3 Hardware

ADDRESS DATA CONTROL SIGNALS (DECODE) EXECUTE
KEY POINTS

3.1 Computer Architecture

- The **CPU (Central Processing Unit)** processes **instructions & data** that are input into the computer so that the **result** can be output
- A **microprocessor** is a type of **integrated circuit** on a single **chip**

Von Neumann Architecture: Components in a CPU

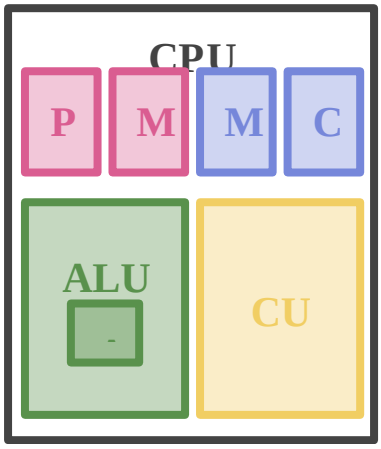
- Instructions are executed **serially** (one at a time)
- Both data and instructions are stored in the same memory unit (**RAM**)

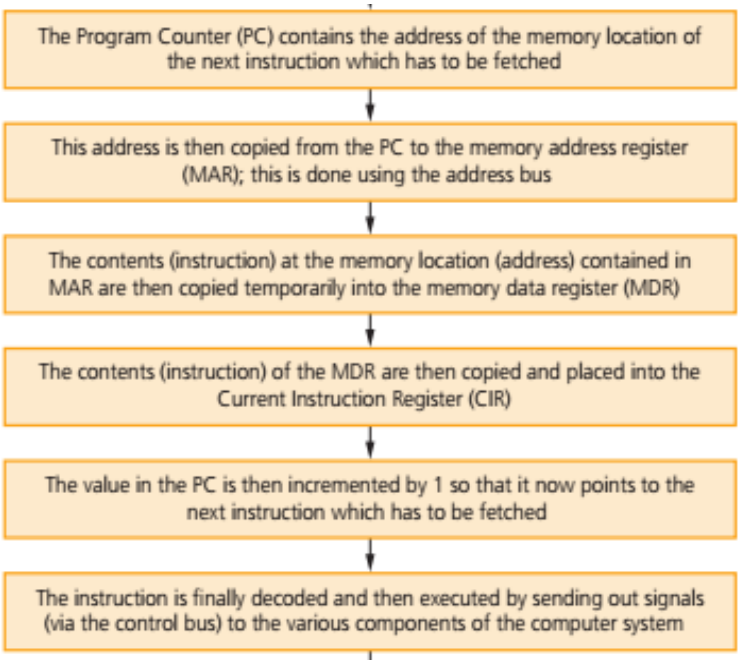
- Units:
  - **CU (Control Unit)**: controls the **flow of data** around the CPU by sending **control signals**; decodes **instructions** using an instruction set; controls the **timings of operations**
  - **ALU (Arithmetic Logic Unit)**: performs **arithmetic & logical operations**

- Registers (temporarily stores data):
  - **PC (Program Counter)**: stores the **address** of the next instruction to be fetched from memory
  - **MAR (Memory Address Register)**: stores the **address** of the data that is currently being fetched from/written to memory
  - **MDR (Memory Data Register)**: stores the **data** that has been fetched from or is being written to memory
  - **CIR (Current Instruction Register)**: stores the current **instruction** that is being decoded & executed
  - **ACC (Accumulator)**: stores the **results** of the **calculations** performed by the **ALU**

- Buses:
  - **Address bus** (unidirectional): transmits addresses from the **CPU** to **memory**
  - **Data bus** (bidirectional): transmits data from the **CPU** to **memory** or **input/output devices**
  - **Control bus** (bidirectional): transmits control signals from the **CU** to **memory** or **input/output devices**

Fetch-Decode-Execute Cycle

F	1. The **PC** holds the **address** of the next **instruction** to be fetched 2. The **address** held in PC is sent to **MAR** using the **address bus** 3. The **instruction** at the address stored in **MAR** is sent to the **MDR** 4. The **instruction** is copied to **CIR** 5. The **PC** is incremented	
D	6. The instruction in the CIR is decoded by the **CU**	
E	7. The instruction is executed by the **ALU** 8. The result is stored in the **ACC** or written to a memory location within memory	



CPU Performance

- **Core**: each core runs separate **FDE cycles** independent of each other simultaneously
  - The more cores a CPU has (dual/quad), the better the performance, as more instructions can be executed per second
  - Doubling the cores does not double the performance, as the CPU needs to communicate with each core, reducing perf.
- **Clock**: produces **timing signals** to synchronise computer operations
  - The faster the clock speed, the better the performance, as more instructions can be executed per second
  - May lead to overclocking → causes operations to be unsynchronised & CPU to overheat
- **Cache**: a temporary memory location using static RAM to hold frequently used data/instructions
  - The larger the cache, the better the performance, as more data can be stored & accessed faster

Instruction Set

- An **instruction set** is a **list of all commands** that can be processed by a CPU and are **machine code**

1. An instruction is decoded into an **opcode & operand**
2. The CPU finds the **opcode** in the processor's **instruction set** and knows what **operation to perform** on the **operand**

Embedded Systems

- An **embedded system** is a computer system (a combination of hardware & software) used to perform a **dedicated function**
- Characteristics
  - **Low power** consumption
  - **Small** physical size
  - **Low cost** to manufacture
  - Can be **controlled remotely**
  - Dedicated to a single task which allows for a **simple interface and OS**
- Devices e.g. security systems (use sensors to check for intruders and send a warning signal if an intruder is detected), lighting systems (automatic control of lighting using light sensors), vending machines (use a keypad, sensors, and actuators to automatically supply customers with an item)
  - Different to general purpose computers e.g. a personal computer (PC), laptop

3.2 Input & Output Devices

Input Devices

Input devices receive **commands & data** from the real world and convert them into **digital data**

Input Device	Uses	Benefits	Drawbacks
Barcode Scanner	- Checkout - Parcel delivery	- Faster checkouts - Automated stock control (stock is up to date, staff can reorder when stock is low) - Less chance of error due to manual entry - No need to price each item individually	- If the barcode scratched, the scanner may fail to read it. - Installation cost is high - No security as barcode can easily copied
QR Code Scanner	- Advertising products - Linking to websites - E-tickets - Show contact information	- Holds more information than a barcode - Can be scanned using a camera on a mobile device - Easy to transmit using images	- QR codes may be used to transmit malicious codes - If the URL changes or is deleted, the QR code becomes useless. Need to print again.
2D and 3D Scanners	- Scan documents, photos and objects	- Converts 2D and 3D objects into digital data which is easier/quicker to transmit	
Digital Camera	- Smartphones (read QR code, video call) - Security systems	- Instant preview and image	
Keyboard	- Entering text e.g. smartphones, laptops	- Universal, easy to use	
Mouse	- Navigating a GUI & making selections	- Intuitive	
Microphone	- Record real-world sound - Record music - Telephone calls - Voice dictation		
Touch Screen ***(resistive, capacitive, infra-red)***	- Entering text & commands on mobile devices - Cash machines - Interactive advertisements - Information screens	"+" – Advantages "-" - Disadvantages **Capacitive (e.g. commercial displays):** + Good image quality, durable, allows multi-touch - Only allow use of bare finger / stylus, sensitive to water & light **Infrared (e.g. tablets):** + Good image quality, durable, allows multi-touch - Only allow use of bare finger / stylus, sensitive to water & light **Resistive (e.g. cash machines):** + Good resistance to dust/water, can be used with fingers/gloves/stylus, cheap - Low touch sensitivity, no multi-touch, poor visibility in sunlight	

Other: card reader, keypad

Output Devices

An **output device** shows the **results of the processing** in a way humans can understand

Input Device	Uses	Benefits	Drawbacks
Actuator	- Translate energy into real-world movement of a physical object		
DLP Projector (digital light processing)	- Project computer outputs onto a **large screen** - Give **presentations** in business & education settings	- Higher **contrast ratios** - Longer **life span** → **reliable** - Smaller and lighter → **portable**	- Lower **colour contrast** - Lower **resolution** - Image has **shadows** if it is moving
LCD Projector (liquid crystal display)		- Higher **colour contrast** - Higher **resolution** - **Low power** consumption	- Lower **contrast ratios** - Shorter **life span** → less **reliable** - Less **portable**
Inkjet Printer *(thermal bubble & piezoelectric technology)*	- Printing **one-off** photos - Useful for **high volume** printing (flyers/magazines)	- Produce **high quality** images - No need to **warm up** - Small **footprint**	- Small **ink cartridges & paper trays** - Ink **smudges** (liquid ink) - Print head **not durable**
Laser Printer *(charged drum & powdered toner)*		- **Fast** at printing **high volume** - Low **cost** per page - Large **toner cartridges & paper trays**	- **Expensive** toner cartridges - More time to **warm up** - Larger **footprint**
3D Printer	- Produce **solid 3D objects**	- Create **prototype/model** (e.g. prosthetics - Models can be **transmitted digitally**	- Installation cost is high - Slow production speed - Requires technical skills
LCD Screen (liquid crystal display)	Used in TVs, monitors, tablets and phones	- **Low power** consumption - Runs at a **cool temperature** - **Bright** image/colours - No **image burn** - High **resolution** - **Cheaper** than LED screen	- Limited viewing angles - Lower contrast - Slower response time
LED Screen (light emitting diode)		- **Low power** consumption - High **resolution** - Longer **life span** - **Thinner** display	- Higher cost - Heat generation in large displays
Speaker	Output **sound waves** which can be heard by humans		

Sensors

Sensors are **input devices** that measure a physical property of their environment & are used for **monitoring & control systems**

1. The acceptable value is keyed in & stored in the microprocessor
2. The ___ **sensor** sends data to the **microprocessor** continuously
3. The data is converted from analogue to digital by an **ADC**
4. **Microprocessor** compares data with the stored acceptable values
   - If the data is outside the acceptable range, the microprocessor sends a signal to an **actuator** e.g. If an infra-red beam is broken / If the acoustic sensor reading > pre-set value / If a pressure sensor reading > pre-set value, the microprocessor sends a signal to an actuator to operate the siren & flashing lights
5. If the data is within the range, there is no change
6. The cycle continues until turned off

How are **QR codes** used for concert entry? [7]

1. Using a **scanner**, a **laser** is shone & the **camera** captures the code
2. The data is sent to the **microprocessor**
3. The data is converted from analogue to digital by an **ADC**
4. Microprocessor compares data with the **database of valid QR codes**
5. If data matches, entry is granted & head **count** is incremented
6. If data does not match, entry is denied

Sensor	Type of Data Captured	Uses
Acoustic/ Sound	Sound levels	• Burglar alarm / security systems • Monitor noise pollution • Leak detection system
Accelerometer	Acceleration rate, tilt, vibration	• Detect sudden changes in vehicle movement (deploy safety features if needed) • Detect orientation of device in mobile phones
Flow	Rate of gas, liquid, or powder flow	• Detect changes in the flow through pipes in water system • Used in respiratory devices and inhalers in hospitals
Gas	Presence of a gas e.g. oxygen, carbon dioxide	• Gas levels in confined spaces • Pollution levels • Oxygen and carbon dioxide levels in greenhouse environment
Infra-red	Detecting motion (using beam) or a heat source	• Burglar alarm / security systems (intruder breaks beam) • Automatic doors (person entering breaks beam)
Level	Liquid levels	• Levels of petrol in a car tank • Levels of water in a water tank
Light	Light levels	• Street lights (switch on/off lights)
Magnetic field	Presence Strength	• In anti-lock braking systems (checks rotation speed of wheels for braking) • Mobile phones
Moisture	Presence Levels of moisture	• Moisture in soil of greenhouse environment
Humidity	Levels of water vapour	• Greenhouse environment
pH	Acidity / alkaline	• pH of soil in greenhouse environment • Chemical processes
Pressure	Gas / liquid / physical pressure	• Burglar alarm / security systems (detects weight of intruder) • Chemical processes
Proximity	Distance	• Monitor position of objects in robotics • Prevents objects colliding in safety systems
Temperature	Temperature	• Central heating / air con system • Chemical processes • Greenhouse environment

3.3 Data Storage

3.3.1-3.3.2 Primary & Secondary Storage

<table>
<tr><td colspan="2">Primary Storage
directly accessed by the CPU & a part of the CPU</td><td>Secondary Storage
not directly accessed by the CPU & permanent storage</td></tr>
<tr><td>Random Access Memory (RAM)</td><td>Read-Only Memory (ROM)</td><td></td></tr>
<tr><td>Stores data, instructions, software, parts of the OS
Currently in use</td><td>Stores the computer's BIOS / start-up instructions
When the computer is initially switched on</td><td>Stores user's files, data, OS, application softwares</td></tr>
<tr><td>• Volatile – temporary memory; all data is lost when the computer is switched off
• Can be read from and written to</td><td>• Non-volatile - data will be stored when the computer is switched off
• Can only be read from (cannot be changed)</td><td>• Non-volatile - data will be stored when the computer is switched off
• Can be read from and written to (can be changed)</td></tr>
<tr><td colspan="2">• Smaller capacity
• Faster data access speeds</td><td>• Larger capacity
• Slower data access speeds</td></tr>
</table>

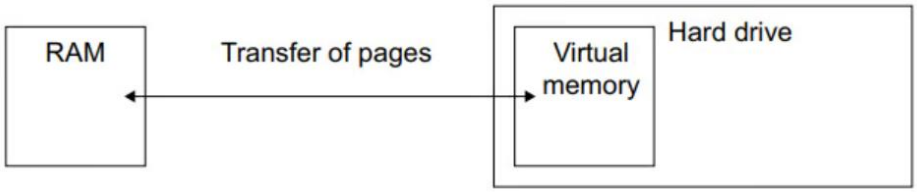
3.3.2 Secondary Storage

<table>
<tr><td>Magnetic Storage
HDD (hard disk drives), floppy disk</td><td>Solid-State Storage (flash memory)
SSD (solid-state drives), USB drive</td><td>Optical Storage
CDs, DVDs, Blu-rays</td></tr>
<tr><td>• Data is stored on platters which are divided into tracks & sectors
• The platter is spun
• Data is read/written using a read/write arm & electromagnets</td><td>• Uses NAND or NOR technology
• Uses transistors as control gates & floating gates to control the flow of electrons
• Flashes data onto chips</td><td>• Uses lasers to create and read pits & lands
• Data is stored on spiral tracks
• The disk is spun</td></tr>
<tr><td>• Has moving parts, high power consumption, longer life span, slower data access speed</td><td>• No moving parts, low power consumption, shorter life span, faster data access speed</td><td></td></tr>
</table>

3.3.3 Virtual Memory

Virtual memory is part of secondary storage which acts as **RAM** when RAM is full

- **Purpose**
  - Prevents the computer system crashing when RAM is full
  - Extends RAM capacity
  - Allows CPU to process large amounts of data
- **Process**
  1. The **hard drive** is partitioned to create **virtual memory** (swap space)
  2. When **RAM** is full, pages of data that are not required are transferred from RAM to virtual memory
  3. Pages of data that needs to be accessed can be transferred into RAM
  4. When the data is required again, the pages can be transferred back to RAM



3.3.4 Cloud Storage

- A collection of **physical servers** that allows data to be access remotely using an internet connection

\+ Data can be accessed from anywhere & from any device with an internet connection
\+ Can increase capacity easily without buying new hardware
\+ Multiple servers are used to backup data, reducing the risk of data loss due to hardware failure

\- If the user has a slow/unstable internet connection, they may have problems accessing their files
\- A large storage capacity can be expensive
\- Data being sent over the internet may be intercepted/hacked

3.4 Network Hardware

Network Interface Card (NIC)

An **NIC** is an internal physical component which enables computers to access a network

Media Access Control (MAC) Addresses

- An **NIC** is given a **MAC address** assigned by the **manufacturer**
- MAC addresses are unique codes used to identify devices on a network
- It is a static address (does not change)
- Consists of 6 pairs of **hex** digits separated by a colon e.g. b4:71:ac:f3:21:a2
    - manufacturer code : serial code

Internet Protocol (IP) Address

- An **IP address** is a unique address used to identify devices, assigned by the **network**
- Can be static or dynamic (changes each time the device is connected to the network)
- Can be public (usually static) or private (usually dynamic)
- Types of IP Addresses
    - **IPv4**: 4 groups of denary numbers (0-255) separated by a full stop (32 bits)
      e.g. 198.167.214.0
    - **IPv6**: 8 groups of 4 hex digits (0000-FFFF) separated by a colon (128 bits)
      e.g. 20A1:12DF:E203:0000:0000:0000:0000:000

Routers

Roles of a Route in a Network

- Send data to a specific destination on a network – find IP address of destination in packet header → send using fastest route
- Assign **IP addresses** to devices within the LAN
- Connect a local network to the **internet**