Chapter 3:
Hardware

Learning objectives

By the end of this chapter you should be able to:

- show understanding of the need for input, output, primary memory and secondary (including removable) storage
- show understanding of embedded systems
- describe the principal operations of hardware devices
- show understanding of the use of buffers
- explain the differences between Random Access Memory (RAM) and Read Only Memory (ROM)
- explain the differences between Static RAM (SRAM) and Dynamic RAM (DRAM)
- explain the difference between Programmable ROM (PROM), Erasable Programmable ROM (EPROM) and Electrically Erasable Programmable ROM (EEPROM).

3.01 Overview of computer system hardware functionality

A computer system has to support three major areas of operational capability:

- the processing of data
- the storage of data
- the input and output of data.

At the heart of the system the processing of data is carried out by the CPU (Central Processing Unit). The workings of the CPU are the subject of Chapter 5 and will not be discussed further here.

Data storage

The terminology used in the computer literature to describe components for storing data is not always consistent. One variation is to distinguish between memory as the component which the processor can access directly and the (file-) store used for long-term storage. An alternative is to describe the memory as primary storage and the remainder as secondary storage.

Whatever names are used, the memory hierarchy is a useful concept when we choose the components to be used in a computer system for data storage. Figure 3.01 shows a version of this hierarchy that includes the trends in the important factors that affect our choice. The factors increase in the direction of the arrow. The register is a component within the CPU that has the fastest access speed. The cache memory has faster access speed than that of main memory, particularly when the cache is a built-in part of the CPU chip.

Component	Category
Register	Processor component
Cache memory	Primary storage
Main memory	
Hard disk	Secondary storage
Auxiliary storage	

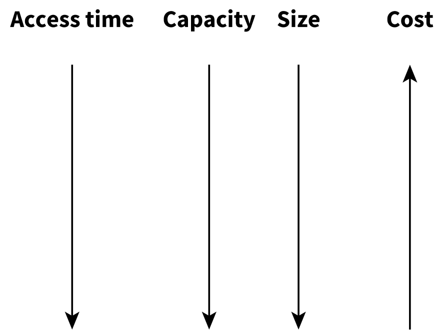

Figure 3.01 Trends in the factors affecting the choice of memory components

Computer users would really like to have a large amount of primary storage that costs little and allows quick access. This is not possible; the fastest components cost more and have limited capacity. In practice, the choice made is a compromise. It could be argued that there is a need for secondary storage because the use of primary storage alone would be far too expensive. However, it is more sensible simply to recognise that long-term storage of data requires separate dedicated components.

An alternative approach when choosing a storage medium or device is to consider which of the following applies:

- it is an integral part of the system, to which the user cannot normally get access – the options here are a hard disk or solid-state drive
- it is an individual item that can be inserted into a drive which is part of the computer system or which can be connected to it – could be a floppy disk, optical disc or magnetic tape cartridge
- it is a peripheral device that can be connected to the system when needed – there are many possibilities here including a hard drive, a memory stick or a memory card
- it is a portable item that the user can carry around with them for attaching to different systems; possibly used for personal backup – usually a flash memory stick nowadays but a floppy disk or optical disc is an alternative

- it is remote from the system, possibly accessible via a network connection; often used for backup – cloud storage is one option, but others are magnetic tape, RAID (Redundant Arrays of Independent Disks) or SAN (Storage-Area Network).

Data output

For data output from a computer system the following options are available:

- screen display
- hardcopy using a printer or plotter
- virtual headset display
- a speaker
- writing to any of the data storage devices described earlier
- transmission on a network link.

Data input

For the input of data to a computer system the following are among the options available:

- keyboard or keypad entry by a user
- user interaction with a screen using screen icons or menus; possibly using a pointing device and possibly involving the use of a touch screen
- a user using a game controller
- a user using a scanner
- a user using a microphone in tandem with voice recognition software
- reading from any of the storage devices described earlier
- transmission on a network link.

Note that input and output in a computer system are controlled by an I/O sub-system. This handles data input to or output from the computer system as well as data read from or written to the internal hard disk or solid-state drive.

3.02 Embedded systems

Much of the hardware in Section 3.01 relates to what we can call a general-purpose computer system. We also need to consider embedded computer systems because there are many more of these systems in use than there are general-purpose systems. Any manufactured item that has mechanical or electrical parts will almost certainly contain one or more embedded systems.

An embedded system must still contain a processor, memory and an I/O capability. If these are constructed on one chip this is called a microcontroller. For some applications the system will have input and output solely associated with the internal workings of the host system. In other cases, perhaps when serving a monitoring or control function, there might be input from within the system but some output is provided to the user. Alternatively, the embedded system can provide a full user interface as, for example, in a mobile phone.

The major advantage of embedded systems is that they are special-purpose; possibly performing only a single function. This function is likely to be required in a wide variety of different manufactured products. Mass production of an embedded system brings economies of scale: the more we make, the cheaper they become. During the early years of their use, embedded systems had the disadvantage that programming was difficult because the memory space available to store a program was limited. For this reason, programs had to be short. In addition, there was the disadvantage that if errors were found following installation then new chips had to be manufactured and used to replace the faulty ones. In modern systems these problems are less likely, but a new problem has developed. Embedded systems are now part of what is called the IoT (Internet of Things). More and more embedded systems are being installed with a network connection. This can greatly improve the usefulness of a product, for example by providing information and updates to the owner. However, this accessibility via a network is a security concern. Embedded systems are less likely to be protected against unlawful actions than general-purpose systems.

Discussion Point:

How might useful information from an embedded system installed in a domestic appliance be communicated over a network to the owner of the appliance?

3.03 Memory components

The components that make up the main memory of a general-purpose computer system are called **random-access memory (RAM)**. The name has been chosen because such memory can be accessed at any location independently of which previous location was used. Because of this it might have been better called 'direct-access memory'. Another possible name would be 'read–write memory' because RAM can be repeatedly read from or written to. A key feature of RAM is that it is volatile, which means that when the computer system is switched off the contents of the memory are lost.

There are two general types of RAM technology. Dynamic RAM (DRAM) is constructed from capacitors that leak electricity and therefore need regularly recharging (every few milliseconds) to maintain the identity of the data stored. Static RAM (SRAM) is constructed from flip-flops that continue to store data indefinitely while the computer system is switched on. The circuits and logic for flip-flops are discussed in Chapter 19 (Section 19.02)).

The major difference between the two types of RAM is that DRAM requires fewer electronic components per bit stored. This means DRAM is cheaper to make and has a higher density for data storage. The major advantage of SRAM is that it provides shorter access time. In a general-purpose computer system, it is normal practice for main memory to be constructed from DRAM but for cache memory to be provided by SRAM because of the faster access speed. By contrast, embedded systems that need RAM with only limited capacity often use SRAM for this.

The second category of memory component is called **read-only memory (ROM)**. Again, this name does not give a full picture of the characteristics of this type of component. ROM shares the random-access or direct-access properties of RAM. However, as the name implies it cannot be written to when in use within the computer system. The other key feature is that the data in ROM is not lost when the computer system is switched off; the memory is non-volatile.

> **TIP**
>
> The word volatile has several meanings. Try to remember that volatile memory no longer stores data when the system is switched off.

ROM has specialised uses for the storage of data or programs that are going to be used unchanged over and over again. In a general-purpose system the most important use is in storing the bootstrap program. This is a program that runs immediately when a system is switched on. There are a number of other uses for ROM in such a system, some of which we will see later in this book. In addition, ROM is used in many embedded systems.

There are four different types of ROM.

1. In the simplest type of ROM the programs or data are installed as part of the manufacturing process. If different contents are needed the chip must be replaced.
2. An alternative is Programmable ROM (PROM). The manufacturer of the chip supplies chips to a system builder. The system builder installs the program or data into the chips. This allows the system builder to test some samples of programmed chip before committing the whole batch to be programmed. As with the simplest type of ROM, the program or data once installed cannot be changed.
3. A more flexible type of ROM is Erasable PROM (EPROM). The installed data or program can be erased (using ultraviolet light) and new data or a new program can be installed. However, this reprogramming usually requires the chip to be removed from the circuit.
4. The most flexible type of ROM is Electrically Erasable PROM (EEPROM). As the name suggests, this works in a similar way to EPROM, except an electrical signal can be used to remove existing data. This has the major advantage that the chip can remain in the circuit while the contents are changed. However, the chip is still used as read-only.

Discussion Point:

Can you find out what memory components are in the computer system you are using and any details about them such as the type and storage capacity?

Buffers

Whenever data has to be transferred from one part of a computer system to another, a problem occurs if the data can be sent more quickly than it can be received. The solution to the problem is to use a **buffer**. Data enters a buffer before being transmitted to its destination. The buffer functions as a queue so the data emerges in the order that it has entered the buffer. Typically, the buffer is created in the computer memory.

Question 3.01

Can you think of examples of data transfer that would need a buffer?

3.04 Secondary storage devices

Before discussing storage devices, we should introduce some terminology. For any hardware device, whether an integral part of the computer system or a connected peripheral, its operation requires appropriate software to be installed. This software is referred to as the ‘device driver’. This should not be confused with the term ‘drive’ associated specifically with a storage device. The term ‘drive’ initially referred to the hardware that housed a storage medium and physically transferred data to it or read data from it. However, as so often happens, such distinctions are often ignored. As a result, for example, references to a ‘hard disk’, a ‘hard disk drive’ or to a ‘hard drive’ have the same meaning.

Magnetic media

Magnetic media have been the mainstay of filestore technology for a very long time. The invention of magnetic tape for sound recording pre-dates the invention of the computer by many years. As a result, magnetic tape was the first storage device. In contrast, the hard disk was specifically invented for computer storage. The hard disk also used magnetisation to write data, and arrived a few years after magnetic tape was first used for storage.

For either type of magnetic medium the interaction with it is controlled by a read head and a write head. A read head uses the basic law of physics that a state of magnetisation will affect an electrical property; a write head uses the reverse law. Although they are separate devices the two heads are combined in a read–write head. The two alternative states of magnetisation are interpreted as a 1 or 0.

A schematic diagram of a hard disk is shown in Figure 3.02. Points to note about the physical construction are:

- there is more than one platter (disk)
- each platter has a read–write head for each side
- the platters spin in unison (all together and at the same speed)
- the read–write heads are attached to actuator arms which allow the heads to move over the surfaces of the platters
- the motion of each read–write head is synchronised with the motion of the other heads
- a cushion of air ensures that a head does not touch a platter surface.

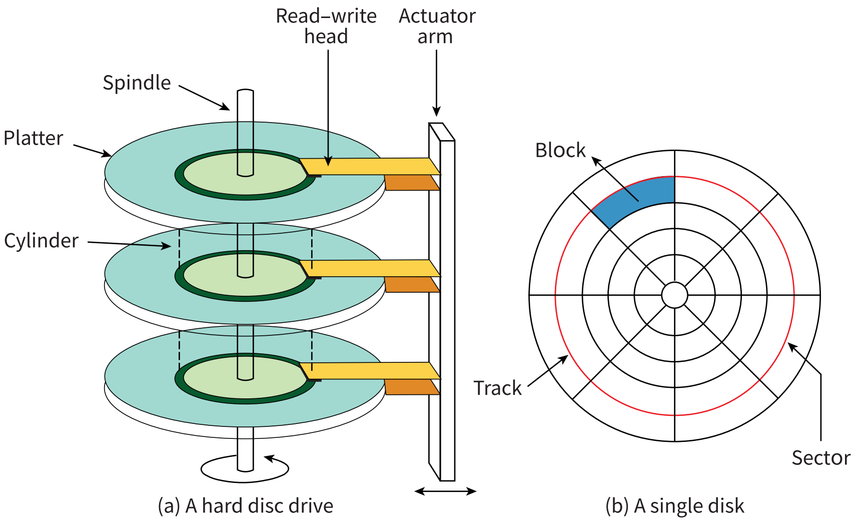

Figure 3.02 A schematic drawing of the components of a hard disk drive

Data are stored in concentric tracks (tracks sharing the same centre). Each track consists of a sequence of bits. These are formatted into sectors where each sector contains a defined number of bytes. The sector becomes the smallest unit of storage. Because the movement of the heads is synchronised, the same tracks on different disks can have related data stored on them. These are accessible by just one movement of the head. The collection of tracks is referred to as a 'cylinder'.

To store a file, a sufficient number of sectors have to be allocated but these might or might not be next to each other. As files are created and subsequently deleted or edited the use of the sectors becomes increasingly fragmented, which degrades the performance of the disk. A defragmentation program can reorganise the allocation of sectors to files to restore performance. This is discussed in Chapter 8 (Section 8.03).

A hard drive is considered to be a direct-access read–write device because any sector can be chosen for reading or writing. However, the data in a sector has to be read sequentially (in order).

This is only a simplified explanation of hard drive technology. There are several issues that arise when making hard drives. For example, the length of a track on the disk gets larger as you move from centre to edge. Manufacturers have to take account of this in their designs, otherwise the data storage capacity will be less than it potentially might be.

Optical media

As with the magnetic tape medium, optical storage was developed from existing technology not associated with computing systems. The compact disc (CD) evolved into CD digital audio (CD-DA) and this became the technology used in the CD-ROM. This was extensively used for distributing software but was of no value as a replacement for the floppy disk. The read–write version (CD-RW) which came later finally meant CD was a complete alternative to floppy disks. However, the CD has now given way to the DVD (originally 'digital video disc' but later renamed as 'digital versatile disc'). The latest and most powerful technology is the Blu-ray disc (BD).

A schematic diagram of a design for an optical disc drive is shown in Figure 3.03. This is equipped to read a CD with infrared laser light of wavelength 780 nm or a DVD with red laser light of wavelength 680 nm.

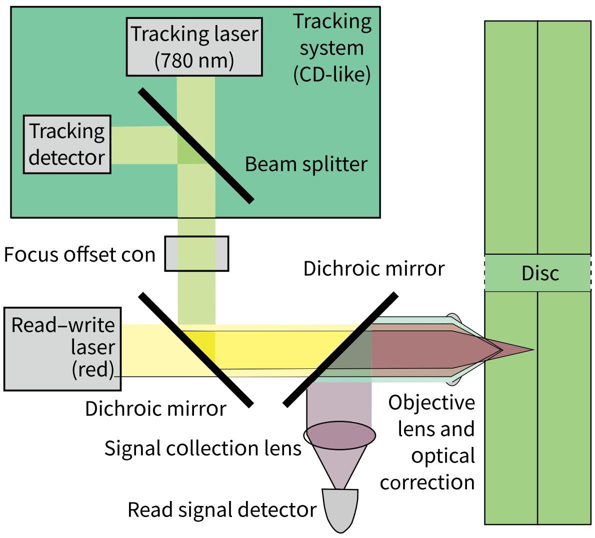

Figure 3.03 A schematic drawing of an optical disc drive

We can ignore the finer details of the construction of the drive and concentrate on the principles of how it operates. The important features for the process of reading data from the disc are as follows.

- The optical disc has one spiral track running from the inner extreme of the surface to the outer edge.
- During operation, the disc spins.
- Simultaneously the laser moves across ensuring that it is continuously focused on the spiral track.
- The track on the surface of the disc has what are referred to as 'pits' and 'lands'.
- The laser beam is reflected from the surface of the disc.

- The difference between the reflection from a pit compared to that from a land can be detected.
- This difference in the intensity of the light the detector receives can be interpreted as either a 1 or a 0 to allow a binary code to be read from the disc.

For CD-RW and DVD-RW technologies, the reflective surface is a special alloy material. When data is being written to the disc (the 'burn' process) the heat generated by the absorption of the laser light changes the material to liquid form. Depending on the intensity of the laser light the material reverts to either a crystalline or an amorphous solid form when it cools. When the disc is read, the laser light is reflected from the crystalline solid but not from the amorphous solid, allowing the coding of a 1 or 0.

Despite there being only one track the disc functions as a direct-access device because the laser can move forwards or backwards. The data is formatted into sectors along the track in a similar way to the formatting of a magnetic hard disk.

Another similarity with magnetic disk technology is that the storage capacity is dependent on how close together individual physical representations of a binary digit can get. There are two aspects governing this for an optical disc. The speed of rotation is one but the most important is the wavelength of the light. Shorter wavelength light can be better focused. This is why a DVD can store more than a CD but much less than a Blu-ray disc.

Solid-state media

Despite the continued improvement in optical technology there is now a powerful competitor in the form of solid-state storage. The basis for this is 'flash' memory, which is a semiconductor technology with no moving parts. The circuits consist of arrays of transistors acting as memory cells. The most frequently used technology is called 'NAND' because the basic circuitry resembles that of a NAND logic gate (see Chapter 4 Section 4.04) with the memory cells connected in series. The writing to the memory and the reading from it is handled by a NAND flash controller. The special feature is that blocks of memory cells can have their contents erased all at once 'in a flash'. Furthermore, before data can be written to a block of cells in the memory the data in the block first has to be erased. A block consists of several pages of memory. When data is read, a single page of data can be read in one operation.

The most frequent use is either in a memory card or in a USB flash drive (memory stick). In the latter case the flash memory is incorporated in a device with the memory chip connected to a standard USB connector. This is currently the technology of choice for removable data storage. How long this will remain so is uncertain with alternative technologies such as phase-change random access memory (PRAM) already under development.

The alternative use is as a substitute for a hard disk when it is often referred to as a solid-state drive (SSD). You might think that, with no moving parts, the technology would last forever. This is not true; with continuous use there is a degradation in the material used for construction. However, this is only gradual and it can be detected and its effects corrected for. Another major advantage over the traditional hard drive is the faster access speed.

Extension Question 3.01

Carry out some research into the technologies currently available for storage.

Consider first the options available for the storage device inside a laptop computer. Create a table showing cost, storage capacity and access speed for typical examples. Then consider the options available for peripheral storage devices. Create a similar table for these.

Can you identify which technologies remain viable and which ones are becoming uncompetitive? Are there any new technologies likely to come into common use?

3.05 Output devices provided for a user of a general-purpose computer system

Screen display

Chapter 1 (Section 1.05) described how an image could be stored as a bitmap built up from pixels. Screen displays are also based on the pixel concept but with one major difference. A screen pixel consists of three sub-pixels typically one each for red, green and blue. Varying the level of light emitted from the individual sub-pixels allows a full range of colours to be displayed.

There have been a number of very different technologies used to create a pixel. In the original cathode ray tube (CRT) technology, there is no individual component for a pixel. The inner surface of the screen is covered with phosphor, which is a material that emits light when electrons fall on it. An individual pixel is lit up by controlling the direction of the electron beam used. Colour CRT displays have individual red, green and blue phosphors arranged so as to create an array of pixels.

Flat-screen technologies now dominate. The **liquid-crystal display (LCD)** screen is an example. It has individual cells containing a liquid crystal to create each pixel. The pixel matrix is illuminated by back-lighting and each pixel can affect the transmission of this light to create the on-screen display. A typical arrangement is shown in Figure 3.04.

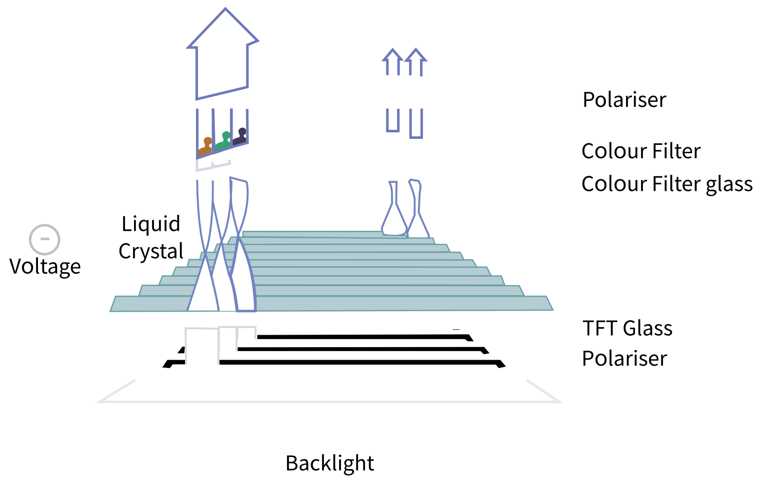

Figure 3.04 The components of a liquid-crystal display screen

The back-lighting is usually provided by light-emitting diodes (LEDs). Polarised light is directed towards the pixel matrix and a further polariser is placed between the pixel matrix and the screen. If a voltage is applied to an individual pixel cell the alignment of the liquid crystal molecules is affected. This changes the polarisation of the light and so changes what is displayed on the screen.

Virtual reality headset

The most important components of a virtual reality headset are the two eye-pieces. These are fed paired images from the controlling system which, when looked at together, give the eyes the sensation of being in a 3D environment. The images can be collected using specialised photographic techniques or can be created using a 3D graphics package. The wearer of the headset can control which part of the 3D environment is in view. They do this by moving their head or by using a controlling device.

Hard-copy output of text

Two technologies have come to dominate the printing of documents from data stored in a computer system. These are the inkjet printer and the laser printer. Both these technologies can be used to print text or images.

An inkjet printer works in the following way. A sheet of paper is fed in; the printhead moves across the sheet depositing ink on to the paper; the paper is moved forward a fraction and the printhead moves across the paper again. This continues until the sheet has been fully printed. The printhead consists of nozzles that spray droplets on to the paper. Ink is supplied to the printhead from one or more ink cartridges.

A schematic diagram of the workings of a laser printer is shown in Figure 3.05. The operation can be summarised as follows.

1. The drum is given an electric charge.
2. The drum starts to revolve step by step.
3. At each step a laser beam is directed by the mirror and lens assembly to a sequence of positions across the width of the drum.
4. At each position the laser is either switched off to leave the charge on the drum or switched on to discharge the position.
5. This process repeats until a full-page electrostatic image has been created.
6. The drum is coated with a charged toner that only sticks to positions where the drum has been discharged.
7. The drum rolls over a sheet of paper which is initially given an electric charge.
8. The sheet of paper is discharged and then is passed through heated rollers to fuse the toner particles and seal the image on the paper surface.
9. The drum is discharged before the process starts again for the next page.

The above sequence represents black and white printing.

For colour printing, separate toners are required for the colours and the process has to take place for each colour. The colours are created from cyan, magenta, yellow and black. The technology produces dots. Image quality depends on the number of dots per inch and software can control the number of dots per pixel.

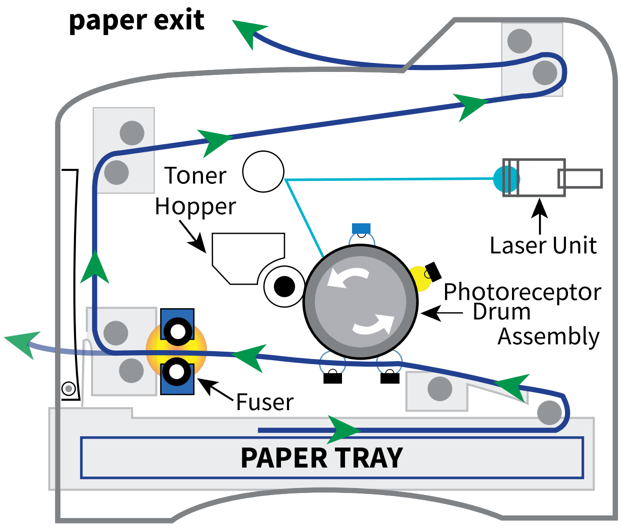

Figure 3.05 A schematic diagram of a laser printer

The same principles apply for colour printing using an inkjet printer, where separate colour inks are used.

Hard-copy graphics output

As discussed in Chapter 1 (Section 1.05) a graphic image can be stored either as a bitmap or as a vector graphic. The printing technology described above can be used to print a hard-copy of a bitmap. If a vector graphic file has been created the image can be displayed on a screen or printed by first converting the file to a bitmap version. However, specialised technical applications often require a more accurate representation to be created on paper. This requires the use of a graphics plotter. A plotter uses pens to write, usually, on a large sheet of paper constrained by sprockets along one pair of sides. The sprockets can move the paper forwards or backwards and pens can either be parked or in use at any given time. The controlling circuitry and software can create the drawing directly from the original vector graphic file.

Graph plotters are used by engineers and designers working in manufacturing. Engineers and designers may also use a 3D printer, which is a device that offers an alternative technology for computer-aided manufacture (CAM).

Figure 3.06 A bionic ear created using a 3D printer

A 3D design is created in a suitable computer-aided design (CAD) package. The design is split into layers. The data for the first layer is transmitted to the 3D printer. Rather than using ink to draw the layer, the 3D printer uses a nozzle to squirt material on to the printer bed to create a physical layer to match the design. This process is repeated for successive layers. When the whole object has been formed it has to be cured in some way to ensure that the layers are stuck together and the material has been converted to the form required for the finished product.

The technology is versatile. Figure 3.06 shows a striking example.

(For those of you interested in the details of Figure 3.06: the bionic ear was constructed with three ‘inks’. Silicone was used for the basic structure, a gel containing chondrocyte cells and silicone infused with silver nanoparticles were the other two ‘inks’. The final curing step involved incubation in a culture medium to allow the chondrocyte cells to produce cartilage. The only missing component was skin.)

3.06 Input devices provided for a user of a general-purpose computer system

The keyboard

The keyboard allows a user to input text data. During text input it appears as though a key press immediately transfers the appropriate character to the computer screen, but this is an illusion. The key press has to be converted to a character code, which is transmitted to the processor. The processor, under the control of the operating system, ensures that the text character is displayed on the screen. The same process takes place if the keyboard is used to initiate some action, perhaps by using a shortcut key combination. The difference is that the processor has to respond by taking the requested action.

To achieve this functionality the keyboard has electrical circuitry together with its own microprocessor and a ROM chip. The significant details of how a keyboard works are as follows.

- The keys are positioned above a key matrix, which consists of a set of rows of wires and another set of columns of wires.
- Pressing a key causes contact at one of the points where wires cross.
- The microprocessor continuously tests to see if any electrical circuit involving a row wire and a column wire has become closed.
- When the microprocessor recognises that a circuit has become closed, it can identify the particular intersection (wire crossing point) that is causing this.
- The processor then uses data stored in the ROM to identify the character code relating to the key associated with that intersection and sends this character to the screen.

The screen

There are a number of ways in which a user can cause data to be input through an interaction with a screen. At one time a computer system user only had access to a keyboard and a screen acting as a monitor. Even then the software could display a menu on the screen and the user could choose an option by keying in a number from the menu.

A significant step forward came with the introduction of graphical user interfaces (GUIs) as standard features for microcomputer systems in the 1980s. A GUI provides a number of different types of screen icon, each of which allows the user to control data input. The user needs a pointing mechanism to use a GUI effectively. One example of a pointing mechanism is a computer mouse that controls the position of a cursor on the screen. The screen is now not just an output device but also an input device activated by a mouse click.

Touch screens

The early versions of touch screen technology worked with a CRT screen but could equally well be used with a flat screen. The mechanism required emitters to be positioned on the sides of the screen with detectors positioned opposite to them. The emitters produced either infrared light or ultrasonic waves. When a finger touched the screen and blocked some of the light or ultrasound, some of the detectors would measure a reduced signal level.

As well as providing improved display capability, flat-screen technology has allowed new mechanisms for touch screen interaction.

The modern version of a touch-sensitive screen has layers providing the light output by the display with further, touch-detecting layers added immediately beneath the surface of the screen. There have been two approaches used. The first is the **resistive touch screen**. This type has two layers separated by a thin space beneath the screen surface. The screen is not rigid so when a finger presses on to the screen the pressure moves the topmost of these two separated layers, so that the top layer makes contact with the lower layer. The point of contact creates a voltage divider in the horizontal and vertical directions.

The second technology is the **capacitive touch screen**. This does not require a soft screen but instead makes use of the fact that a finger touching a glass screen can cause a capacitance change in a circuit component immediately below the screen. The most effective technology is projective capacitive touch (PCT) with mutual capacitance. PCT screens have a circuit beneath the screen that contains an array of capacitors. This capacitive technology can detect the touch of several fingertips at the same time, which allows for more sophisticated applications.

In any type of touch screen the processor takes readings from measuring devices and uses these readings to calculate the position of the touch. This calculation then allows the processor to set in motion whatever action the user was requesting.

Extension Question 3.02

Consider the different possibilities for interacting with a screen display. Create a table showing the advantages and disadvantages for each technique.

Discussion Point:

Investigate which flat-screen technologies are used in any computer, laptop, tablet or mobile/cell phone that you use. Discuss the benefits and drawbacks associated with their use.

Input of a graphic

There are several ways to store and use image (graphic) data in a computer. A webcam is a device used to stream video images into a computer system. A digital camera can be connected to a computer and stored images or videos can then be downloaded into the computer. Another option is to use a scanner. Effectively, a scanner reverses the printing process in that it takes an image and creates a digital representation from it. A sheet of paper containing the image (which may be text) is held in a fixed position and a light source moves from one end of the sheet to the other. It covers the width of the paper. The reflected light is directed by a system of mirrors and lenses on to a charge-coupled device (CCD).

You don’t need to know the details of how a CCD works, but three aspects to note are:

- a CCD consists of an array of photo-sensitive cells
- a CCD produces an electrical response proportional to the light intensity for each cell
- a CCD needs an analogue-to-digital converter to create digital values to be transmitted to the computer.

3.07 Input and output of sound

Voice input and output

IP telephony and video conferencing are two applications that require both voice input and voice output. In addition, voice recognition can be used as an alternative technique for data input to a computer and voice synthesis is being used for an increasing variety of applications.

For input, a microphone is needed. This is a device that has a diaphragm, a flexible material that is caused to vibrate by an incoming sound. If the diaphragm is connected to suitable circuitry the vibration causes a change in an electrical signal. A condenser microphone uses capacitance change as the mechanism; an alternative is to use a piezoelectric crystal. The analogue electrical signal is converted to a digital signal by an analogue-to-digital (ADC) converter so that it can be processed inside the computer.

For output, a speaker (loudspeaker) is needed. How this works is effectively the reverse process to that for input. Digital data from the computer system is converted to analogue by a digital-to-analogue (DAC) converter. The analogue signal is fed as a varying electrical current to the speaker. In most speakers, the current flows through a coil suspended within the magnetic field provided by a permanent magnet in the speaker. As the size and direction of the current keep changing, the coil moves backwards and forwards. This movement controls the movement of a diaphragm, which causes sound to be created.

The input and output are controlled by a sound (audio) card installed in the computer.

Other types of sound input and output

Music as well as voice sounds can be recorded or live streamed in the same way that voices are recorded. Some sound recording devices carry out the analogue to digital conversion very early on in the process so that all the sound processing is done digitally. Music can be output via speakers or stored in digital form for later play back.

Reflection Point:

The description ‘peripheral’ is often used to describe devices that can be connected to a computer. In your research did you come across the word being used? Is it a useful one or is it possibly not so because of the lack of a clear definition?

Summary

- Primary storage is main memory, consisting of RAM (DRAM or SRAM) and ROM (possibly PROM, EPROM or EEPROM).
- Secondary storage includes magnetic, optical and solid-state media.
- Output devices include screens, printers, plotters and speakers.
- Input devices include the keyboard, scanner and microphone.
- Screens can be used for both input and output.

Exam-style Questions

1 a Examples of primary and secondary storage devices include:

- hard disk
- DVD-RW
- flash memory

For each device, describe the type of media used.

Hard disk

DVD-RW

Flash memory [3]

b Describe the internal operation of the following devices:

DVD-RW

2 a Pressing a key on a computer keyboard can cause a character to be displayed on the computer screen.

i Identify **four** aspects of the basic internal operation of a keyboard that makes this happen. [4]

ii Describe an alternative method for a user to enter some text into a computer system. [2]

b i In the operation of a laser printer there are a number of initial stages which lead up to the creation of a full-page electrostatic image. Identify **three** of these stages and present them in the order that they would occur. [3]

ii Identify **two** of the stages that make use of this electrostatic image. [2]

iii State the difference in the procedure used for colour printing from that used for black and white printing. [1]

3 a Describe the operation of a touch screen technology that can be used in association with any type of computer screen. [4]

b Describe the operation of a touch screen technology that is only applicable for use with a flat screen. [4]

4 a Examples of primary and secondary storage devices include: [3]

- hard disk
- DVD-RW
- flash memory

For each device, describe the type of media used.

Hard disk

DVD-RW

Flash memory [3]

b Describe the internal operation of the following devices:

- DVD-RW
- DVD-RAM [2]

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5 a Describe **two** differences between RAM and ROM. [2]

b State **three** differences between Dynamic RAM (DRAM) and Static RAM (SRAM). [3]

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