

Unit 1.3: Hardware and Software

1.3.2 VON NEUMANN ARCHITECTURE

Central processing unit: the main processing unit of the system

Primary memory: fast to access and is directly accessible by the processor

-RAM + ROM + cache memory + registers

Secondary storage: slow to access and isn't directly accessible by the processor

-E.g. hard drives, CD-ROM

Cache memory: a portion of memory used for high-speed storage

Register: internal memory within the CPU that temporarily holds data and instructions during processing

-**Accumulator:** register used for arithmetic & logic calculations

Control Unit: controls the flow of data through the CPU & the interactions between the different parts of the CPU

-Tells different components & linked hardware how to respond to the instruction given

Immediate Access Store (IAS): holds data & instructions needed to process that data

-Known as the CPU memory

-Data and instructions are loaded into the main memory then brought to the IAS to be processed

Arithmetic Logic Unit (ALU): carries out calculations on data

Input/output: allow interaction with the computer

-Instructions are processed to and from them in the CPU

Bus: series of conductors, 'highway' for information

-**Data bus:** carries data

-**Address bus:** carries the memory address

-**Control bus:** carries the instructions

Instructions and data are stored as binary numbers

Stored-program concept: the Von Neumann architecture is based on the concept of a stored-program computer

-**Stored-program computer:** stores programs & instructions into digital memory

-Modern stored-program computer keeps its programmed instructions and data in **RAM**

Multiprogramming: more than one program is stored in the computer at any given time

Fetch the instruction – fetches necessary data and instructions and stores them in the IAS

-CPU puts the address of the next item to be fetched on the **address bus**

- Data from this address is then moved from main memory into the IAS
 - oTravels along the **data bus**
 - oRegisters are used to store and move the data to MDR that will decode the instruction

Decoding the instruction – fetches necessary data and instructions and decodes them

- Instruction set**: CPU uses this in order to decode the instruction
 - Specific set of commands the CPU is designed to understand
- Moving of data & decoding the instructions controlled by the control unit
 - Travels along the control bus

Executing the instruction – where any processing of the data needed for the instruction takes place

- Arithmetic calculations needed in the instruction is carried out by the ALU

1.3.3 INPUT DEVICES

Hardware: the physical components of a computer

- Allows user to enter data into a computer system
- Manual input device**: requires user to physically enter the data into a computer system
 - E.g. keyboard
- Automatic input device**: automatically reads data and inputs it into a computer system
 - E.g. temperature sensor

Keyboard: allow entry of letters, numbers & symbols

- Can have special command and function keys that perform a specific task
- On-screen keyboard**: keys are not physically pressed down
 - Created by software
 - Software**: programs & instructions run on a computer
- Concept keyboard**: flat surface that has a grid of buttons
 - Each button is programmed to do a specific task
 - An overlay is then placed over the buttons to indicate the task they perform
 - Used when there is a limited amount of data so orders are inputted quickly
- Advantages**:
 - Simple to use
 - Inputting data can be very efficient if trained
- Disadvantages**:
 - Easy to make a mistake
 - Inputting data can be slow if not trained

Mouse: enables user to navigate around the screen

- **Older style mouse:** has a ball in the underside that rolls against internal rollers to move the pointer in the direction intended
- **Newer style mouse:** uses an optical laser that tracks the movement of the mouse across a surface to move the pointer in the direction intended
- **Trackball:** used when desk space is limited / to increase precision
 - User rotates the ball whilst main body parts stay still
 - Used in CAD drawings
- **Advantages:**
 - Simple to use
 - Lets user efficiently navigate around a screen
- **Disadvantages:**
 - Needs to be on a flat surface
 - If dirt clogs roller ball or covers optical laser it stops working properly

2D scanner: shines light into the surface of the document and moves across it, reflected light is captured onto a light-sensitive device and the image is converted into a digital signal for input to a computer

- **Optical character recognition (OCR):** text on a scanned document is recognised & converted to digital text
 - Isn't very reliable & can be prone to errors
- **Flatbed scanner:** moves the light & sensor itself, whole image is scanned automatically
- **Handheld scanner:** light & sensor must be manually pushed along the image to scan it
 - Used to scan small images
- **Advantages:**
 - Flatbed scanners are able to produce digital copies of documents in high quality
 - Copy can be edited in software
 - Copy of scanned document can be attached to an email
- **Disadvantages:**
 - Can cost a lot
 - Scanned copy won't be as high quality as original

3D scanner: scans the object using a laser / light source

- Measures & inputs the geometry of an object into a computer system, creates a model of it that can be a digital model or a replica using the 3D printer
- Used in airports as a security measure
- **Biometric device:** recognises human physical characteristics
 - Biometric data is stored on a chip in the passport, it is scanned to input person's biometric data, face is scanned and matched with information stored in chip

Barcodes: represented by black vertical bars with spaces

- Prevents health problems like repetitive strain injury
- Data is pre-coded & converted into a barcode
- Barcode reader scans the barcode → translates it into a number

–Barcode is scanned and is illuminated by an illuminator (red light), a sensor detects the light reflected back from the barcode and converts the analogue signal received into a digital signal, the digital signal is then decoded by the decoder and sent to a computer

–**Advantages:**

- Efficient method of entering a product's detail & finding out its price
- Can help keep record of stock levels for a product

–**Disadvantages:**

- If barcode is damaged, it may not scan properly
- Barcode data has to be recorded in the computer system

QR codes: made up of black and white **modules** (squares)

–QR codes are 2D whilst a barcode is 1D

- Stores data vertically & horizontally

–Can store much more numbers than a barcode

–**Reed Solomon method:** error correction method built in QR codes

- Even if some modules are covered or misprinted it can still be scanned

–**Advantages:**

- Efficient method of storing information
- Can store a variety of information e.g. videos, links
- Can often still be read even if some areas are covered

–**Disadvantages:**

- Not as commonly used as barcodes
- Used for advertising & distributing information
- People have to be able to read it

Digital camera: encodes digital images & videos, then stores them for viewing

–**Encoding:** the process of converting data or information into a particular form

–Image is stored in built-in memory on an SD card

–Captures an image by recording the image via a **charge-coupled device** (sensor)

- Larger number of pixels, CCD is capable of a higher quality of image
- Pixels determine the quality of a digital camera

–**Advantages:**

- Image taken can be immediately seen on screen
- Images can have backups
- Can be easily shared
- Easy to edit

–**Disadvantages:**

- Poor quality image when there is a small number of pixels
- User can accidentally share images unintended
- Requires storage space

Touch screen: interactive device that combines a liquid crystal display with touch-sensitive sensors

–Recognise simple touches by finger/stylus

–Determines which parts have been touched according to application utilising it, translates input into action

–**Capacitive touch screen:** uses the natural electrical signals that's in our body to detect when we're touching the screen

–Can't detect signals through a glove

–**Resistive touch screen:** have multiple layers with spaces in between, when slight pressure is applied to the screen the layers touch and the device then recognises where the screen has been touched

–**Advantages:**

–Simple to use

–Saves space as they combine a screen & an input device

–**Disadvantages:**

–Can be imprecise

–Inputs may not be possible if screen is damaged

Microphone: analogue input device that records sound

–Computer can save sound in a file for later use

–**Used for:** video conferencing, speech-to-text software, in-game speech

–**Advantages:**

–Allows the use of speech recognition systems

–Disabled users can use this to input commands to a computer

–**Disadvantages:**

–May not be accurately recorded

–Speech recognition systems have to be trained to work properly

SENSORS

Sensor: a type of input device that detects changes in the environment surrounding it

–Records data on the environment around it and outputs it in the form of a signal for a computer to process

–Replace the need for a human to detect & record changes

–E.g. when situations are too dangerous for humans to collect data

Light sensor: detect the ambient light level

–**Ambient light:** the brightness or darkness at the current time

–**Used in streetlights:** when it gets too dark, the lights will automatically turn on

–**Used in security systems:** sensor beams light to another sensor, if a beam of light is broken the next sensor recognises this and sends a signal to the computer telling it the security system has been breached. This causes a response like an alarm

Temperature sensor: detects changes in temperature; measures heat generated by an object or system

–**Contact temperature sensor:** need to have physical contact with an object to measure its temperature

–**Non-contact temperature sensor:** measures energy that is transmitted/ radiated from an object

- Used in fridges: take regular samples of the temperature inside the refrigerator and adjusts the temperature to keep it at a constant level
- Used in heating systems: thermostat has two pieces of metal that will open or close depending on the temperature, when the metal closes to complete a circuit so electrical current will flow to heat up or cool down the atmosphere. Once temperature is correct circuit breaks

-Thermostat: a device that keeps temperature at a consistent level

Infrared sensor: detect infrared radiation that emits from a person/object

- Used in televisions: sensor detects infrared waves from the remote control, interprets the signal, and passes the instructions to the television
- Used in cameras: used to catch criminals, measure temperatures, astronomy (stars)

Motion sensor: detects movement using heat or sending out microwaves that bounce off objects

- Used in lighting rooms: turns light on when it detects movement in the room
- Used in gaming: Kinect (Microsoft), Move (Sony), Nintendo Wii
- Accelerometer: a device that detects rotation & tilt (motion sensor)

Magnetic field sensor: detects changes in magnetic field; measure the strength & direction of a magnetic field and responds to changes

- Used in mobile phones: magnetometers allow an application in our phone to act as a compass; a magnet is placed inside the cover of a mobile phone case, the sensor detects the magnet close by and will turn the mobile screen off

Gas sensor: detects the presence of gas in a certain area

- Used in homes to detect the presence of carbon monoxide: placed in rooms that use a gas central-heating system/gas fireplace, it triggers an alarm when concentration is too high
- Used in areas of industry:
 - E.g. nuclear energy - detects any gases that could cause fire & a potentially critical situation
 - E.g. Wastewater treatment plants - detects any toxic gases when trying to purify water

Pressure sensor: measures the pressure of a liquid/gas

- Used to measure the pressure of liquid flowing through pipes
- Used to maintain electricity conducted through pipe at a certain rate: level is matched to a set level of pressure
 - More pressure, level of electricity conducted will increase

Moisture sensor: measures the amount of moisture in a certain material

- Used in soil: waters the crop when moisture level is low, alerts farmer when moisture level is too high

Humidity sensor: measures the amount of water vapour present in the air & current temperature of the air

- Used by people affected by humidity: high level causes growth of bacteria that can affect health; low level can cause breathing problems as air is too dry
- Used in museum & art galleries: high level can damage certain artefacts & paintings

pH sensor: measures how acidic/alkaline a material is

- Used to correct pH of drinking water
- Used to monitor water in aquariums

1.3.4 OUTPUT DEVICES

Peripheral: an external device that is connected to a computer

- Footprint:** space taken by a peripheral

Displays: outputs information via a screen/projector

- Quality of image depends on the resolution of the display
- Resolution:** the number of pixels in a display
- Monochrome images:** has a foreground & background colour only
- Colour images:** combine the primary colours
- Colour depth:** the degree to which a particular colour can be represented
 - E.g. how bright/pale a colour is
 - Represented in bits, the more bits the greater the number of possible shades can be produced
- Portrait display:** offers more height, suitable for viewing documents/books/articles
- Landscape display:** offers more width, suitable for viewing images/videos

Cathode ray tube display: consists of a sealed glass tube with a fluorescent coating of phosphor dots on the inside

- Electrons are fired at the tube by three separate electron guns that illuminate fluorescent coating to create an image
- Limited resolution, bulky in size, requires a lot of energy

Flat panel display:

- Advantages:**
 - High resolution, bright, flicker-free images
 - Can be made at an ideal size for portable devices
 - Low energy requirement
- Disadvantages:**
 - Easily damaged when dropped
 - Can suffer from dead pixels

Liquid crystal display: made up of separate RGB coloured pixels arranged in tiny blocks

- Blocks are made up of liquid crystals that turn solid/transparent by altering the electric current that is supplied to the block
- Light let through → pixels illuminated
- Advantages:**
 - Thin in size
 - Saves energy
 - Doesn't produce glare

Light-emitting diode display: pixels are backlit with LEDs and produce brighter, more direct light

-Advantages:

- Thinner
- Lighter
- Visible over a wider viewing angle

-Disadvantages:

- Can suffer from uneven brightness across the display
- Less energy efficient than LCDs

Digital projector: used when an output needs to be shown on a large scale

LCD projector: contains three separate LCD glass panels

- Light passes through LCD panels → individual pixels can be opened to let light pass
- Used when contrast & brightness is needed

DLP projector: uses millions of tiny mirrors to reflect light towards the projection lens

- Excellent colour reproduction
- Small & portable

Printer: produce hard copies of information

- Printing resolution is measured in dots per inch

Inkjet printer: uses ink to print information

- Provided in a cartridge and is sprayed through a microscopic nozzle onto paper

-Advantages:

- Cheap
- Image quality is excellent with photographic paper

-Disadvantages:

- Expensive in terms of buying ink cartridges
- Image quality poor on printing paper
- Difficult to print both sides
- Slow

Laser printer: uses toner to print information

- Uses a laser to create static electricity on certain areas of the page, toner is scattered onto the page and static electricity attracts the toner to stick to the page, a fusing element makes sure the toner is bonded to the page

-Advantages:

- Cheap to run
- Good quality on printing paper
- Quick
- Suitable for double-sided printing

-Disadvantages:

- Laser technology is expensive
- Bad quality on photographic paper
- Larger footprint than inkjet printers

3D printer: uses polymers to print object

- Requires an object to be drawn up as a 3D model in a digital file and the object is then split into thousands of extremely thin, horizontal layers
 - Created using a CAD application / scan an object using a 3D scanner
 - **CAD:** software that allows a user to design & create an image of an object
- **Advantages:**
 - Prototype can be made quickly
 - Any shape can be printed
 - Reduce costs to a designer
 - Designs can be easily shared by sharing a digital file
- **Disadvantages:**
 - Expensive
 - May not be as durable as manufactured product
 - Dangerous items can be printed
 - Copyright issues

Computer-aided manufacturing (CAM): a computer controls machinery to manufacture an object

- **Computer-numerical control (CNC):** method of control used by CAM
- **Advantages:**
 - Items manufactured to a higher precision than hand
 - High production quality maintained
 - Produce high quality bespoke items & prototypes
- **Disadvantages:**
 - Requires training
 - Expensive to produce items
 - Hardware & software have high costs

2D CAM machines: manipulate materials into 2D

- **Blade cutters:** used to cut & trim materials
 - Used to create signs & advertising material
 - Cheap but noisy
- **Waterjet cutters:** uses a pressurized stream of water mixed with an abrasive element to cut & trim reflective material
 - Enable precision cutting without spoiling the material coating
- **Laser cutters:** uses a laser to etch into materials e.g. wood, plastic
 - Industrial manufacturing: precise shapes cut out of sheets/blocks
 - Excess material is drawn out of the machine by an extractor
 - Quick, accurate, quiet

3D cutters: used to test & modify prototype designs for bespoke products

- used for cutting wood, wax, plastics etc.

Speakers & headphones: used to output sound

- Speakers translate signal into a sound-wave by moving a cone to vibrate air
- **Advantages:**
 - Allows a variety of information to be provided to user
 - Aid disabled users

- Useful to warn lots of people about an emergency
- Disadvantages:
 - Built-in speakers have low quality sound reproduction
 - Sound may disturb others
 - Need to have a sound card with a DAC

Actuators: a mechanical output device that produces movement

- Moving part of actuator is connected to another device to move it
- Can rotate, open, close, push & pull
- Apply movement through energy (energy → motion)

1.3.5 MEMORY, STORAGE DEVICES AND MEDIA

Primary storage: can be accessed quickly & directly by processor

- Holds data ready for processing
- Random Access Memory: can be written to & read
 - Volatile - loses its content when power is switched off
 - Holds data to be processed & programs in use temporarily
 - Embedded computers: computer is built into device & performs specialised tasks
 - General purpose computers: used for many different applications
- Read Only Memory: can be read
 - Non-volatile - doesn't lose its content when power is switched off
 - Firmware: ROM that holds programs that run on an embedded computer
 - Bootstrap: ROM that contains start-up instructions for the computer
 - Contains instructions that determine basic hardware structures of the computer & instructions for finding and loading the operating system
 - Erasable programmable read only memory: ROM that can be erased & re-written
 - Used when firmware is upgrading
 - Flashing: process of erasing & re-writing data to ROM
 - Smaller in capacity

Secondary storage: cannot be accessed by CPU

- Holds data & software on a more permanent basis
- Transfers data, programs to RAM
- Erased/overwritten when no longer required
- Magnetic storage: read, write, erase data by using electromagnetic & magnetic fields to control magnetic dots of data
 - Dots represent binary
 - Tape-based devices: use a cartridge of looped magnetic tape

- Magnetised data dots are stored in series along tape, it passes over an electromagnetic read/write head that reads, writes, erases magnetic dots
- **Disk-based devices:** consists of platters (several disks) made from glass/metal
 - Have a magnetised coating where data dots are stored, dots lie in tracks that run around a platter which is attached to a rotating spindle. Data is read/written/erased as dots pass under read/write heads that sit on a moving arm that moves back & forth to access data in different tracks
 - Disks are transferred faster with HDDs than tape
- **Optical storage:** read data by shining a laser beam onto the surface of plastic disks
 - Disks are covered with aluminium to be reflective, reflective surface is covered in a track that spirals outwards from the centre of the disk
 - **Pit:** an indentation on the surface of an optical disk, used to represent data
 - **Land:** the raised surface between pits on an optical disk
 - **Burning:** process of recording data onto an optical disk
 - E.g. compact disk (CD), digital versatile disk (DVD), Blu-ray disk
 - higher capacity, tighter packed pits & lands
 - Blue-ray disk: uses a blue-violet laser that operates at a shorter wavelength than red lasers in CD & DVDs, more precise & more than one reflective layer can be stored
 - Optical media types:
 - ROM: read only
 - R: read & written to once only
 - RW: read & written repeatedly
- Solid-state storage: uses high-speed flash memory to store data
 - RAM stick: used to transport data
 - Solid-state drive: equivalent to an HDD
 - SD card: used to store & transfer data
 - Can be written to & read many times