1.2 Memory and Storage

1.2.1 Primary Storage

A computer system needs primary storage for any data that it needs to access quickly. This includes the start-up instructions, the operating system, programs that are running and any associated data. There are two main types of primary storage: RAM and ROM.

Random Access Memory (RAM) - is required to hold the operating system, applications that are running and any associated data while the computer is on and in use. RAM is volatile, meaning it needs electrical power to operate. Any data stored in RAM is lost when the power is turned off. RAM can be read from or written to by the computer.

Read-only memory (ROM) – stores the bootstrap loader / BIOS that helps 'boots' the computers – meaning it start it from scratch. ROM is non-volatile memory, which means it does not require power to maintain its contents. ROM is read only.

It is not always possible to store all the data we need in RAM. If a computer is running complex programs or have lots of programs open simultaneously, there may be insufficient RAM to hold them all. In this case the computer can allocate a section of secondary storage to temporarily act like RAM. It does this by selecting data in RAM that is not currently required by the CPU and moving it temporarily into secondary storage. Once that data is required by the CPU, it is moved back from secondary storage into RAM. The area of secondary storage used to temporarily store data from RAM is called virtual memory.

- Moving data between RAM and virtual memory is relatively slow – so using virtual memory slows down the performance of the computer.
- Adding more RAM reduces the need for virtual memory. If less data is held in virtual memory, then there are fewer slow data transfers between RAM and virtual memory.
- Therefore, adding more RAM improves the performance of the computer.

1.2.2 Secondary Storage

Secondary storage is needed to store files and programs. It needs to be: non-volatile, so doesn't lose data when switched off, low cost, high capacity and reliable.

Magnetic storage mostly uses hard disk drives (HDDs).

- They are made of a stack of magnetic disks (or platters) that rotate.
- A moving read/write head moves across the surface of the platters to read and write data.
- Magnetic disks are reliable and cost effective and provide high-capacity storage at low cost
- Not very portable due to having moving parts

Solid-state storage uses flash memory.

- Because they use flash memory, SSDs have no moving parts.
- No moving parts means access to data is faster than for a magnetic hard disk drive.
- No moving parts also means power requirements are low and no noise or heat is generated.
- SSDs are robust, lightweight and compact making them ideal for use in portable devices.
- SSDs have a smaller capacity than magnetic hard disk drives
- The cost per unit of storage is high.
- SSDs are commonly used in tablet computers, mobile phones

Optical storage devices use the properties of light to store data.

- The most common optical storage medium are optical disks – CDs, DVDs and Blu-Ray disks.
- They work by reflecting laser light onto the surface of the rotating disk and reading the reflections as 1s or 0s.
- Easily damaged by mishandling and scratches.

1.2.3 Units

Computers use switches to store data and these switches can be in one of two states: on or off. Because of this we need to convert all data and instructions into binary, which can represent on or off using the two digits 0 and 1. Each stored binary digit is called a bit (binary digit). A group of 8 bits is called a byte. Half a byte, 4 bits, is called a nibble.

4 bits	1 nibble
8 Bits	1 byte
1000 bytes	1 kilobyte (KB)
1000KB	1 megabyte (MB)
1000MB	1 gigabyte (GB)
1000GB	1 terabyte (TB)
1000TB	1 petabyte (PB)

It is important to be able to calculate the required data capacity when choosing storage media. To do this, we add up the estimated file size for each of the files we need to store and add up to 10% to cover overheads.
For example:

10 pages of word-processed documents @ 100KB -> (10 x 100KB) = 1MB
3 postcard sized images @ 6MB -> 18MB
5 minutes of MPEG video @ 50MB -> 250MB
Total -> 269MB + 10% overheads => 296MB capacity required

sound file size = sample rate (Hz) × duration (s) × bit depth
image file size = colour depth × image height (pixels) × image width (pixels)
text file size = bits per character x number of characters

1.2.4 Data Storage

Denary number range 0 – 255
Hexadecimal range 00 – FF
Binary number range 00000000 – 11111111

Left shift is the same as multiplying by 2 and right shift is the same as dividing by 2.
Overflow error may happen when adding together two binary numbers, this is when there is a carry bit / left over bit

The leftmost digit in the number is called the most significant bit (MSB) and the rightmost digit the least significant bit (LSB). In an 8-bit number, the MSB value represents 128 in decimal and the LSB value represents 1.

Characters
Each character is represented by a numeric binary code. The character set of a computer is a list of all the characters available to the computer.

ASCII is a 7-bit code able to represent the English alphabet, numbers, some symbols and some control characters. There are 2^7 or 128 characters available.

Extended ASCII uses the 8th bit in the byte to include extra symbols, mathematical symbols and some non-English characters. There are 2^8 or 256 characters available.

Unicode originally used a 16-bit code to represent many additional non-English characters and a wide range of symbols. The 16-bit code has 216 or 65536 characters available. Unicode has since been extended to use even more bits to represent billions of characters. The original ASCII and extended ASCII codes are the same in Unicode so ASCII can be considered a subset of Unicode.

Images
Images are represented on screen as a series of pixels. Pixels are stored in a computer as binary codes. The number of bits used for each pixel determines how many colours each pixel can represent. With 1 bit for each pixel we have just two possibilities: 0 or 1. This means a pixel can only be one of two colours.
To store more than two colours we need more bits per pixel: 2 bits to store 4 (2^2) colours per pixel. 3 bits to store 8 (2^3) colours per pixel. 8 bits to store 256 (2^8) colours per pixel.
Image metadata contains information that tells the computer how to reproduce the image from the binary data stored and includes:

- Colour depth – the number of bits used per pixel.
- Resolution – the number of dots (pixels) per unit of distance, for example dots per inch (DPI).

Higher colour depth: a larger number of colours can be represented giving a better-quality image. More data is stored making the image file larger.

Higher resolution: more pixels are used to represent the image meaning the quality is better and it can be made larger without losing resolution. More data is needed to represent the pixel, meaning the file needed to store the data is larger.

Sound
Sounds are a series of vibrations that continuously vary and can take any value – this means they are analogue. In order to store this on a computer sound is sampled at regular intervals by a device that converts analogue to digital signals, and the digital values are stored as binary.

The sample rate is the number of samples taken per second, measured in Hz (hertz). 1 Hz means one sample per second. The duration is the length of time that the sound is sampled for, measured in seconds or minutes. The bit depth is the number of bits used to store each sample.

Sound file size depends on:
The more frequently the sample is taken the better the approximation to the original sound – but the larger the file needed to store the data. The longer the duration the larger the file needed to store the data. The greater the bit depth the more data is stored about each sample and the better the quality of the sound – but the greater the file needed to store the data.

1.2.5 Compression

When transmitting files, storing very large files or storing a large number of files we need to compress the data to make it smaller.

Lossy compression

- Some of the data is removed to make the file smaller.
- Algorithms remove data that is least likely to be noticed.
- The original file cannot be restored from the compressed version.

Lossless compression

- None of the data is removed.
- Algorithms look for patterns in the data so that repeated data items only need to be stored once, together with information about how to restore them.
- The original file can be restored