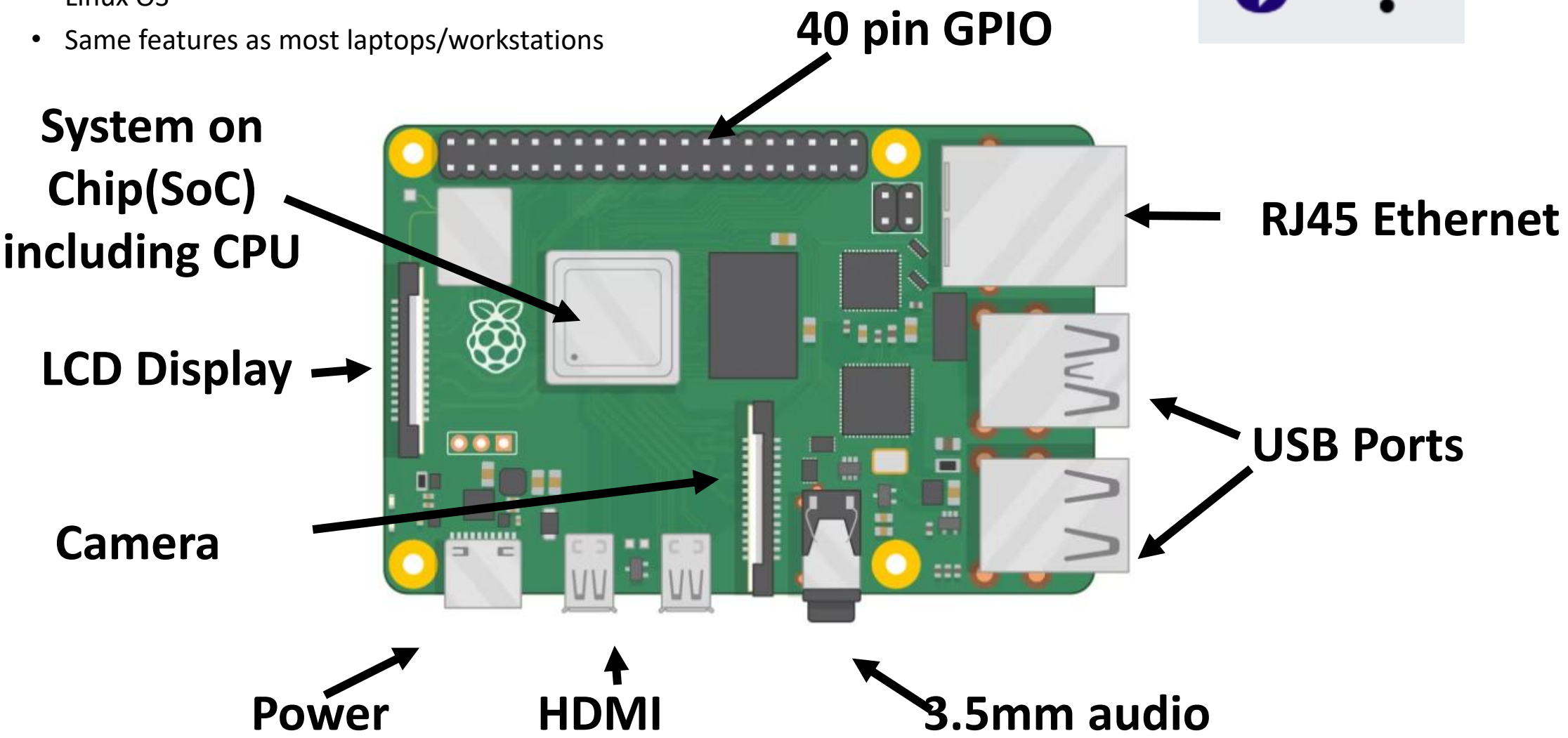
Best of Both Worlds

Arduino Uno Q

"Combines a Linux® Debian-capable Qualcomm® Dragonwing™ QRB2210 microprocessor with a real-time STM32U585 microcontroller (MCU). It’s Arduino, it’s a computer, it’s anything you want to build."

Raspberry Pi 4

- Low cost, single board computer
- Linux OS
- Same features as most laptops/workstations



Raspberry Pi History

- First launched in **2012** by the Raspberry Pi Foundation in the UK.
- Inspired by BBC Micro
- Aimed to make computing accessible to everyone.
- Evolved from the original Raspberry Pi Model B to the latest Raspberry Pi 4 and Raspberry Pi 400.

1981

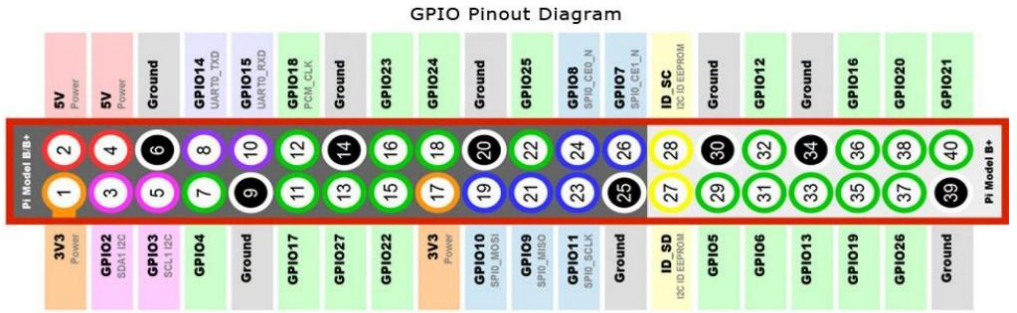
2016

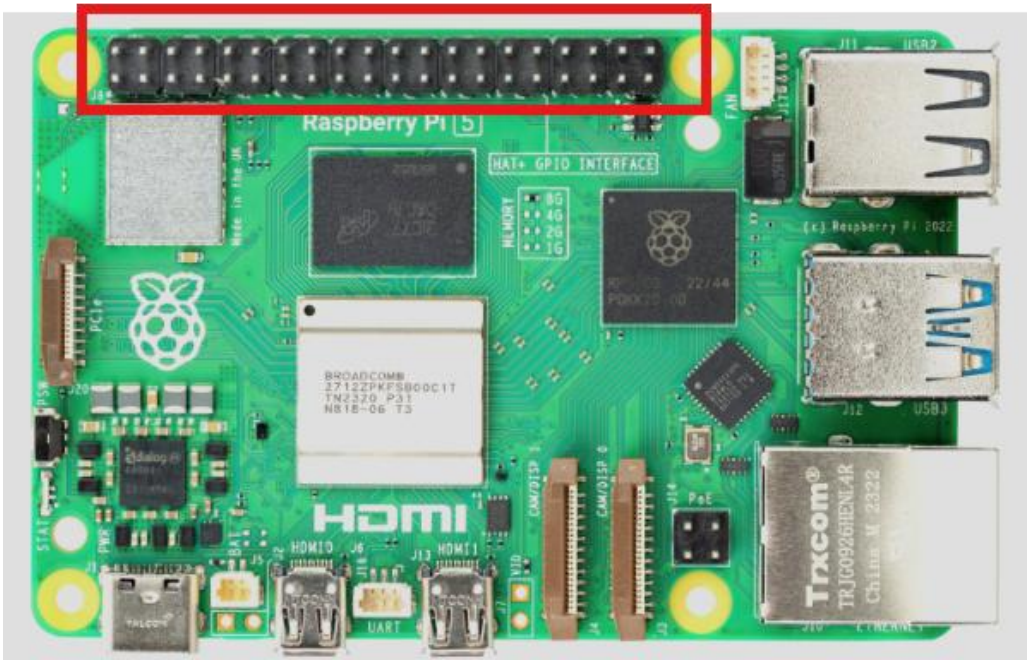
Raspberry Pi Models

- **Raspberry Pi 4**: 2GB, 4GB, or 8GB of RAM
- **Raspberry Pi 5**: 4GB or 8GB of RAM, significantly faster 2.4GHz quad-core Cortex-A76 CPU
- **Raspberry Pi Zero**: Ultra-compact.embedded/ lightweight applications;
- **Raspberry Pi 400**: Keyboard-integrated model containing Pi 4-class hardware, designed for an all-in-one desktop computing

GPIO Pins and Hardware Control

- **GPIO (General Purpose Input/Output)** pins allow control over electronic devices.
- Used for:
  - Sensors
  - LEDs
  - Motors
  - Cameras
- Makes Raspberry Pi ideal for robotics and IoT projects.





Popular Applications of Raspberry Pi

- **Education**: Teaching programming and computer science.
- **DIY Projects**: Smart home devices, weather stations, robots, etc.
- **Media Centers:** Turn your TV into a smart media center with software like **Kodi**.
- **Gaming**: Retro gaming consoles using **RetroPie**.

Warning - Don't fry your RPi

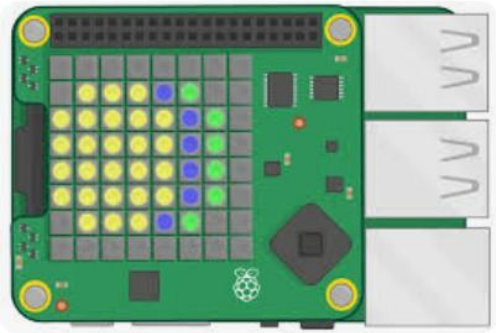
- RPis are fairly robust but...
- If using with keyboard/screen
  - Connect the USB keyboard and USB first
  - Connect the HMDI connector
  - Turn on the monitor
- Plug in the power cable
  - Do not plug in the SenseHat when the RPi is plugged in and booted into Raspian.
  - ALWAYS plug in the HAT before plugging in the power cable.

Pros and Cons of Raspberry Pi

- **Pros**:
  - Affordable
  - Versatile and customizable
  - Large community and resources
- **Cons**:
  - Limited processing power compared to full desktops and laptops
  - Usually need to get more stuff (enclosure, HATs, LCD Screens, cables)

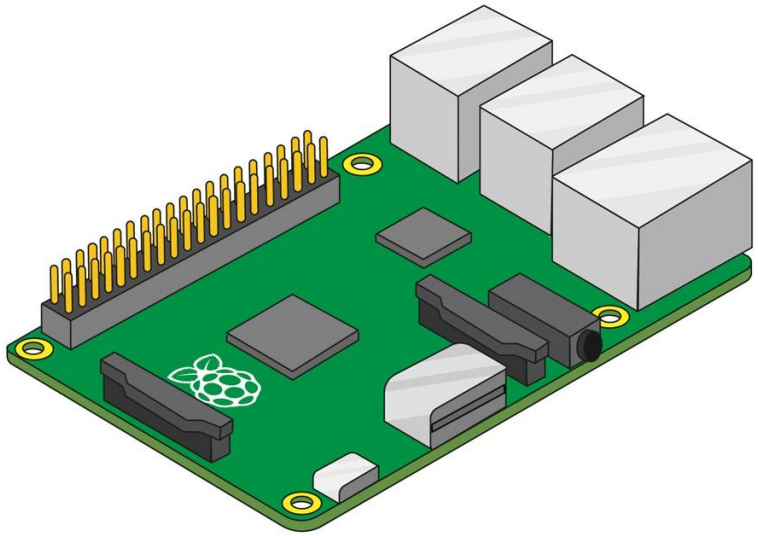
SenseHAT

- The Sense HAT (Hardware Attached on Top) is an add-on board for the Raspberry Pi featuring a collection of sensors and a programmable LED matrix
- **LED Matrix**: An 8x8 RGB LED matrix for display and visual output.
- **Sensors**:
  - Temperature
  - Humidity
  - Pressure
  - Gyroscope (orientation)
  - Accelerometer (movement)



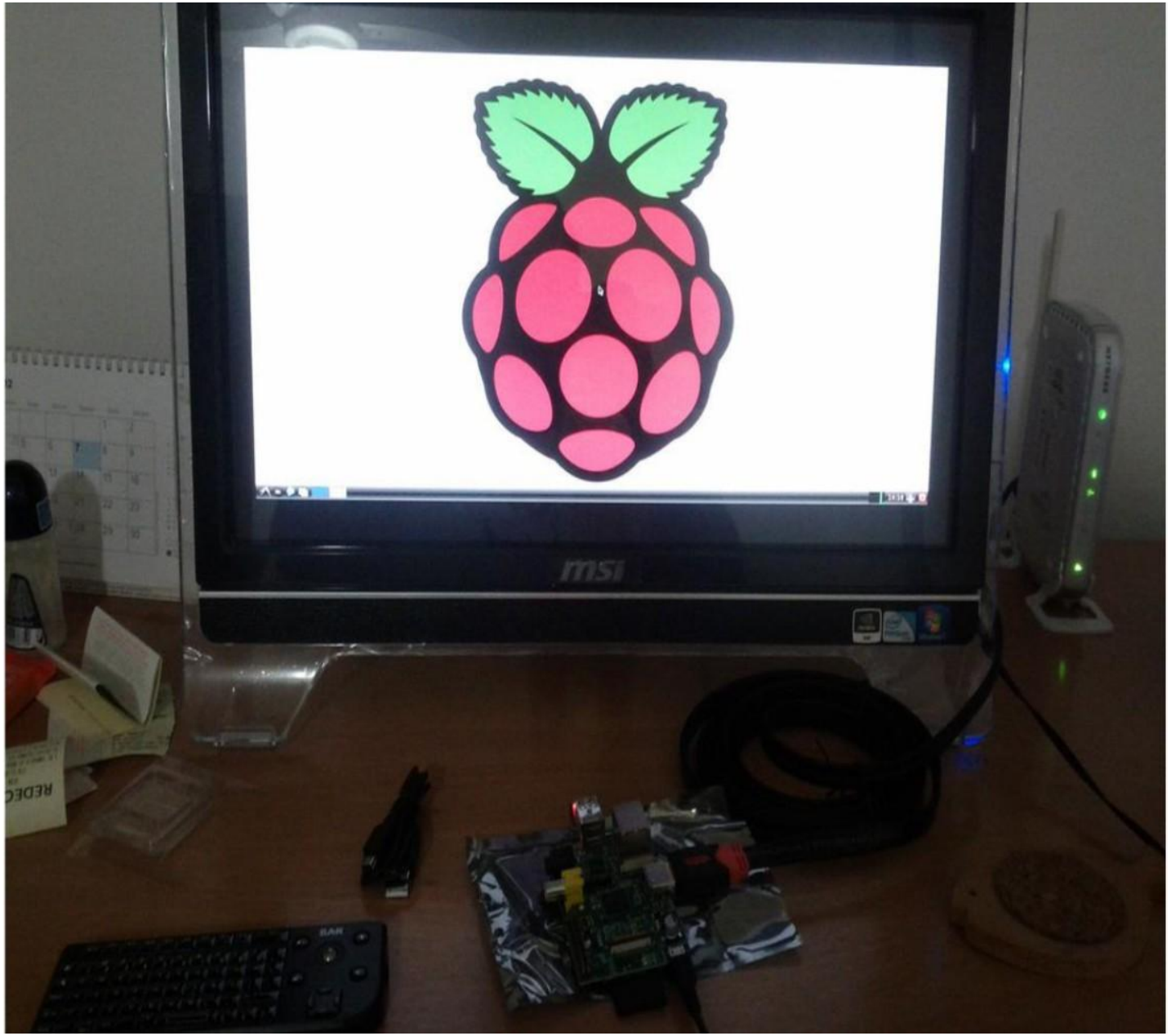
Attaching the SenseHAT

See the Lab



Getting Started - Conventional

- Raspberry Pi 3 B
- Keyboard and mouse
- HDMI display monitor
- SD Card (8 GB+ recommended)
- SD Card Reader (usually a laptop)



Getting Started –Headless

- Raspberry Pi 3 B or higher
- ~~Keyboard and mouse~~
- ~~HDMI display monitor~~
- SD Card (8 GB+ recommended)
- SD Card Reader (usually a laptop)
- Accessible WiFi network