Computer Architecture

- **Von Neumann Architecture** has one control unit, ALU, registers and memory unit with a shared memory and data bus used for data and instructions.
- **Harvard Architecture** has separate memories for instructions and data. It is more commonly used in embedded processors
- Von Neumann Architecture is cheaper to develop as the control unit is simpler and allows programs to be optimised in size.
- Harvard Architecture allows data and instructions can be fetched in parallel and both memories can be different sizes.

Contemporary Processing

- Combines Harvard and Von Neumann architecture
- Von Neumann is used when working with data and instructions in main memory
- Harvard is used when working with cache.
- Has a separate instruction and data cache.

RAM and ROM

Random Access Memory (RAM)

- Volatile
- Holds data and programs which are currently in use
- High access speeds
- Very expensive per gigabyte

Read Only Memory (ROM)

- Non-volatile (Cannot be modified)
- Used to store fixed instructions such as the computer start up routine

Fetch Decode Execute Cycle and Registers

- The order operations take place to execute an instruction.
- Fetch Phase:
  - Address copied from the PC to the MAR.
  - Data bus copies the instruction from that location to the MDR
  - At the same time, the contents of the PC increase by 1
  - The value is them copied from the MDR to the CIR
- Decode Phase:
  - The contents of the CIR are split into operand and opcode
- Execute Phase:
  - The opcode is executed on the operand.

Busses and Assembly Language

- Assembly code uses mnemonics to represent instructions.
- Instructions are divided into operand and opcode
- Opcode is the type of instruction and the hardware to execute it.
- Operand is the address where the operation is performed.

Multi-core and Parallel Systems

- Multi-core CPUs have many cores which complete separate fetch-execute cycles independently.
- Parallel systems can carry out multiple instructions simultaneously using a single core using techniques like pipelining.

Unit 1.1 The Characteristics of Contemporary Processors, Input, Output and Storage Devices

CPU Components

- The **ALU** (Arithmetic and Logic Unit) carries out arithmetical and logical operations.
- The **CU** (Control Unit) directs operations inside the processor.
- **Registers** are small, fast memory cells used to temporarily store data.

Program Counter (PC)	Stores the address of the next instruction to be executed.
Accumulator (ACC)	Stores the results of calculations.
Memory Address Register (MAR)	Holds the address in memory that is to be written to or read from.
Memory Data Register (MDR)	Holds data which has been read or needs to be written.
Current Instruction Register (CIR)	Stores the current instruction, split into operand and opcode.

- Buses are parallel wires connecting two or more CPU components together.
- The number of parallel wires determines the bus width.
- The system bus contains the data bus, control bus, and address bus.

Data Bus	A bi-directional bus which transfers data and instructions between components.
Address Bus	Transmits the location in memory where data should be read or written.
Control Bus	A bi-directional bus which transmits control signals.

Flash Storage

- Fast and compact
- Logic gates store an electrical charge
- High represents a binary 1
- Low represents a binary 0
- Information is stored in blocks which are combined to form pages
- More expensive
- Limited lifespan

Solid State Drives

- Light and portable
- No moving parts
- More resistant to damage from movement than hard disk drives
- High data transfer rates
- Smaller capacity than hard disk drives

Magnetic Storage

- Two magnetic states represent binary
  - Polarised sectors represent 1
  - Unpolarised sectors represent 0
- Can be damaged by strong magnets

Hard Disk Drives

- High capacity
- Magnetic platters rotate at high speeds beneath a read/write head
- Multiple platters are stacked to maximise storage capacity
- Moving parts can become damaged

Magnetic Tape

- An older storage medium
- Tape is round onto reels within a cartridge.
- The tape drive spins the reels to move the tape across a reader

Floppy Disks

- A thin magnetic disk in a plastic case.
- Small and portable
- Typical storage capacity of 1MB

Reduced Instruction Set Computers (RISC)

- Small instruction set
- One instruction is one line of machine code
- Used in personal computers

Complex Instruction Set Computers (CISC)

- Large instruction set
- Instructions built into hardware
- Used in microcontrollers and embedded systems
- Compiler has less work to do
- Less RAM is needed to store the code

Optical Storage

- Use lasers to read and write to a disk.
- Sectors of the disc are written in a spiral.
  - Pits scatters light representing 0
  - Lands reflects light representing 1
- Small and light so very portable
- Easily scratched
- Not very fast

Compact Disk (CD)

- Commonly used for audio but can store any data type
- Stores relatively little information

Digital Versatile Disc (DVD)

- Higher storage capacity than CDs
- Often used to store videos

Blu-Ray

- More than five times as much storage as a DVDs
- Used to store HD films

Virtual Storage

- A method of storing information remotely.
- Allows multiple computers to access data over a network or The Internet.
- Includes cloud storage and network accessible storage.
- Becoming more popular as network and Internet speeds increase.
- Relies on a network connection for access to data.
- Limited by network speed.

Input, Output and Storage Devices

- Input devices are used to send data to the computer, such as a keyboard, mouse or sensor.
- Output devices allow the computer to send information out, such as a speaker or screen.
- Storage devices allow data to be stored such as a hard drive.
- Some devices can be both an output and input device, such as a touch screen.
- Factors such as speed, accuracy, cost and relevance to the task should be considered when choosing devices.

Pipelining

- Allows three instructions to be processed through the fetch, decode and execute cycle at the same time.
- Data is stored in a buffer close to the CPU until required.
- Whilst one instruction is being executed, another can be decoded and another fetched.
- Reduces the amount of CPU idle time.

Graphics Processing Unit (GPU)

- Had multiple processors working in parallel.
- Efficiently completes repetitive tasks.
- Used for image processing and machine learning.
- A co-processor (a secondary processor which supports the activities of the primary processor.

Factors Affecting CPU Performance

Clock Speed:

- Determined by the system clock
- All activities begin on a clock pulse
- Each operation starts when the clock changes from 0 to 1
- The clock speed is the number of clock cycles which can be completed in a second.
- Faster clock speed = better performance

Number of Cores:

- Each core is an independent processor which executes its own fetch-execute cycle
- CPUs with several cores can complete more than one fetch-execute cycle at the same time
- Some applications can only use one core.
- More cores = better performance

Amount and type of Cache Memory

- Cache memory is fast memory built into the CPU
- Instructions are held in cache allowing them to be accessed quickly if needed.
- As cache fills up, unused instructions are overwritten.
- More cache = better performance
- Cache can be Level 1, 2, or 3
- Level 1 is the fastest but smallest
- Level 3 is the slowest but largest