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UPDATED TO 2023-2025 SYLLABUS

# CAIE IGCSE COMPUTER SCIENCE

SUMMARIZED NOTES ON THE THEORY SYLLABUS

# 1. Data Representation

## 1.1. Number Systems

### Binary System

- Base 2 number system
- Has two possible values only (0 and 1)
- 0 represents OFF and 1 represents ON
- A point to be noted is that the most left bit is called the MSB (Most Significant Bit)

### Denary System

- Base 10 number system
- Has values from 0 to 9

### Hexadecimal (aka Hex)

- Base 16 number system
- Has values from 0 to 9 followed by A to F
- A represents 10, B represents 11 and so on until 15 which is F

| Binary Value | Hexadecimal Value | Denary Value |
|---|---|---|
| 0000 | 0 | 0 |
| 0001 | 1 | 1 |
| 0010 | 2 | 2 |
| 0011 | 3 | 3 |
| 0100 | 4 | 4 |
| 0101 | 5 | 5 |
| 0110 | 6 | 6 |
| 0111 | 7 | 7 |
| 1000 | 8 | 8 |
| 1001 | 9 | 9 |
| 1010 | A | 10 |
| 1011 | B | 11 |
| 1100 | C | 12 |
| 1101 | D | 13 |
| 1110 | E | 14 |
| 1111 | F | 15 |

# Number Conversions

## 1.2. Converting Binary to Denary

- Take the binary value and place it in columns of 2 raised to the power of the number of values from the right starting from 0.e.g. For binary value 11101110, place it in a table like this:

| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |

- As it can be seen that it starts from 1 and then goes till 128 from left to right
- Now values with 1 are to be added together giving the final answer, as for the example, it is 128 + 64 + 32 + 8 + 4 + 2 = 238

## Converting Denary to Binary

- Take the value and successively divide it by 2 creating a table like follows:

| 2 | 142 | | |
|---|---|---|---|
| 2 | 71 | Remainder: | 0 |
| 2 | 35 | Remainder: | 1 |
| 2 | 17 | Remainder: | 1 |
| 2 | 8 | Remainder: | 1 |
| 2 | 4 | Remainder: | 0 |
| 2 | 2 | Remainder: | 0 |
| 2 | 1 | Remainder: | 0 |
| | 0 | Remainder: | 1 |

- Note that when the value itself is not divisible by 2, it is divided by the previous value of the current number and 1 is added to the remainder column for that specific number
- When you reach 0, the remainder has to be read from bottom to top giving us the binary value ( as in this case, it is 1 0 0 0 1 1 1 0 )

## Converting Hexadecimal to Binary

- Separate each value from each other and convert them to denary
- Each separate denary value to be converted to binary
- All the binary values to be merged together
  e.g.

Hexadecimal : 2 1 F D
Denary : 2 1 15 13
Binary : 0010 0001 1111 1101

Final Answer: 0010000111111101

## Converting Binary To Hexadecimal

- Divide the binary value into groups of 4 starting from the right. If at the end, the last division is less than 4, add 0s until it reaches 4
- For each group, find the denary value as shown above, and then convert each denary value to its corresponding hexadecimal value (if less than 10, then itself, else, 10 is A, 11 is B, 12 is C, 13 is D, 14 is E and 15 is F).

- After conversion, just put all the hexadecimal values in order to get the final answer

Given Value : 1 0 0 0 0 1 1 1 1 1 1 1 0 1
When grouped: 10 0001 1111 1101

After 2 values added to left: 0010 0001 1111 1101

After Conversion to Denary: 2 1 15 13

Denary to Hexadecimal: 21FD

### Converting Hexadecimal to Denary

- Convert the value to binary as shown above, and then convert the final answer to denary

### Converting Denary to Hexadecimal

- Convert the value to binary, and then convert it to hexadecimal as explained above

## Addition of Binary

- Binary values are not added the way denary values are added, as when adding 1 and 1, we cannot write two because it doesn't exist in binary.

### 1.3. Points to note:

- 0 + 0 = 0
- 1 + 0 / 0 + 1 = 1
- 1 + 1 = 0 (1 carry)
- 1 + 1 + 1 = 1 (1 carry)

### Overflow:

- When adding two values, if the solution exceeds the limit of given values, e.g., the solution has 9 bits, but the question had 8 bits per value, the 9th bit (most left bit) is called overflow.
- This indicates that the memory doesn't have enough space to store the answer to the addition done in the previous part.

### Steps to add two values (with example):

- The values we will add are 1 1 0 1 1 1 0 and 1 1 0 1 1 1 1 0
    1. Convert both the bytes into 8 bits (add zero to the left-hand side to match them).
       e.g., 1 1 0 1 1 1 0 would become 0 1 1 0 1 1 1 0
    2. Add the values as follows with the points given above

| Carry | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
|---|---|---|---|---|---|---|---|---|
| Byte 1 | | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| Byte 2 | | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| | OVERFLOW | | | | | | | | |
| Solution | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |

**Note:** We move from RHS to LHS, and when adding values, we use the rules given above. If the bit crosses the limit (overflows), we put the value in brackets, denoting it is overflow.

iii. The solution would now be (1) 0 1 0 0 1 1 0 0

### Logical Shifts

- The logical shift means moving a binary value to the left or the right
- When doing a logical shift, keep in mind that the bit being emptied is going to become 0

### Explaining with an example:

- **Shifting 10101010 - 1 place left:**
    1. The furthest bit in the direction to be logically shifted is removed ( in this case, one at the LHS is removed) - ==(if it were 2 places, 2 bits would have been removed)==
    2. Every bit is moved in given places to the given direction ( every bit is moved one place to the left in this case, and the leftover bit in the right is marked 0, so **10101010** would become **01010100**)

### Two's complement (Binary Numbers):

- Two's complement is a method used to represent negative values in binary. Here, the MSB ( Most Significant Bit) is replaced from 128 to -128; thus, the range of values in a two's complement byte is -128 to 127

#### Converting binary values to two's complement

- Firstly, write the binary value and locate the first one from the right; e.g., 1101100 would have the first one at the third position from the right.
- Now, switch every value to the left of the first one located above (not switching the one), e.g., the value in our example becomes 0010100, which is the two's complement of itself.

#### Converting negative values to two complement

- Find the binary equivalent of the value ignoring the - sign
- Convert the binary value to two's complement
- Make the MSB 1, if not already

#### Converting two's complement value to denary:

- We do it the same way as a normal value is converted from binary to denary; we only just replace 128 with -128 e.g., for 10111010 we do the:

| -128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |

-128 + 32 + 16 + 8 + 2 = -70

## 1.4. Use of the Hexadecimal System

**Examples:**

- Defining colours in Hypertext Markup Language (HTML)
- Media Access Control (MAC) addresses (a number that uniquely identifies a device on a network)
- Assembly languages and machine code
- Memory Dumps
- Debugging (method to find errors in a program)
- Display error codes (numbers refer to the memory location of the error)
- IP (Internet Protocol) addresses

**Memory Dumps**

- Hexadecimal is used when developing new software or when trying to trace errors.
- Memory dump is when the memory contents are output to a printer or monitor.

**Assembly code and machine code (low-level languages)**

- Computer memory is machine code/ assembly code
- Using hexadecimal makes writing code easier, faster, and less error-prone than binary.
- Using machine code (binary) takes a long time to key in values and is prone to errors.

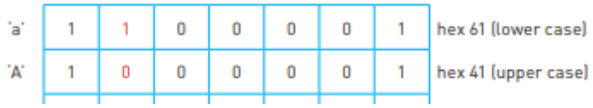
# Text

## 1.5. ASCII

- The standard ASCII code character set consists of 7-bit code that represent the letters, numbers and characters found on a standard keyboard, together with 32 control codes
- Uppercase and lowercase characters have different ASCII values
- Every subsequent value in ASCII is the previous value + 1. e.g. “a” is 97 in ASCII , “b” will be 98 (which is 97 + 1)
- Important ASCII values (in denary) to remember are as follows:

- [ ] 0 is at 48
- [ ] A is at 65
- [ ] a is at 97

- ASCII uses one byte to store the value
- When ASCII value of a character is converted to binary, it can be seen that the sixth bit changes from 1 to 0 when going from lowercase to uppercase of a character and the rest remains the same. e.g.




## Unicode

- ASCII does not contain all of the international languages, thus Unicode is used to solve this problem
- For the first 128 values, it is the same to ASCII
- Unicode supports up to four bytes per character allowing multiple languages and more data to be stored

**To represent text in binary, a computer uses a character set, which is a collection of characters and the corresponding binary codes that represent them**

# Sound

- Sound is analogue, and for it to be converted to digital form, it is sampled
- The sound waves are sampled at regular time intervals where the amplitude is measured, however, it cannot be measured precisely, so approximate values are stored

### How is sound recorded

- The amplitude of the sound wave is first determined at set time intervals
- The value is converted to digital form
- Each sample of the sound wave is then encoded as a series of binary digits
- A series of readings gives an approximate representation of the sound wave

### Sampling Resolution:

- The number of bits per sample is known as the sampling resolution (aka bit depth)
- Increasing the sampling resolution increases the accuracy of the sampled sound as more detail is stored about the amplitude of the sound
- Increasing the sampling resolution also increases the memory usage of the file as more bits are being used to store the data

### Sampling rate

- Sampling rate is the number of sound samples taken per second which is measured in Hertz (Hz)
- Using a higher sampling rate would allow more accurate sound as less estimations will be done between samples

# Images

## Bitmap images

- Bitmap images are made up of pixels
- A bitmap image is stored in a computer as a series of binary numbers

### Color Depth

- The number of bits used to represent each colour is called the colour depth.
- An 8 bit colour depth means that each pixel can be one of 256 colours (because 2 to the power of 8 = 256)
- A 1 bit color depth means each pixel can store 1 color (because 2 to the power of 1 is 2) - ( This is done as the bit can either be 0 or 1, with 0 being white and 1 being black)
- Increasing colour depth increases the size of the file when storing an image

### Image Resolution

- Image resolution refers to the number of pixels that make up an image; for example, an image could contain 4096 × 3072 pixels
- Photographs with a lower resolution have less detail than those with a higher resolution
- When a bitmap image is ' blurry ' or ' fizzy ' due to having low amount of pixels in it or when zoomed, it is known as being **pixelated.**
- High resolution images use high amounts of memory as compared to low resolution ones

## 1.6. Measurement of the Size of Computer Memories

- A binary digit is referred to as a **BIT**
- 8 bits is a **byte**
- 4 bits is a **nibble**
- Byte is used to measure memory size

IECB System (more commonly used):

| Name of memory size | No. of Bytes | Equivalent Denary Value |
|---|---|---|
| 1 kibibyte (1KB) | $2^{10}$ | 1 024 bytes |
| 1 mibibyte (1MB) | $2^{20}$ | 1 048 576 bytes |
| 1 gibibyte (1GB) | $2^{30}$ | 1 073 741 824 bytes |
| 1 tibibyte (1TB) | $2^{40}$ | 1 099 511 627 776 bytes |
| 1 pibibyte (1PB) | $2^{50}$ | 1 125 899 906 842 624 bytes |

Conventional System:

| Name of memory size | No. of Bytes | Equivalent Denary Value |
|---|---|---|
| 1 kilobyte (1KB) | $10^3$ | 1 000 bytes |
| 1 megabyte (1MB) | $10^6$ | 1 000 000 bytes |
| 1 gigabyte (1GB) | $10^9$ | 1 000 000 000 bytes |
| 1 terabyte (1TB) | $10^{12}$ | 1 000 000 000 000 bytes |
| 1 petabyte (1PB) | $10^{15}$ | 1 000 000 000 000 000 bytes |

## Calculation of file size

- The file size of an image is calculated as: image resolution (in pixels) × colour depth (in bits)
- The size of a mono sound file is calculated as: sample rate (in Hz) × sample resolution (in bits) × length of sample (in seconds). (For a stereo sound file, you would then multiply the result by two.)

## 1.7. File types

### Musical Instrument Digital Format (MIDI)

- Storage of music files
- Communications protocol that allows electronic musical instruments to interact with each other
- Stored as a series of demands but no actual music notes
- Uses 8-bit serial transmission (asynchronous)
- Each MIDI command has a sequence of bytes:
  - First byte is the status byte – informs the MIDI device what function to preform
  - Encoded in the status byte is the MIDI channel (operates on 16 different channels)
- Examples of MIDI commands:
  - Note on/off: indicates that a key has been pressed
  - Key pressure: indicates how hard it has been pressed (loudness of music)
- Needs a lot of memory storage

### MP3

- Uses technology known as Audio Compression to convert music and other sounds into an MP3 file format
- This compression reduces the normal file size by 90%
  - Done using file compression algorithms which use Perceptual Music Shaping
  - Removes sounds that human ear cannot hear properly
  - Certain sounds are removed without affecting the quality too much
- CD files are converted using File Compression Software
- Use lossy format as the original file is lost following the compression algorithm

### MP4

- This format allows the storage of multimedia files rather than just sound

- Music, videos, photos and animations can be stored
- Videos, could be streamed without losing any real discernible quality

Joint Photographic Experts Group (JPEG)

- JPEG is a file formats used to reduce photographic file sizes
- Reducing picture resolution is changing the number of pixels per centimetre
- When photographic file undergoes compression, file size is reduced
- JPEG will reduce the raw bitmap image by a factor between 5 and 15

# Lossless and Lossy File Compression

## 1.8. Lossless File Compression

- All the data bits from the original file are reconstructed when the file again is uncompressed
- Important for files where loss of data would be disastrous (spreadsheet)
- An algorithm is used to compress data
- No data is lost
- Repeated patterns/text are grouped together in indexes

### Run-Length Encoding

- It reduces the size of a string of adjacent, identical data (e.g. repeated colours in an image)
- A repeating string is encoded into two values: the first value represents the number of identical data items (e.g. characters) and the second value represents the code of the data item (such as ASCII code if it is a keyboard character) e.g. 'aaaaabbbbccddddd' becomes "05 97 04 98 02 99 05 100"
- RLE is only effective where there is a long run of repeated units/bits
- One difficulty is that RLE compression isn't very good for strings like "cdcdcdcdcd". We use a flag to solve this, e.g. 255 can be made the flag. Now 255 will be put before every repeating value, e.g. our previous example becomes 255 05 97 255 04 98 255 02 99 255 05 100 where 255 now indicated that now the next character/set of characters is approaching

## Lossy File Compression

- The file compression algorithm eliminates unnecessary bits of data like MP3 and JPEG formats
- Impossible to get original file back once compressed
- Reduces file quality
- In this, resolution of the image is reduced, and colour depth is reduced

# 2. Data Transmission

## 2.1. Types and Methods of Data Transmission

### Data Packets

- Packet Structure -
  - Header
    - Contains the IP address of the sender and the receiver
    - Sequence number of the packet
    - Size of the packet
  - Payload
    - Contains the actual data
  - Trailer
    - Includes a method of identifying the end of the packet
    - Error-Checking methods
- Packet Switching - Method of data transmission where the data is broken into multiple packets. Packets are then sent independently from start to end and reassembled at the receiver's computer.

| Advantages | Disadvantages |
|---|---|
| No need to create a single line of communication | Packets may be lost |
| Possible to overcome failed or busy nodes | More prone to errors in real-time streaming |
| High data transmission speed | Delay at the receiver while the packets are being re-ordered |
| Easy to expand package usage | |

### Data Transmission

- *Simplex data transmission* is in one direction only (e.g. computer to printer)
- *Half-duplex data transmission* is in both directions but not at the same time (e.g. phone conversation where only one person speaks)
- *Full-duplex data transmission* is in both directions simultaneously (e.g. broadband connection on phone line)
- *Serial data transmission* is when data is sent one bit at a time over a single wire
- *Parallel data transmission* is when data several bits (1 byte) are sent down several wires at the same time

### Comparsion of Serial and Parallel data transmission

| Serial | Parallel |
|---|---|
| Better for longer distances (Telephone Lines) | Better for short distances (Internal circuits) |

| Serial | Parallel |
|---|---|
| Cheaper Option | Expensive (More hardware required) |
| Used when the size of data transmitted is small | Used when speed is necessary |
| Slower Option | Faster than Serial |

# Universal Serial Bus (USB)

- USB is an asynchronous serial data transmission method
- USB consists of:
  - Four-wire shielded cable
  - Two wires used for power and earth
  - Two wires used in data transmission

| Advantages | Disadvantages |
|---|---|
| Automatically detected | Transmission rate is less than 120 mb/sec |
| Only fit one way, prevents incorrect connections | Maximum cable length is about 5 metres |
| Different data transmission rates | |
| Backwards compatible | |
| Industry standard | |

# Methods of Error Detection

### 2.3. Parity Checks

- Uses the number of 1-bits in a byte
- Type Types -
  - Even - Even number of 1-bits
  - Odd - Odd numbers of 1-bits
- Example (Even Parity) -

| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
|---|---|---|---|---|---|---|---|

- The MSB (Most Significant Bit) is the parity bit. As the number of 1s is even, the parity bit would be set to even.

**Limitations with Parity Checks**

- Two bits may change during transmission; therefore, an error is not found
- Even though the parity checks would reveal the errors, the bit(s) changed wouldn't be identified

### Parity Blocks

- To overcome the limitations of parity bits, Parity blocks would be used.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| B | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| C | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| D | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| E | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |

- Any changes in bits would be identified through the rows and columns

### Checksum

- Whenever a block of data needs to be sent, the sender would calculate the checksum value using a specific algorithm.
- Once the data has been sent, The receiver would calculate the checksum again with the same set of data and the same algorithm used before.
- The receiver would then compare the value received and the newly calculated value. If they aren't matched, A request is made to re-send the data.

### Echo Check

- Once the data has been sent, The receiver will send the data back to the sender for verification.
- The sender would compare the received and original data for errors.
- The only downside is that we wouldn't know if the error occurred when sending the data or sending the data back for verification.

### Check Digits

- Check digits are calculated from all the other digits in the data (ex-codes). The check digit would be the last digit of the code.
- These are used to identify mistyping errors such as -
  - 6372 typed as 6379
  - 8432 typed as 842

### Automatic Repeat Requests (ARQs)

- Uses acknowledgments and timeouts to make sure the user received the data
- The receiver would check the data for errors; if none are found, a positive acknowledgment is sent to the sender. However, if errors are found, a negative acknowledgment will be sent, and the data will be sent again.
- The sender uses timeouts to wait a pre-determined amount of time for the acknowledgment.
- If no acknowledgments are received after the timeout, the data will be sent again to the receiver.

# Encryption

- Encryption is a process of turning the data into an unreadable form so it doesn't make sense to hackers and other attackers.

### 2.4. Plaintext and Ciphertext

- Plaintext is the original data that is being sent
- Ciphertext is the text produced after encryption

### Symmetric and Asymmetric Encryption

- Symmetric Encryption:
  - It uses an encryption key for the encryption process, The same key is used for both encrypting and decrypting the data.
- Asymmetric Encryption:
  - Uses a public key and a private key. The public key is available to everyone whereas the private key is only available to the user
  - The receiver would have the private key and they would send the public key to the sender. The sender can encrypt the message with the public key and the data can be on decrypted using the private key.

# 3. Hardware

## 3.1. Computer Architecture & Von Neumann architecture

- The central processing unit (CPU) (also known as a microprocessor or processor) is central to all modern computer systems
- ~~**The CPU consists of the following architecture:**~~

  **Processor:** The processor contains the Arithmetic and Logic Unit (ALU)
  **Control Unit:** The control unit controls the operation of the memory, processor and input/output devices
  **Arithmetic Logic Unit:** Carries out the logic system like calculations
  **System Clock:** System clock is used to produce timing signals on the control bus

  **Busses:** Carry data through components. The following are it's types

  *Address bus* – unidirectional
  *Data Bus* – bi-directional
  *Control Bus* – unidirectional and bi-directional

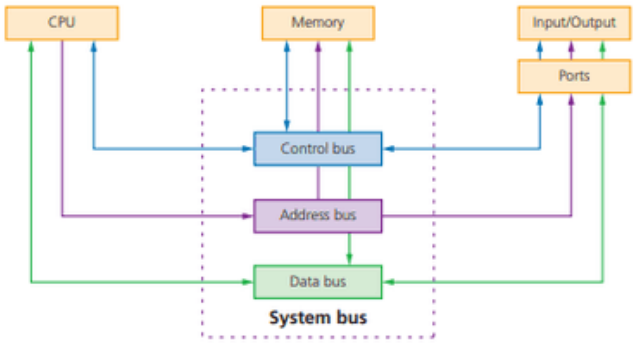
  **Immediate Access Store:** Stores the instructions that are to be processed which are fetched by the CPU
  \
- ~~**Following registers also exist in the architecture:**~~
  Program Counter:
  - Increments the value of the instructions by 1 and also fetches the data and instructions.

  Memory Address Register:
  - Stores the Address of the instruction and copies it and sends to MDR

  Memory Data Register:
  - Stores the Data from the address received from the MAR and sends data to CIR

  Current instructions Register:
  - Data gets executed from here by sending to bios or processed by sending to ALU

  Accumulator:
  - During calculations data is temporarily held in it




Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

## The Fetch-Execute Cycle

1. PC contains address of the next instruction to be fetched
2. This address is copied to the MAR via the address bus
3. The instruction of the address is copied into the MDR temporarily
4. The instruction in the MDR is then placed in the CIR
5. The value in the PC is incremented by 1, pointing the next instruction to be fetched
6. The instruction is finally decoded and then executed

### Stored program concept:

- Instructions are stored in main memory
- Instructions are fetched, decoded and executed by the processor
- Programs can be moved to and from the main memory

### Memory Concept

- A computer's memory is divided in partitions : Each partition consists of an address and its contents e.g.

| MEMORY LOCATION | CONTENT |
|---|---|
| 10101010 | 01010110 |

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

# Factors that determine the performance of a CPU

## 3.2. System Clock

The clock defines the clock cycle that synchronises all computer operations. **By increasing clock speed, the processing speed of the computer is also increased.** This **doesn't** mean that the performance of the computer is increased however.

### Overclocking

Using a clock speed higher than the computer was designed for.
It leads to multiple issues

- Operations become unsyncronised - (the computer would frequently crash and become unstable)
- can lead to serious overheating of the CPU

## Length of data buses

**The wider the data buses, the better the performance of the computer**

## Cache

Cache memory is located within the CPU itself
-- allows faster access to CPU
-- stores frequently used instructions and data that need to be accessed faster, which improves CPU performance
**The larger the cache memory size the better the CPU performance**

## Cores

**More the cores in the CPU, the better and faster the performance**

## 3.3. Input Devices

**Two-dimensional Scanners:**

- Used to input hard-copy documents
- The image is converted into an electronic form which can be stored in the computer
  - Document is placed on a glass panel
  - A bright light illuminates the document
  - A scan head moves across the document until the whole page is scanned. And image of the document is produced and sent to a lens using a series of mirrors
  - The lens focuses the document image
  - The focused image now falls onto a *charge couple device (CCD)* which consists of a numbers of integrated circuits
  - Software produces a digital image from the electronic form
- *Optical Character Recognition (OCR)* is a software which converts scanned documents into a text file format
- If the original document was a photo/image, then the scanned image forms an image file such as JPEG

**Three-dimensional Scanners**

- 3D scanners can scan solid objects and produce a three-dimensional image
- Scanners take images at several points, x, y and z (lasers, magnetic, white light)
- The scanned images can be used in *Computer Aided Design (CAD)* or to a 3D printer to produce a working model

**Application of 2D Scanners at an Airport:**

- Make use of (OCR) to produce digital images which represent the passport pages
- Text can be stored in ASCII format
- The 2D photograph in the passport is also scanned and stored as jpeg image
- The passenger's face is also photographed using a digital camera and compared using face recognition software
- Key parts of the face are compared (distance between eyes, width of nose)

**Barcode readers/scanners**

- A barcode is a series of dark and light parallel lines of varying thicknesses
- The numbers 0 -9 are each represented by a unique series of lines
- The left and right hand sides of the barcode are separate using guard bars
- Allows barcode to be scanned in any direction
  - Barcode is read by a red laser or red LED
  - Light is reflected back off the barcode; dark areas reflect little light which allows the bars to be read
  - Reflected light is read by sensors (photoelectric cells)
  - Pattern is generated which is converted to digital

**Quick Response (QR) Codes**

- Another type of barcode is the QR codes
- Made up of a matrix of filled in dark squares on a light background
- Can hold more storage (7000 digits)
- Advantages of QR codes:
  - No need for the user to write down website address
  - QR codes can store website addresses

**Digital Cameras**

- Controlled by microprocessor which automatically adjusts the shutter speed, focus the image, etc.
- Photo is captured when light passes through the lens onto a light sensitive cell

- Cell is made up of pixels
- Number of pixels determines size of the file

### Keyboards

- Connected to computer with a USB connection or by wireless connection
- Each character has an ASCII value and is converted into a digital signal
- Slow method
- Prone to errors

### Pointing devices

- Mouse/trackball
  - Traditional; mechanical ball, connected by USB port
- Modern type; red LEDs to detect movement

### Microphones

- Used to input sound to a computer
- When a microphone picks up sound, a diaphragm vibrates producing an electric signal
- The signal goes to a sound card and is converted into digital values and stored in computer
- *Voice recognition,* voice is detected and converted into digital

### Touchscreens

- Capacitive (medium cost tech)
  - Made up of many layers of glass
  - Creating electric fields between glass plates in layers
  - When top layer of glass is touched, electric current changes
  - Co-ordinates where the screen was touched is determined by an on-board microprocessor
- Infra-red *heat* (expensive)
  - Use glass as the screen material
  - Needs warm object to carry an input operation
- Infra-red *optical* (expensive)
  - Uses glass as screen material
  - Uses an array of sensors (grid form)
  - Point of contact is based on which grid co-ordinate is touched
- Resistive (inexpensive)
  - Upper layer of polyester, bottom layer of glass
  - When the top polyester is touched, the top layer and bottom layer complete a circuit
  - Signals are then sent out which are interpreted by a microprocessor, determine where screen was touched

### Sensors

- Devices which read or measure physical properties
- Data needs to be converted to digital
- *Analogue to Digital Converter (ADC)* converts physical values into digital

### Control of Street Lighting

- Light sensor sends data to the ADC
- Digitises data and sent to the microprocessor
- Microprocessor samples data every minute
- If data from sensor < value stored in memory:
  - Signal sent from microprocessor to street lamp
  - Lamp switched on

## 3.4. Output Devices

### Inkjet Printers

- Used to print one-off pictures and documents

1. Data from document sent to printer driver
2. Printer driver ensures data is in correct format
3. Check made by printer driver that chosen printer is available
4. Data is sent to printer, stored in a temporary memory (printer buffer)
5. Sheet of paper is fed; sensor detects if paper is available in paper tray
6. Print head moves across paper printing text/image, four ink colours sprayed in exact amount
7. Paper is advanced so next line is printed
8. Repeated until buffer is empty
9. Once it is done, printer send an interrupt to the processor (request for more data to be sent)

### Laser Printers

- Used to print flyers, high quality
- Use dry powder ink (toner) and static electricity to produce text and images
- Prints the whole page in one go

1. (steps 1-4 same as inkjet)
2. Printing drum is given a positive charge; as the drum rotates, a laser beam is scanned across it removing the positive charge leaves negatively charged areas which match the text/image
3. Drum is then coated with positively charged *toner*, it only sticks to negatively charged parts of the drum
4. A negatively charged sheet is rolled over the drum
5. Toner on the drum now sticks to the paper to produce copy of page
6. Paper finally goes through a fuser (set of heated rollers); heat melts the ink so it is permanent
7. Discharge lamp removes all electric charge from the drum, ready to print next page

### 3D Printers

- Used for models of cars
- Produce solid objects that work
- Built up layer by layer, using powdered resin, ceramic powder
- A design is made using Computer-aided Design (CAD)

### 2D and 3D Cutters

- 3D cutters can recognise objects in x, y, z direction
- 3D laser cutters can cut; glass, crystal, metal, wood

**Actuators**

- Used in many control applications involving sensors and devices (ADC and DAC)

**Loudspeakers/Headphones**

- Sound is produced by passing the digital data through a DAC then through amplifier and then emerges from loudspeaker
- Produced by voltage differences vibrating a cone in the speaker at different frequencies

**LCD and LED Monitors**

- Front layer of monitor is made up of *Liquid Crystal Display* (LCD), these tiny diodes are grouped together in threes as pixels (LCD doesn't emit any light)
- LCD monitors are back lit using *Light Emitting Diode (LED)* because:
  - LEDs reach their maximum brightness immediately
  - LEDs sharpens image (higher resolution), CCFL has yellow tint
  - LEDs improve colour image
  - Monitors using LED are much thinner than CCFL
  - LEDs consume very little power
- Before LEDs, LCD monitors were backlit using CCFL
- CCFL uses two fluorescent tubes behind the LCD screen which supplies the light source

**Light Projectors:**

- Two common types of light projectors:
  - Digital Light Projector (DLP)
  - LCD Projector
- Projectors are used to project computer output onto larger screens/interactive whiteboards

**Digital Light Projectors (DLP)**

- Uses millions of micro mirrors
- the number of micro mirrors and the way they are arranged on the DLP chip determines the resolution of the image
- When the micro mirrors tilt towards the light source they are *on*
- When the micro mirrors tilt away from the light source they are *off*
- This creates a light or dark pixel on the projection screen
- A bright white light source passes through a colour filter on its way to the DLP chip
- White light splits into primary colours

**LCD Projectors**

- Older technology than DLP
- A powerful beam of white light is generated from a bulb
- This beam of light is then sent to a group of chromatic-coated mirrors; these reflect the light back at different wavelengths
- When the white light hits the mirrors, the reflected light has wavelengths corresponding to red, green and blue
- These three different light pass through three LCD screens; these screens show the image to be projected as millions of pixels in grayscale
- When the coloured light passes through the LCD screens, a red, green and blue version of the grey image emerges
- Finally, the image passes through the projector lens onto the screen

| | Advantages | Disadvantages |
|---|---|---|
| Digital light projector (DLP) | higher contrast ratios | image tends to suffer from 'shadows' when showing a moving image |
| | higher reliability/longevity | |
| | quieter running than LCD projector | DLP do not have grey components in the image |
| | uses a single DMD chip, which mean no issues lining up the images | the colour definition is frequently not as good as LCD projectors because the colour saturation is not as good (colour saturation is the intensity of a colour) |
| | smaller and lighter than LCD projector | |
| | they are better suited to dusty or smoky atmospheres than LCD projectors | |
| LCD projector | give a sharper image than DLP projectors | although improving, the contrast ratios are not as good as DLPs |
| | have better colour saturation than DLP projectors | LCD projectors have a limited life (that is, the longevity is not as good as DLPs) |
| | more efficient in their use of energy than DLP technology – consequently they generate less heat | since LCD panels are organic in nature, they tend to degrade with time (screens turn yellow and the colours are subsequently degraded over time) |

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

## 3.5. Memory, Storage Devices & Media

**Primary Memory:**
**Random Access Memory (RAM)**

- Features of RAM
  - Volatile/temporary memory (contents lost if RAM is turned off)
  - Used to store; data, files
  - It can be written to or read from and the contents from the memory can be changed
- Larger the size of the RAM, faster the computer will operate
- RAM never runs out of memory, continues to run slow
- As RAM becomes full, the processor has to continually access the hard drive to overwrite old data on RAM with new data
- RAM is of two types:

DRAM (Dynamic RAM) and SRAM (Static RAM)

| DRAM | SRAM |
|---|---|
| consists of a number of transistors and capacitors | uses flip flops to hold each bit of memory |
| needs to be constantly refreshed | doesn't need to be constantly refreshed |
| less expensive to manufacture than SRAM | has a faster data access time than DRAM |
| has a higher memory capacity than SRAM | CPU memory cache makes use of SRAM |
| main memory is constructed from DRAM | |
| consumes less power than SRAM | |

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

**Read Only Memory (ROM)**

- Features of ROM
  - Non-volatile/permanent memories (contents remain even when ROM is turned off)

- Used to store start up instruction (basic input/output systems)
- Data/contents of a ROM chip can only be read, cannot be changed

**Secondary Storage:**
**Hard Disk Drives (HDD)**

- Data is stored in a digital format on the magnetic surface of the disks (platter)
- Number of read/write heads can access all of the surfaces of the disk
- Each platter will have two surfaces which can be used to store the data
- Data is stored on the surfaces in sectors and tracks
- HDD have very slow data access compared to RAM

**Solid-State Drive (SSD)**

- No moving parts and all data is received at the same time (not like HDD)
- Store data by controlling the movement of electrons within NAND chips, as 1s and 0s
- Non-volatile rewritable memory
- Benefits of using SSD rather than HDD:
  - More reliable (no moving parts)
  - Considerably lighter (suitable for laptops)
  - Lower power consumption
  - Run much cooler than HDDs
  - Very thin
  - Data access is faster than HDD
- Drawback – questionable longevity (20GB per day)

**Off-Line Storage:**
**CD/DVD Disks**

- Laser (red) light is used to read and write data in the surface of the disk
- Use a thin layer of metal alloy to store data
- Both systems use a single, spiral track which runs from the centre of the disk to the edge
- DVD uses *Dual-Layering* which increases the storage capacity (two individual recoding layers)

**Blu-ray Disks**

- Uses blue laser to carry out read and write operations
- Wavelength of laser light is less than CD and DVD (stores up to five times more data than DVD)
- Automatically come with secure encryption (prevent piracy and copyright infringement)
- Used as back-up systems

**USB Flash Memories**

- Very small, lightweight suitable from transferring files
- Small back-up devices for photo, music
- Solid state so need to be treated with care

**Cloud Storage:**

- Cloud storage is a method of data storage where data is stored on remote servers
- The same data is stored on more than one server in case of maintenance or repair, allowing clients to access data at any time. This is known as **data redundancy.**
- The following are it's types:
  » Public cloud – this is a storage environment where the customer/client and cloud storage provider are different companies
  » Private cloud – this is storage provided by a dedicated environment behind a company firewall; customer/client and cloud storage provider are integrated and operate as a single entity
  » Hybrid cloud – this is a combination of the two above environments; some data resides in the private cloud and less sensitive/less commercial data can be accessed from a public cloud storage provider
  \
- There is a risk that important and irreplaceable data could be lost from the cloud storage facilities.

## 3.6. Embedded Systems

- Combination of Hardware and Software which is designed to carry out a specific set of tasks.
- Embedded systems may contain -
  - Microcontrollers - CPU, RAM, ROM and other peripherals on one single chip
  - Microprocessor - Integrated circuit with CPU only
  - System on Chips (SoC) - microprocessor with I/O ports, storage and memory
- Process of Embedded Devices -
  - Input from the user is sent to the microprocessor (ADC needed if the data is analogue)
  - Data from the user interface is also sent to the microprocessor
  - Microprocessor then sends signals to actuators which is the output
- Non-programmable devices need to be replaced if they need a software update.
- Programmable devices have two methods of updating -
  - Connecting the device to a computer and downloading the update
  - Updating automatically via a satellite, cellular or Wi-Fi link

< centre>Advantages and Disadvantages of using embedded systems

| Advantages | Disadvantages |
|---|---|
| Small in size, therefore can easily fit into devices | Can be difficult to upgrade |
| Low cost to make | The interface can be confusing sometimes |
| Requires very little power | Troubleshooting is a specialist's job |

| Advantages | Disadvantages |
|---|---|
| Very fast reaction to changing input | Often thrown away as difficult to upgrade and faults are harder to find |
| Dedicated to one task only | Increased garbage as they are thrown away |
| Can be controlled remotely | Any computerised system is prone to attacks |

- Applications of Embedded devices -
  - GPS systems
  - Security Systems
  - Vending Machines
  - Washing Machines
  - Oven
  - Microwave

# Network Hardware

## 3.7. Network Interface Card (NIC)

A network interface card (NIC) is needed to allow a device to connect to a network (such as the internet

## Media Access Control (MAC) Address

A MAC address is made up of 48 bits which are shown as six groups of hexadecimal digits. The first six display the manufacturer's code and the second half shows the device serial number.

- These do not change and are mostly constant for every device
- there are two types of MAC address: the Universally Administered MAC Address (UAA) and the Locally Administered MAC Address (LAA)

The only differences between the two types are UAA is made Universally and cannot be changed, but it is opposite for LAA

## IP Addresses

- IP address allocation:
  - IP addresses are allocated by the network.
  - Two types of IP addresses: static and dynamic.
- Static IP addresses:
  - Assigned manually to a device.
  - Does not change over time.
- Dynamic IP addresses:
  - Assigned automatically by a DHCP (Dynamic Host Configuration Protocol) server.
  - Changes periodically or when the device connects to a different network.
- IPv4 (Internet Protocol version 4):
  - Widely used protocol.
  - Consists of four groups of decimal numbers separated by dots (e.g., 192.168.0.1).
  - Provides approximately 4.3 billion unique addresses.
- IPv6 (Internet Protocol version 6):
  - Developed to address the limitations of IPv4.
  - Uses eight groups of hexadecimal numbers separated by colons (e.g., 2001:0db8:85a3:0000:0000:8a2e:0370:7334).
  - Provides an extremely large number of unique addresses (approximately 340 undecillion).
- Differences between IPv4 and IPv6:
  - Address format: IPv4 uses a 32-bit address, while IPv6 uses a 128-bit address.
  - Address space: IPv4 provides approximately 4.3 billion addresses, whereas IPv6 offers around 340 undecillion addresses.
  - Address allocation: IPv4 addresses are allocated using DHCP or manually, while IPv6 addresses are primarily assigned using stateless autoconfiguration.

## Routers

- Router functionality:
  - A router is a networking device that directs data packets between different networks.
  - It determines the most efficient path for data transmission.
- Sending data to a specific destination on a network:
  - A router examines the destination IP address of incoming data packets.
  - It uses routing tables to determine the next hop or the next router on the path to the destination.
  - The router forwards the data packet to the appropriate next hop.
- Router's role in IP address assignment:
  - A router can act as a DHCP server (Dynamic Host Configuration Protocol) and assign IP addresses to devices on a local network.
  - It dynamically allocates IP addresses from a predefined range to connected devices.
  - DHCP allows for automatic IP address configuration and simplifies network management.
- Connecting a local network to the internet:
  - A router serves as the gateway between a local network and the internet.
  - It connects the local network to an internet service provider (ISP) network.
  - The router receives data packets from devices on the local network and forwards them to the internet.
  - It also receives incoming data packets from the internet and routes them to the appropriate devices on the local network.

# 4. Operating Systems

- Operating Systems are designed to establish communication between the user and the computer

- Functions of a typical operating system -
  - Providing HCI
  - Multitasking
  - Memory Management
  - Managing files
  - Management of user accounts
  - Hardware management
  - Platform for running application software
- WIMP - Windows, Icons, Menu and Pointing Devices

Advantages and Disadvantages of CLI and GUI

| Interface | Advantages | Disadvantages |
|---|---|---|
| command line interface (CLI) | the user is in direct communication with the computer<br>the user is not restricted to a number of pre-determined options<br>it is possible to alter computer configuration settings<br>uses a small amount of computer memory | the user needs to learn a number of commands to carry out basic operations<br>all commands need to be typed in which takes time and can be error-prone<br>each command must be typed in using the correct format, spelling, and so on |
| graphical user interface (GUI) | the user doesn't need to learn any commands<br>it is more user-friendly; icons are used to represent applications<br>a pointing device (such as a mouse) is used to click on an icon to launch the application – this is simpler than typing in commands or a touch screen can be used where applications are chosen by simply touching the icon on the screen | this type of interface uses up considerably more computer memory than a CLI interface<br>the user is limited to the icons provided on the screen<br>needs an operating system, such as Windows, to operate, which uses up considerable memory |

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

- Memory Management - Manages the RAM and the HDD/SSD during the execution of programs
- Security Management - Providing security features such as Anti-Virus, System updates and so on
- Hardware Peripheral Management - Managing the device drives, Inputs, Outputs, Queues and buffers
- File Management - Opening, Creating, Deleting, Renaming and many more functions
- Multitasking - OS would share the hardware resources with each of the processes
- Management of User Accounts - OS would allow multiple users where each individually customize their account.

### 4.1. Running of Applications

- The computer starts its OS (booting up the computer) through the bootstrap loader.
- The BIOS (Basic Input/Output System) tells the computer the location of the OS in the storage.
- BIOS is often referred to as the firmware

#### Interrupts

- Signal that causes the operating system to stop what it's doing and service a task
- Ensures important tasks are dealt on priority basis
- Can be a software or a hardware interrupt
- Can be generated by peripherals like keyboard & mouse
- Different interrupts have different levels of priority
- After interrupt is dealt with previous process continues

# Programming Languages, Translators and IDEs

- Computers can only understand **machine code** therefore translators are needed

#### High-Level Languages

- Easier to read and understand as the language is closer to human language
- Easier to write in a shorter time
- Easier to debug at the development stage
- Easier to maintain once in use

#### Low-Level Languages

- Refer to machine code
- Binary instructions that the computer understands

| Language | Advantages | Disadvantages |
|---|---|---|
| High-level | independent of the type of computer being used<br>easier to read, write and understand programs<br>quicker to write programs<br>programs are easier and quicker to debug<br>easier to maintain programs in use | programs can be larger<br>programs can take longer to execute<br>programs may not be able make use of special hardware |
| Low-level | can make use of special hardware<br>includes special machine-dependent instructions<br>can write code that doesn't take up much space in primary memory<br>can write code that performs a task very quickly | it takes a longer time to write and debug programs<br>programs are more difficult to understand |

Source: Cambridge IGCSE and O Level Computer Science - Second Edition (Hodder Education)

#### Assembly Language

- Few programmers use assembly language to -
  - Make use of special hardware
  - Write code that doesn't take up much space
  - Write code that runs very quickly

## 4.2. Translators

#### Compiler

- Translates a program written in high-level language into machine code
- Used without compiler
- Executable file of machine code produced
- One high-level language translated into several machine code instructions
- Used for general use

#### Interpreter

- Executes a high-language program a statement at a time
- No executable file of machine code produced
- One high-level language program statement may require several machine code instructions to be executed
- Interpreted programs cannot be used without interpreter
- Used when program is being developed

**Assembler**

- Translates a low-level language program into machine code
- Executable file of machine code produced
- One low-level language translated into one machine code instructions
- Can be used without assembler
- Used for general use

### Integrated Development Environments (IDEs)

- An IDE would usually have these features -
  - Code Editor
  - Translator
  - Debugger
  - Error Reports
  - Auto-Completion and Auto-Correction
  - Auto-Documenter
  - Pretty Printing

# SOFTWARE

## 4.3. Types of Softwares:

1. **System Software** e.g. Operating System, Utility programs and device drivers
2. **Application Software** e.g. spreadsheet, word processor etc.

### System Software:

- these are a set of programs which control and manage operations of hardware
- gives a platform for other softwares to run
- it is required to allow hardware and software to run without problems
- provides a human computer interface (HCI) to the user
- controls the allocation and usage of hardware resources

### Application Software:

- allows a user to perform specific tasks using the computer's resources
- may be a single program (for example, NotePad) or a suite of programs (for example, Microsoft Office)
- user can execute the software as and when they require and is mostly not automatic

## Examples

### System Software:

- Compiler: Translates high-level language into machine code, allowing for direct use by a computer to perform tasks without re-compilation.
- Linker: Combines object files produced by a compiler into a single program, allowing for the use of separately written code modules in the final program.
- Device driver: Software that enables hardware devices to communicate with a computer's operating system, without which a device like a printer would be unable to work.
- Operating system: Software that manages basic computer functions such as input/output operations, program loading and running, and security management, making computers more user-friendly.
- Utility programs: Software that manage, maintain, and control computer resources by carrying out specific tasks, such as virus checking, disk repair and analysis, file management, and security.

### Application Software:

- Word Processor: Software used for manipulating text documents including creating, editing, and formatting text with tools for copying, deleting, spell-checking, and importing images.
- Spreadsheet: Organizes and manipulates numerical data using a grid of lettered columns and numbered rows, with each cell identified using a unique combination of columns and rows. It can carry out calculations using formulas, produce graphs, and do modeling and "what if" calculations.
- Database: Software used to organize, analyze, and manipulate data consisting of one or more tables that hold records and fields. Provides the ability to query and report on data, as well as add, delete, and modify records in a table.
- Control and Measuring Software: A program designed to interface with sensors and allow a computer or microprocessor to measure physical quantities and control applications by comparing sensor data with stored data and altering process parameters accordingly.
- Apps: A type of software designed to run on mobile phones or tablets, which are downloaded from an "App Store" and range from games to sophisticated software such as phone banking. Common examples include video and music streaming, GPS, and camera facilities.
- Photo and Video Editing Software: Software that allows users to manipulate digital photographs or videos, including changing color, brightness, contrast, applying filters and other enhancements, and creating transitions between clips.
- Graphics Manipulation Software: Software that allows the manipulation of bitmap and vector images, with bitmap graphics editors changing pixels to produce a different image, while vector graphics editors manipulate lines, curves, and text to alter the stored image as required.

# Utility Software

- Computer users have access to utility programs as part of system software
- Utility programs can be initiated by the user or run in the background without user input
- Common utility programs include virus checkers, defragmentation software, disk analysis and repair tools, file compression and management software, backup software, security tools, and screensavers.

## 4.4. Virus Checker / Anti Virus software

- Virus checkers or anti-virus software are important for protecting computers from malware.
- They should be kept up to date and run in the background to maintain their effectiveness.
- Anti-virus software checks files before they are run or loaded and compares possible viruses against a database of known viruses.
- Heuristic checking is used to identify possible viruses that are not yet on the database.
- Infected files are put into quarantine for automatic deletion or for the user to decide.
- Anti-virus software must be kept up to date as new viruses are constantly discovered.
- Full system scans should be carried out regularly to detect dormant viruses.

## Disk Defragmenting Software

- Defragmentation software is used to rearrange the blocks of data on a hard disk drive (HDD) to store files in contiguous sectors, reducing head movements and improving data access time.
- As an HDD becomes full, blocks used for files become scattered all over the disk surface, making it slower to retrieve data as the HDD read-write head needs several movements to find the data.
- When a file is deleted or extended, the vacant sectors are not filled up straight away by new data, causing the files to become more scattered throughout the disk surfaces.
- A disk defragmenter rearranges the blocks of data to store files in contiguous sectors wherever possible, allowing for faster data access and retrieval.
- The defragmentation process can free up previously occupied sectors and leave some tracks empty.

## Backup Software

- Backup software is a utility software that helps in creating and managing backup copies of data files and programs.
- Manual backups using memory sticks or portable hard drives are good practices, but using operating system backup utilities is also recommended.
- Backup utilities allow scheduling backups and only backup files if changes have been made to them.
- For total security, there could be three versions of a file: the current version stored on the internal HDD/SSD, a locally backed-up copy on a portable SSD, and a remote backup on cloud storage.

## Security Software

- Security software is a utility software that manages access control, user accounts, and links to other utilities such as virus and spyware checkers.
- It also protects network interfaces using firewalls to prevent unauthorized access.
- Security software uses encryption and decryption to ensure intercepted data is unreadable without a decryption key.
- It oversees software updates to verify legitimate sources and prevent malicious software from installing.
- Access control and user accounts use IDs and passwords to secure user data and prevent unauthorized access.

## Screensavers

- Screensavers display moving and still images on the monitor screen after a period of computer inactivity.
- They were originally developed to protect CRT monitors from 'phosphor burn'.
- Screensavers are now mostly used for customizing a device and as a part of computer security system.
- They are used to automatically log out the user after a certain period of inactivity.
- Some screensavers activate useful background tasks like virus scans and distributed computing applications.

## Device Drivers

- Device drivers translate data into a format that can be understood by the hardware device they are associated with.
- Without the appropriate device driver, a hardware device cannot work with a computer and may not be recognised by the operating system.
- USB device drivers contain descriptors, which include a vendor id (VID), product id (PID) and unique serial number that allow the operating system to identify the device.
- Serial numbers must be unique to avoid confusion if two different devices with the same serial number were plugged into a computer at the same time.

# 5. The Internet

## 5.1. The Internet and the World Wide Web

| Internet | World Wide Web (WWW) |
|---|---|
| Uses transmission protocols such as TCP and IP (Internet Protocols) | Collection of webpages and other information on websites |

| Internet | World Wide Web (WWW) |
|---|---|
| Allows the user to communicate with other users via chat, email, calling and more | Uses HTTP(S) protocols that are written using Hypertext Mark-up Language (HTML) |
| Worldwide Collection of Interconnected Networks and Devices | URLs (Uniform Resource Locator) are used for the location of the web pages |
| | Web pages can be accessed by web browsers |

### Uniform Resource Locator (URLs)

- URLs are used to locate and access web pages. The typical format of URLs is -

  protocol://website address/path/file name

- The protocol would usually be **HTTP** or **HTTPS**
- The website address would contain -
  - domain host (www)
  - domain name (website name)
  - domain type (.com, .org, .net, .gov) or sometimes country codes (.uk, .in, .cy)
- The path would usually become the file directory roots. for example, https://www.znotes.com/computer-science
  - The /computer-science is the file name

### HTTP and HTTPS

- HTTP stands for Hypertext transfer protocol and HTTPS stands for Hypertext transfer protocol secure
- They are safety protocols maintained while transmitting data.

### Web Browsers

- It is software used to connect to the internet
- It translates the HTML code
- ensures SSL & TLS security can be established
- Offers additional features like search history & ad blockers

**Retrieval and Location of web pages**

- Browser sends URL to the domain name server (DNS)
- DNS stores index and matches with the IP
- IP is sent to browser if it exists
- Browser sends request to IP of webserver
- Browser interprets the HTML

### Cookies

- Cookies are small files stored on the user's computer
- They are used to track data about the users and autofill forms or give suggestions accordingly
- Types of Cookies -

| Session Cookie | Persistent Cookie |
|---|---|
| Temporary cookies which are stored in the RAM till the browser is closed. | Remembers the user's login in details so the user doesn't have to log in every time they visit a website |
| Doesn't collect any information on the user | Stored on the hard disk on the computer until their expiry date or the user deletes them |
| A good example is the virtual shopping basket on e-commerce websites | |

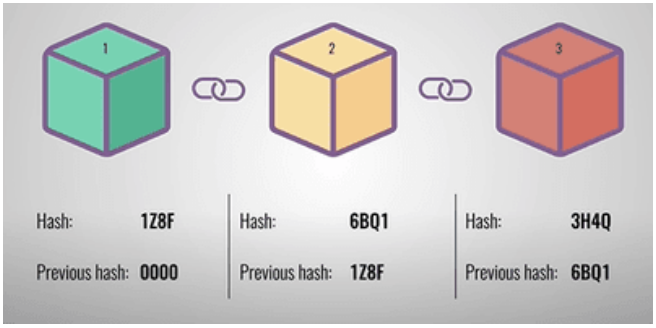
# Digital Currency

- Form of payment to pay for goods and services
- A few examples are Debit/Credit Cards, Apps (Paypal, Apple Pay, Bank Transfers and many more)
- Cryptography was later introduced due to the problem in centralised banking systems.
- Cryptocurrency uses cryptography to maintain track of transactions.
- Cryptocurrency is also more secure because it uses **Blockchain Network**

## 5.2. Blockchain Network

- Blockchain Network involves several interconnected computers where the transaction data is stored
- Hacking isn't possible here as transaction details would be sent to all the computers and the data can't be changed without the consent of all the network members

**How do blockchains work**

- Every time a transaction takes place, A block is created. The block would contain -
  - Data - Name of the sender and the receiver, amount of money and more
  - Hash Value - Unique value generated by an algorithm
  - Previous Hash Value - Hash Value of the previous block in the chain
- 

  The first block is called the genesis block as it doesn't point to any previous block (Previous Hash Value - 0000)

# Cyber Security

**Brute Force Attack:**

- Hackers try to guess your password by trying all the different combinations of letters, numbers and symbols.
- Effect:
  - Hacker gets access to user's personal data (credit cards, passwords and more)
- To remove risk:
  - Use stronger passwords with more characters and symbols

**Data Interception:**

- This involves stealing data by tapping into a wired or a wireless transmission line
  - Wardriving - The act of locating and using wireless internet connections illegally
  - Packet Sniffing - Uses Packet sniffers to examine packets sent over a line, all the data collected is sent back to the attacker
- Effect:
  - Can cause a computer to crash
  - Can delete or corrupt files/data
- To remove risk:
  - Install anti-virus software
  - Don't use software from unknown sources
  - Be careful when opening emails from unknown

**Distributed Denial of Service Attacks (DDoS)**

- An attempt at preventing users from accessing part of a network
- Usually temporary but may be damaging
- Attacker may be able to prevent user from:
  - Accessing their emails
  - Accessing websites
  - Accessing online services

**Hacking**

- The act of gaining illegal access to a computer system
- Effect:
  - Leads to identity theft, gaining personal information
  - Data can be deleted, changed or corrupted
- To remove risk:
  - Firewalls
  - Strong passwords/ user IDs
  - Use of anti-hacking software
- Difference between hacking and cracking
  - Hacking breaks into computer system to steal data
  - Cracking is where someone edits a program code, malicious

**Malware**

- Stands for Malicious Software, A few examples are -
  - Virus - Program that can replicate itself with the intention of deleting or corrupting files, cause computer malfunction
  - Ransomware - Attackers encrypt the user's data until a certain amount of money is paid
  - Adware - Displays unwanted ads on user's screen
  - Trojan Horse - Programs that are disguised as legitimate software
  - Spyware - Sends data about all the activities of the user to the attacker
  - Worms - Programs that can replicate itself with the intention of corrupting the entire network instead of the computer alone

**Phishing**

- Attackers send legitimate-looking emails to bait the user into giving out their information.
- To remove risk:
  - Don't open links from unknown receivers
  - Use anti-phishing tools
  - Block pop-up ads
  - Have an up-to-date browser

**Pharming**

- The attacker installs a malicious code on the computer which redirects the user to fake websites
- Effect:
  - User gives out login details and other personal details
- To remove risk:
  - Using anti-virus software
  - Checking the spelling and the weblink carefully
  - Making sure that the green padlock is present in the URL bar

**Social Engineering**

- Attackers create a social situation which leads to victims giving out their details (For example - Spam calls informing that your account has been hacked)

## 5.3. Keeping data safe from threats

- Access Levels - Having Different levels of access for different people (for example - Only doctors can have access to patient's data)
- Antivirus - Protects user's computer from malware attacks
- Authentication - User proving who they are. Most common methods are passwords, PINs, Mobiles (OTPs), biometrics and more)

Benefits and Drawbacks of Biometric Method

| Biometric Methods | Benefits | Drawbacks |
|---|---|---|
| Fingerprint Scans | Most development Method, Very easy to use, Requires very low storage to store the biometric data | Intrusive as used to identify criminals, Can't be used if the finger gets dirty or damaged (e.g. cuts) |

| Biometric Methods | Benefits | Drawbacks |
|---|---|---|
| Retina Scan | Very high accuracy, Impossible to replicate a person's retina | Very intrusive, Takes longer to verify, Expensive to install and set up |
| Face Recognition | Non-intrusive method, Relatively cheaper | Can't identify if there are any changes in the lighting, change in age or person's age. |
| Voice Recognition | Non-Intrusive method, verification is done quickly and relatively cheaper | Voices can be recorded and used for verification, low accuracy, illnesses such as cold or cough can affect a person's voice making identification impossible. |

- Two-Step Verification - Requires two methods of authentication to prove who the user is
- Automatic Software Updates - Latest updates contain patches which improve device security
- Spelling and Tone - Fake emails tend to have wrong spelling and grammar (amazonn instead of amazon), and the tone would also seem urgent
- Firewalls - Hardware or Software which monitors the traffic between a network and the user's computer
- Proxy Servers - Acts as an intermediate between the user's computer and the web server. They are used for -
  - Filtering Internet traffic
  - Keeping the user's IP Address Confidential
  - Blocking access to certain websites
  - Attacks like DDoS and Hacking attack the proxy server keeping the web server safe
  - Acts as a firewall as well.
- Privacy Settings - Used to limit on who can access and see user's profile
- SSL (Secure Socket Layer) - Set of rules used while communicating with other users on the internet.

# 6. Automated and Emerging Technologies

## 6.1. Automated Systems

- Automated Systems are a combination of software and hardware that are designed to function without any human intervention.
- Process of Automated Systems -
  - Inputs are taken by sensors and they are sent to the microprocessor. The data is usually analogue, so it has to go through Analouge- to-Digital Converter (ADC)
  - The microprocessor processes the data and takes the necessary decisions based on it's program
  - The actions are then executed by the actuators (Motors, wheels and so on)

Advantages and Disadvantages of Automated Systems

| Advantages | Disadvantages |
|---|---|
| Faster and Safer | Expensive to set up and maintain |
| Any changes can be identified quickly | Any computerised systems are prone to attacks |
| Less Expensive in the long run | Over-Reliance on automated systems may cause humans to lose skills |
| Higher Productivity and Efficiency | |

# Robotics

- Robotics is the branch of computer science that brings together the design, construction and the operation of robots.
- Isaac Asimov's Laws of Robotics -
  - A robot may not injure a human through action or inaction
  - A robot must obey orders given by humans unless it comes into conflict with Law 1
  - a robot must protect itself, unless this conflicts with law 1.
- Characteristics of a robot -
  - Ability to sense their surroundings
  - Have a degree of movement
  - Programmable

**NOTE - ROBOTS DO NOT POSSESS AI, THEY TEND TO DO REPETITIVE TASKS RATHER THAN REQUIRING HUMAN CHARACTERISTICS**

- Types of Robots -
  - Independent - Have no human intervention, They can completely replace humans
  - Dependent - Needs human intervention through an interface, can supplement but can't completely replace humans

Advantages and Disadvantages of Robots

| Advantages | Disadvantages |
|---|---|
| Robots can work 24/7 | Robots can find it difficult to do non-standard tasks |
| Robots can work in hazardous conditions | Robots can lead to higher unemployment |
| They are less expensive in the long run | Risk of deskilling as robots replace humans in some task |
| They have high productivity and are more consistent | Expensive to install and maintain in the short run |

| Advantages | Disadvantages |
|---|---|
| | Robots have the risk of getting hacked |

# Artificial Intelligence

- AI is the branch of computer science dealing with the simulation of intelligent human behaviour
- Types of AI -
  - Narrow AI - Machine has superior performance to a human when doing one specific task
  - General AI - Machine is similar to a human when doing one specific task
  - Strong AI - Machine has superior performance to a human in many tasks
- Characteristics of AI -
  - Collection of Data and Rules
  - Ability to Reason
- Ability to learn and adapt

### 6.3. Types of AI

- **Expert System** - AI that is developed to mimic human knowledge and experiences. They are usually used for answering questioning using knowledge and inference.
- They have many applications including chatbots, diagnosis in the medical industry, financial calculations and so on

Advantages and Disadvantages of Expert Systems

| Advantages | Disadvantages |
|---|---|
| High level of Expertise | Setup and Maintenance costs are very high |
| High Accuracy and Consistent | Can only rely on the information in the system |
| High response times | Tend to give cold responses sometimes |

- **Machine Learning -** Subset of AI in which machines are trained to learn from their past experiences.

Difference Between AI and Machine Learning

| AI | Machine Learning |
|---|---|
| Representation of human intelligence in machines | Machines are trained to make decisions without being programmed to |
| The aim is to build machines that think like humans | The aim is to make machines learn through data acquisitions |

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## Computer Science