CHAPTER 1

Types and components of computer systems

In this chapter you will learn about:

- hardware
- software
- the main components of a computer system
- operating systems:
  - graphical user interface (GUI)
  - command line interface (CLI)
- different types of computer systems.

1.1 Hardware and software

Computer systems are now commonplace in every part of our daily life. This chapter introduces the basic components that make up these computer systems; most of these will be described in much greater depth in later chapters. Comparing books with computers is a good analogy: the actual pages and the ink used on the pages are equivalent to the hardware used to make up these computers; the words written on these pages are equivalent to the software. Without the words, the book is useless. Similarly, without software, computers would be of little use to any of us.

Hardware is a general term for the physical components that make up a computer system, for example keyboard, mouse, monitor, processor, circuit board and so on.

Software is a general term for the programs that control the computer system. There are two types of software:

- **systems software**: programs that allow the hardware to run properly, e.g. operating systems
- **applications software**: programs that allow the user to do specific tasks, e.g. spreadsheets.

1.2 Main components of computer systems

A typical computer system is made up of hardware and software. Figure 1.1 shows an example of a computer system consisting of input devices, output devices and secondary storage. These will be discussed in more detail in Chapter 2, but examples include:

- **input devices**: keyboard, mouse
- **output devices**: monitor, printer
- **secondary storage devices**: DVD R/W drive, removable hard drive.

However, one part of the computer system has not yet been mentioned. This is shown as the 'Processor and internal memory devices' in the diagram – this consists of four key components called the **central processing unit (CPU)**, internal **hard disk**, **random access memory (RAM)** and **read only memory (ROM)**.

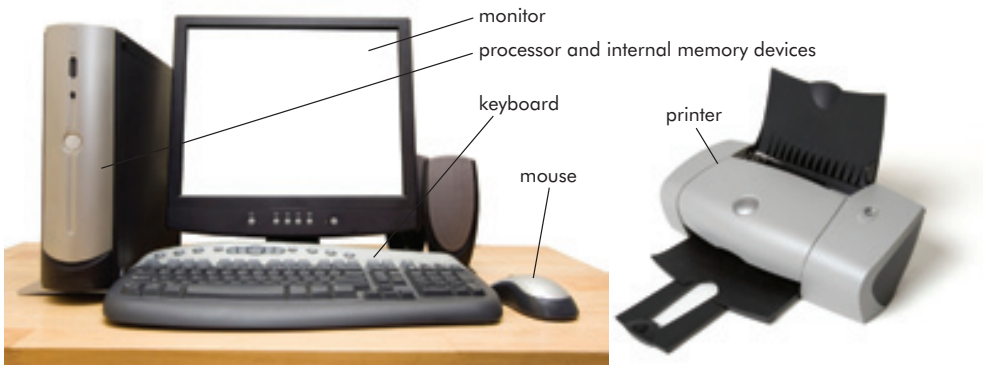


Figure 1.1 A typical computer system

The central processing unit (CPU) is the part of the computer which interprets and executes the commands from the computer hardware and software. CPUs used to be made up of discrete components and numerous small integrated circuits, which were combined together on one or more circuit board/s. However, due to modern manufacturing techniques, the term **microprocessor** is now used instead of CPU. This is a single integrated circuit (see Figure 1.2) which is at the heart of most PCs and is also found in many household devices and equipment where some control or monitoring is needed (e.g. the engine management system in a car).

The internal hard drive is the computer's main memory; this is where the **applications software**, disk **operating system** and **data files** are stored. The main advantage of these memories is the fast data transfer/access times and their large capacity to store data (this is discussed further in Chapter 3).

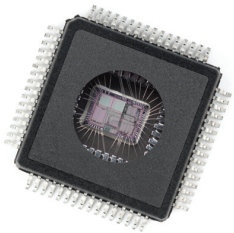


Figure 1.2 Typical microprocessor

Random access memory (RAM) is an internal chip where data is temporarily stored when running applications. This memory can be written to and read from. Since its contents are lost when power to the computer is turned off, it is often referred to as a 'volatile' or 'temporary' memory.

Read only memory (ROM) is a memory used to store information that needs to be permanent. It is often used to contain, for example, configuration data for a computer system. These chips cannot be altered and can only be read from (hence their name). One of the main advantages is that the information stored on the ROM chip is not lost even when power is turned off to the computer. They are often referred to as 'non-volatile' memories.

It is worth noting that ROM also contains some coding known as the boot file. This code tells the computer what to do when it first starts up; it is often referred to as the **BIOS (basic input/output system)**. When the computer is turned on, the BIOS carries out a hardware check to find out if all the devices are present and whether they are functional. Then it loads the operating system into the RAM. The BIOS stores the date, time and system configuration in a non-volatile chip called a **CMOS (complementary metal oxide semiconductor)**, which is usually battery powered.

1.3 Operating systems

Reference to operating systems has already been made earlier in this chapter.

To enable users to communicate with computer systems, special software, known as operating systems, have been developed. The general tasks for a typical operating system include:

- controlling the operation of the input, output and backing storage devices
- supervising the loading, running and storage of applications programs

- dealing with errors that occur in applications programs
- maintaining security of the whole computer system
- maintaining a computer log (which contains details of computer usage)
- allowing communication between user and the computer system (user interface).

Computer users need to be able to communicate with the operating system – this is called the 'user interface'. There are two main types of user interfaces: **command line interfaces (CLIs)** and **graphical user interfaces (GUIs)**.

Command line interfaces

CLIs require a user to type in instructions in order to choose options from menus, open software etc. There are often a number of commands that need to be typed in, for example, to save or load a file. The user therefore has to learn a number of commands just to carry out basic operations. It is also slow having to key in these commands every time an operation has to be carried out. However, the advantage of CLI is that the user is in direct communication with the computer and is not restricted to a number of pre-determined options.

For example, Figure 1.3 shows the CLI code required for importing data into a table called B.

```
1. SQLPrepare(hStmt,
2. ?            (SQLCHAR *) "INSERT INTO tableB SELECT * FROM
                tableA",
3. ?            SQL_NTS):
4. ? SQLExecute(hStmt);
```

Figure 1.3 Example of CLI code

The above statements show how complex it is just to carry out a fairly straightforward operation using CLI.

Graphical user interfaces

GUIs allow the user to interact with a computer (or MP3 player, gaming device, mobile phone, etc.) using pictures or symbols (**icons**) rather than having to type in a number of commands. For example, the whole of the CLI code shown in Figure 1.3 could have been replaced by a single icon:  (table update). Simply selecting this icon would automatically execute all of the steps shown in Figure 1.3 without the need to type them in each time.

GUIs use various technologies and devices to provide the user interface. One of the most common is **windows icons menu and pointing device (WIMP)** which was developed for use on **personal computers (PCs)**. This uses a mouse to control a cursor, which then selects icons to open/run windows. Each window contains an application and modern computer systems allow several windows to be open at the same time. In the example shown in Figure 1.4, a number of icons can be seen on the left-hand side and on the bottom right; three windows are open and these are shown as grey rectangles at the bottom of the screen.

A windows manager looks after the interaction between windows, the applications and the windowing system (which handles the pointing devices and the cursor's position).

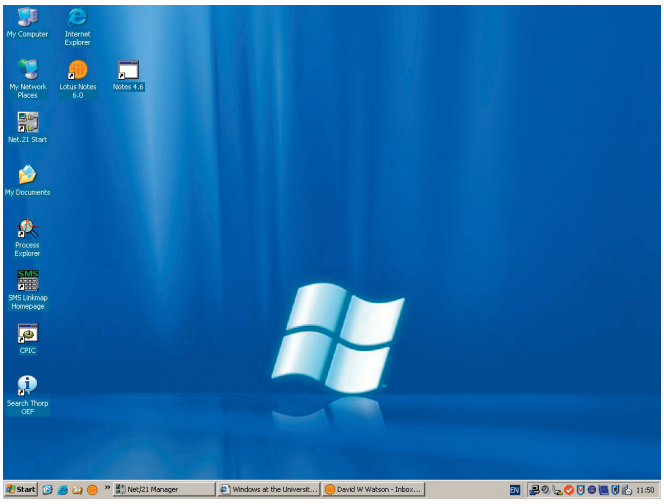


Figure 1.4 A typical GUI

In recent years, devices such as **touch screen** phones use **post-WIMP** interaction, where fingers are in contact with the screen. This allows actions such as **pinching** and rotating, which would be difficult to do using a single pointer and device such as a mouse.

1.4 Types of computers

There are many types of computer systems in existence. This section summarises some of the more common types currently available.

PC/desktop computers

PC/**desktop** usually refers to a general purpose computer which is made up of separate monitor, keyboard, mouse and processor unit (see Figure 1.1). The term PC (personal computer) usually refers to computer systems which are IBM-compatible, thus distinguishing them from, for example, Macintosh systems.

It is worth making a comparison here with laptop computers:

Advantages

- Spare parts and connections tend to be standardised, which usually results in low costs.
- Desktops tend to have a better specification (e.g. faster processor) for a given price (often due to size and construction constraints in laptops).
- The large casing allows good dissipation of any heat build-up.

Disadvantages

- Desktops are not particularly portable since they are made up of separate components.
- All the components need to be hooked up by wiring, which can be quite complex and clutters up the desk space.
- Because they are not particularly portable, it is necessary to copy files, etc. when you want to do some work elsewhere (e.g. at home).

Laptop computers

Laptop (or notebook) refers to a type of computer where the monitor, keyboard, pointing device and processor are all together in one single unit. This makes them extremely portable systems.

The key features you would expect to find in a laptop are:

- low weight (to aid portability)
- low power consumption (and also long battery life)
- a processor that does not generate too much heat (cooling is very important).

Advantages

- They are very portable, since the monitor, pointing device, keyboard, processor and backing store units are all together in one single box.
- There are no trailing wires, etc. because everything is in one single unit.
- They can take full advantage of **WiFi** (see discussion in Chapter 4).
- Since they are portable, they can link into any multimedia system.

Disadvantages

- Since they are portable, they are easy to steal!
- They have limited battery life so the user may need to carry a heavy adaptor.
- The keyboards and pointing devices can sometimes be awkward to use.
- Heat dissipation is more difficult due to the structure of the laptop computers.

Netbooks

Netbook is a term used to describe a computer that can almost fit onto a hand and is a smaller version of a laptop. These used to be known as **palmtop** computers, but this term now generally applies to much smaller devices which use touch screens and often a stylus to key in data (see below).

Advantages

Netbook computers have many of the features of laptops and therefore have similar advantages and disadvantages.

Disadvantages

In addition to the disadvantages listed above for laptops:

- netbooks don't have optical drives
- the keyboards are only about 80 per cent the size of laptop keyboards
- they lack some of the features found in larger machines, principally due to the size constraints and to the fact that they are cheaper to purchase.

Personal digital assistants

Personal digital assistants (PDAs) are small handheld computers that usually come with a touch screen that is activated using a stylus. Data (e.g. text) is entered by using a keyboard that appears on the touch screen. Originally, these devices were used as personal organisers but their use has expanded somewhat to include new generation mobile phones, **data loggers**, satellite navigation systems, etc. Many PDAs now have basic database, **word-processing** and **spreadsheet** facilities.

Advantages

- They can be used anywhere because of their size.
- They are very lightweight and are more portable than laptop computers.

Disadvantages

- It is difficult to enter text quickly.
- They have very limited capabilities due to the software and the operating system used.

Mainframe computers

Mainframe computer is a term used for a large, very powerful, computer system. The name comes from the days when the individual components were housed in large (often room-sized) frames.

Uses

Their main purpose is to run commercial applications, such as banking and insurance, where huge amounts of data need to be processed each day.

The main features of main frame computers are as follows.

- They can have several CPUs.
- They have very fast processor speeds.
- They can support multiple operating systems.
- They have huge amounts of storage capacity.
- They have huge internal memories (e.g. several hundred Gbyte of RAM).
- They often operate using time sharing or batch processing (see Chapter 7).

Advantages

- Due to the features listed above, they can be used to do very large jobs which require large memories and very fast processor time.
- They are used in time-sharing systems to allow users to be given a time slice of the very powerful facilities afforded by a mainframe system.
- They are capable of very large number crunching, and so can deal with very complex mathematical functions (e.g. fractals) which would be very time consuming using, for example, a PC.

Disadvantages

- Mainframe computers need to be permanently housed in a large room, so cannot be moved around.
- They are very expensive to operate and maintain.

CHAPTER 2

Input and output devices

In this chapter you will learn about:

- input devices:
  - the uses of each device
  - the advantages of each device
  - the disadvantages of each device
- output devices:
  - the uses of each device
  - the advantages of each device
  - the disadvantages of each device
- control applications and the uses of each device.

2.1 Input devices

As the name suggests, input devices are hardware devices that allow data to be input into a computer. Many such devices exist, ranging from the more common ones, such as the keyboard, through to the more specialist devices, such as barcode readers. A number are described in this section.

Keyboards

These are the most common input devices and are used to input text, numbers and instructions into the computer. Most use the **QWERTY** layout (this name comes from the keys on the top row, which spell out 'QWERTY').

Ergonomic keyboards have also been developed recently. These are designed to reduce health-related problems associated with the standard keyboard (e.g. carpal tunnel syndrome or repetitive strain injury (RSI) – see Section 6.7).

Uses

- Keyboards are used to input data into applications software (e.g. text into word processors, numbers into spreadsheets, etc.).
- They are also used for typing in commands to the computer (e.g. Prnt Scrn, Ctrl+P to print out, etc.)

Advantages

- Keyboards enable fast entry of new text into a document.
- They are a well-tried technology and a well-known method of entry.
- Most people find them easy to use.
- It is easy to do **verification** checks as data is entered, as it appears on the screen simultaneously.

Disadvantages

- Users with limited arm/wrist use can find keyboards hard to use.
- Entering data using a keyboard is slow when compared to direct data entry (e.g. **optical mark recognition**).
- Keyboards are fairly large devices that use up valuable desk space.

The **concept keyboard** uses icons or phrases instead of standard letters. These are often used in, for example, fast food restaurants, offices and shops, where a single key represents an item. For example, the symbol shown in the photo represents 'add tax'. The person using the keyboard only needs to touch this key to calculate the tax on an invoice.

Advantages

- Concept keyboards enable fast data entry, as there is no need to type in whole commands.
- They are waterproof, which is useful in a restaurant environment.
- These keyboards are tamper proof and so are useful in certain applications (e.g. at unmanned airport information kiosks), preventing people from keying in information which could potentially corrupt the computer system.

Numeric keypads

A **numeric keypad** is used to enter numbers only (although some have a function key to allow input of alphabetic characters).

Uses

- Numeric keypads are used in **automatic teller machines (ATMs)**, where customers can key in their **personal identification number (PIN)**, an amount of money, etc.
- Telephones have numeric keypads to allow phone numbers, etc. to be keyed in.
- **Electronic point of sale (EPOS) terminals** have numeric keypads in case the barcode reader fails to read the barcode and the number has to be keyed in manually by the operator.
- Chip and PIN devices have numeric keypads for entry of PIN, amount of money, etc.
- They are used to enable fast entry of numeric data into a spreadsheet.

Advantages

- Numeric keypads are faster than standard keyboards for entry of numeric data.
- Since many are small devices (e.g. mobile phones), they are very easy to carry around.

Disadvantages

- They can be difficult to use, due to very small keys.
- It is difficult to use them for entering text.
- Sometimes the order of the numbers on the keypad isn't intuitive.

Mice

The **mouse** is an example of a **pointing device**. A ball is used underneath the mouse to detect movement, so by moving the mouse around the user can control the position of a pointer on the screen. There are usually two buttons, which have different functions: very often the left button is used to select something by double clicking it and the right button brings up drop-down menus (see Figure 2.1).

Many mice also have a scroll button, which speeds up the process of moving through a document.

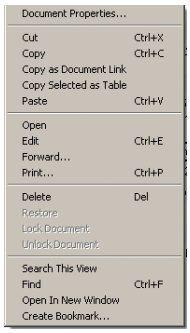


Figure 2.1 Example of a drop-down menu

Recent developments have produced the **optical mouse** (where movement is detected by reflected light rather than the position of a moving ball) and the **cordless mouse** (which is an example of a wireless device). The advantage of an optical mouse is it has no moving parts and it also doesn't pick up any dirt. This makes it more robust and improves its performance, since the older type of mouse can 'skid' on certain surfaces reducing the control of the pointer.

Uses

- Mice can be used for opening, closing and minimising software.
- They can be used for grouping, moving and deleting files.
- They are very useful when editing images, for example controlling the size and position of a drawing pasted into a document.
- Mice are used for controlling the position of a pointer on the screen to allow selection from a menu or selecting an icon and for scrolling up and down/left to right.

Advantages

- It can be faster to select an option using a mouse rather than a keyboard.
- Mice enable rapid navigation through applications and the internet.
- Mice are small and so take up little area.

Disadvantages

- People with restricted hand/wrist movement can find it hard to operate a mouse.
- Mice are easily damaged and the older type of mouse also quickly becomes clogged up with dirt.
- They are difficult to use if there is no flat surface readily available (e.g. on an aeroplane).

Touchpads

Touchpads are used in many laptop computers as a pointing device. The pointer is controlled by the user moving their finger on the touchpad and then gently tapping it to simulate the left hand button of a mouse (i.e. selection). They also have buttons under the touchpad which serve the same function as the left and right buttons on a mouse.

Uses

The uses of a touchpad are the same as those of a mouse.

Advantages

- It can be faster to select an option using a touchpad rather than a keyboard.
- Touchpads enable rapid navigation through applications and the internet.
- Since the touchpad is integrated into the laptop computer, there is no need for a separate mouse, aiding portability.
- They can be used even when there are no flat surfaces available.

Disadvantages

- People with limited hand/wrist movement find touchpads difficult to use.
- It can be more difficult to control the pointer when compared with a mouse.
- They are more difficult to use when doing certain operations such as 'drag and drop'.

Trackerballs

Trackerballs are similar to a mouse, except that the ball is on the top of the device and the user controls the pointer on the screen by rotating the ball with the hand. Some trackerballs have two buttons which have the same function as the left- and right-hand mouse buttons. If they have a third button, this is equivalent to a double click.

Uses

- They have the same pointing/cursor control capability as a mouse.
- They are used in applications where the user has a disability (such as RSI).
- They are used in a control room environment, where it is faster than a mouse to navigate through process screens and is more robust than a mouse.

Advantages

- Trackerballs do not need the same fine control as a mouse.
- People with limited hand/wrist movement find it easier to use than a mouse.
- The pointer can be positioned more accurately on the screen than with a mouse.
- They take up less desk space than mice since they are stationary.

Disadvantages

- Trackerballs are not supplied with the computer as standard, so they are more expensive.
- User may need training since they are not standard equipment.

Remote controls

A **remote control** is used to control the operation of other devices remotely by using infra red signals. The buttons on the keypad are used to select options (such as television stations, sound levels on a hifi, timings on a DVD recorder, etc.).

Uses

- Most home entertainment devices such as a television, satellite system, DVD player/recorder, hifi systems, etc. have remote controls.
- Remote controls are also used to control multimedia systems.
- They are used in industrial applications to remotely control processes, stop and start machinery, etc.

Advantages

- Remote controls enable devices to be operated from any distance, which is particularly useful for people with disabilities.
- Some chemical processes are hazardous, so it is safer to operate equipment from a distance.

Disadvantages

- People with limited hand/wrist movement can find them hard to use.
- The signal between the control and the device can be easily blocked.

Joysticks

Joysticks have similar functions to mice and trackerballs. By gripping the stick, a pointer on the screen can be controlled and buttons are used to make selections. Often they have another button on the top of the stick that is used for gaming purposes, e.g. to fire a weapon.

Uses

- Video/computer games are often controlled by joysticks.
- They are used in **simulators** (e.g. flight simulators) to mimic actual controls.

Advantages

- It is easier to navigate round a screen using a joystick rather than a keyboard.
- Control is in three dimensions.

Disadvantages

- It is more difficult to control the on-screen pointer with a joystick than with other devices, such as a mouse.

Touch screens

With this system the user can choose an option by simply touching the button/icon on the screen. The selection is automatically made without the need for any pointing device.

Uses

- Touch screens are used for self-service tills, e.g. petrol stations, where the user just touches the screen to select the fuel grade and payment method.
- Touch screens are used where selections are made on screen, for example ATMs, point of sale terminals (e.g. at restaurants), public information systems at airports, railway stations, tourist offices.
- Personal digital assistants (PDAs), mobile phones and satellite navigation systems use touch screens.
- Interactive white boards used for education are large touch screens.
- Touch screens are used in computer base training (CBT) where selections are made in answering on screen testing.

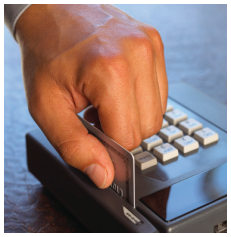
Advantages

- Touch screens enable faster entry of options than using a keyboard or a mouse.
- It is very easy to choose options.
- It is a user friendly method for inputting data, so no training is necessary.
- Touch screens are tamper proof, preventing people from keying in information which could potentially corrupt the computer system (e.g. at unmanned ticket collection kiosks).

Disadvantages

- There is a limited number of options available.
- Using touch screens frequently can lead to health problems (e.g. straining of arm muscles, RSI, etc.).
- The screen can get very dirty with constant touching.

Magnetic stripe readers



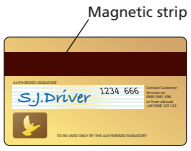


Figure 2.2 The magnetic stripe on a credit card

These are used to read information on the **magnetic stripe** found, for example, on the back of a credit card (see Figure 2.2). The stripe contains useful information, such as the account number, sort code, expiry date and start date.

Uses

- Credit and debit cards have magnetic stripes that are used by ATMs or EFTPOS (electronic funds transfer point of sale) terminals.
- Security cards for entry to buildings, hotel rooms, etc. use magnetic stripes.
- Travel systems (e.g. train and underground tickets) use magnetic stripes.

Advantages

- Data entry is faster compared with keying in using a keyboard or keypad.
- The system is error free, since no typing is involved.
- The information held on the magnetic stripe is secure: because it cannot be read directly by a person; and, since there is no typing, there is not the risk of somebody observing your key strokes.
- They can prevent access to restricted/secure areas.
- Magnetic stripes are unaffected by oil, water, moisture, etc.
- There are no moving parts, so they are physically very robust.

Disadvantages

- If the magnetic stripe gets damaged (e.g. due to exposure to a strong magnetic field or excessive use) the data is lost.
- The card needs to be in close contact with the reader, so magnetic stripe readers don't work at a distance.
- Since the information is not human readable, this can be a disadvantage in some applications (e.g. hotel room numbers are not printed on the card, so there needs to be another way of showing the information for the customer).

Smart card readers

Figure 2.3 The chip on a smart card

Smart cards contain chips (see Figure 2.3) and are similar to magnetic stripe cards. With these cards the information is stored on the chip (e.g. PIN and personal data). The data stored on the chip can be updated (e.g. on loyalty cards). For example, certain oil companies use these cards: when a customer buys fuel at a filling station, the loyalty card is swiped and 'points' are added to the card; these points can be used for air miles, money off next purchases, and so on. The storage capacity of the chip is much greater than a magnetic stripe, so more information (such as customer details) can be stored.

Uses

- Loyalty cards, ID cards and public transport passes use smart cards.
- Smart cards can be used to track customer/passenger movements (e.g. on a metro system).
- They are used with satellite systems to decode program signals.
- Smart cards are used for electronic passports and driving licences.

Advantages

- Some smart cards (e.g. transport tickets) are used instead of money, reducing the need to carry cash.
- The chip on the card does not need to be in contact with reader, so there is less damage compared with a magnetic stripe reader.
- Data is more secure, since it is easier to copy information on a magnetic stripe than it is to copy information on a chip.

Disadvantages

If the card is lost, information stored on the chip could be used in identity theft.

Chip and PIN readers

Chip and PIN readers are similar to smart card readers, but are used at EFTPOS terminals. The device has a slot into which the card is placed and the chip is read. The PIN is entered using the keypad. A small screen is also part of the reader, which gives instructions to the operator.

Uses

- Chip and PIN readers are used where payments are made using cards (restaurants, supermarkets, travel agents, etc.).

Advantages

- Chip and PIN readers provide a more secure payment system than requiring a signature or using a magnetic stripe, since the PIN typed in must match up with PIN stored on chip.
- Chip and PIN readers provide a more robust system than magnetic stripe readers, since the chip does not need to be in contact with the reader.

Disadvantages

- Since the customer types in the PIN, they need to be careful that it isn't read by somebody else, thus giving an opportunity for fraud.

Scanners

Scanners are used to enter information on hard copy (e.g. text documents, photographs) into a computer. The most common type is the flat bed (as shown here) which is made up of a glass panel and lid. The hard copy document or photo is scanned by a light source and produces a computer-readable image.

The subsequent image can then be manipulated using a drawing package. Images can also be used with optical character recognition (OCR) software to allow the information to used in a word processor, desktop publishing, presentation software, etc. Specialist scanners exist which are designed to carry out a specific task, e.g. barcode scanners (discussed later in this section).

Uses

- Scanners are used to scan in documents and convert them into a format for use in various software packages.
- Old and valuable documents and books can be scanned, thus protecting the originals from damage through handling and also producing records in case the paper copies are lost or destroyed.
- Non-digital photographs need to be scanned if they are to be stored on computer.

Advantages

- Images can be stored for editing at a later date (paper documents cannot be edited unless they are scanned first).
- Scanners are much faster and more accurate (i.e. no typing errors) than typing in documents again.
- It is possible to recover damaged documents and photographs by scanning them and then using appropriate software to produce an acceptable copy.

Disadvantages

- The quality can be limited, depending on how good the scanner resolution is.

Barcode readers

Figure 2.4 A barcode

Barcode readers are used to read information in the form of a bar code (illustrated in Figure 2.4). The readers are usually in the form of a barcode scanner and are often built into POS terminals in supermarkets. *Handheld scanners or wands* (as shown here) are also very common for reading barcodes if portability is required (e.g. if the barcodes are on large or fixed objects).

Uses

- Barcode scanners are used in supermarkets and other shops where the goods are marked with a barcode; the barcodes are used to give information about the product, which enables automatic stock control, itemised billing, etc. to take place.
- They are used in libraries, to scan both users' library cards and barcodes on books, in order to keep track of books on loan.
- They are used as a safety function in many companies to ensure that electrical equipment is checked on a regular basis. Barcodes are placed on an item to identify it and a database holds all the information related to that barcode so it is possible to interrogate the system as part of a safety audit.

Advantages

- Scanning barcodes is much faster than keying in data manually and fewer mistakes are made.
- When barcodes are used as a way of recording data, they can improve safety.
- Barcodes enable automatic stock control.
- Barcode scanning is a tried and trusted technology.
- When an item price is changed, only the central database needs to be updated. There is no need to change the prices individually on each item.

Disadvantages

- Barcode scanning is a relatively expensive system to administer since every item in the shop needs a barcode and every barcode needs to be entered on to the central database. Also, there is a need to invest in the computer technology together with staff training, which can all be very expensive.
- The system is not foolproof – barcodes can be swapped around on items!

OMR devices

Optical mark recognition (OMR) is a system which can read marks written in pen or pencil. The places where the pen or pencil marks can be made are clearly shown on the form, for example:

1 ●–● 2 ● ● 3 ● ●

In this example, a pencil mark has been made between the dots on answer 1. The position of the mark is stored in the computer's memory after being read by the OMR device.

Uses

- OMR devices are used to read questionnaires, multiple-choice examination papers and many other types of form where responses are registered in the form of lines or shaded areas.

Advantages

- It is a very fast way of inputting the results of a survey, etc. – the documents are fed in automatically and there is no user input.
- Since there is no typing, it is more accurate than keying in the data.
- OMR is more accurate than OCR (discussed later in this section).

Disadvantages

- The forms need to be carefully designed to make sure that the marks/shading are correctly positioned to gather accurate information.
- There can be problems if the forms haven't been filled in correctly and sometimes they have to be manually checked before being read by the OMR device – this is both time consuming and expensive.

OCR readers

Optical character recognition (OCR) is the name given to software that takes scanned text and converts it into a computer readable form. The text can then be used in various application packages such as word processors, desktop publishers and presentation software.

Uses

- One of the most recent uses is in the processing of passports and identity cards.
- OCR is used when scanning in documents so that they can be modified using a word processor or desktop publisher package.

Advantages

- It is a much faster data entry system than manually keying in data.
- Since no manual data entry, the number of errors is also reduced.

Disadvantages

- The system still has difficulty reading handwriting.
- It is still not a very accurate technique.

MICR devices

Magnetic ink character recognition (MICR) is a system which can read characters printed in a special ink (containing iron particles). Only certain characters written in a standard font can be read, for example the characters at the bottom of a bank cheque (see Figure 2.5). These characters are converted into a form that the computer can understand and then stored in a computer file.

Figure 2.5 A bank cheque

Uses

- It is primarily used to process cheques in banking operations. When a cheque is presented its value is then printed on the cheque in the special ink. The cheques are all gathered together (either at the end of the day or after some specified period) and then read using a **batch processing** method (see Section 7.9).

Advantages

- MICR offers greater security than OCR since the printed characters cannot be altered.
- There is no manual input, thus errors are reduced.
- Even if somebody writes over the magnetic ink characters (e.g. with a signature) they can still be read.

Disadvantages

- Only certain characters can be read and the number of different characters is very limited.
- It is a more expensive method than other methods used in direct data entry.

Digital cameras

Digital cameras are rapidly replacing traditional, film-based cameras. Once photographs are stored in memory, they are easily transferred to a computer using a **universal serial bus (USB)** connection (see Figure 2.6). Once saved, the images can be manipulated (e.g. cropped, re-sized, contrast altered, etc.).

Figure 2.6 USB connectors

Uses

- Digital cameras produce photographs for transfer to a computer directly or to print out by connecting directly to a printer.
- Many digital cameras also allow short video clips to be produced.
- Photographs can be uploaded directly into applications software such as word processors, desktop publishers, etc.

Advantages

- It is easier to produce better quality photographs than with a traditional camera.
- It is easier and faster to upload photographs to a computer rather than having to scan in hard copies when using traditional methods.
- There is no need to develop film and print out photographs any more – this saves money and is also environmentally more acceptable (saves paper and no longer need the chemicals used in developing the films).
- It is easy just to delete an image from memory if it is not satisfactory and take the photograph again.
- The memory cards can store several hundred photographs. A traditional camera was limited by the number of photographs that could be taken on a roll of film.

Disadvantages

- The camera user needs to be computer literate to use the cameras properly; also the transferring, storing and manipulating of the images via a computer requires some understanding of how computers work.
- There is some artistry lost since clever software now corrects errors in the photographs (e.g. incorrect exposure, removal of red eye, etc.).
- The resolution is not yet as good as traditional cameras, although this is improving all the time. The quality of photographs depends on the number of **pixels** (many cameras now offer more than 10 mega pixels per image), quality of lens, etc.
- Images often need to be compressed to reduce the amount of memory used (a single image can use more than 2 Mbytes of memory, for example).
- It is possible to fill up computer memory very quickly with several photographs of the same subject in an attempt to find the 'perfect' snap shot.

Webcams

Webcams are similar to digital video cameras; however, they are connected directly to the computer (through a USB port) and they do not have a memory. The information that the webcam picks up is transmitted directly to the computer. Many computer systems now have webcams built into the top of their monitors as standard equipment.

Uses

- While chatting online, many people use webcams as a more personal way of having a conversation.
- They are used to enable video conferencing to take place (discussed in Chapter 4).

Advantages

- Webcams can be left on constantly, only being activated as required.
- They allow people to keep in contact with each other without the need to travel, so they are particularly useful for elderly or disabled people.

Disadvantages

- Webcams have very limited features and the picture is often of poor quality.
- They need to be connected to the computer, although this is less of an issue with laptop computers when the webcam is built into the monitor lid.

Microphones

Microphones can be connected directly to a computer. Sounds can be inputted and then manipulated. The input sound is converted to an analogue signal and then converted into a digital signal. The computer's sound card usually does this automatically (i.e. it acts as an **analogue to digital converter (ADC)**.

Uses

- Microphones are used to input speech/sounds to be used in various applications, e.g. presentations, sampling (in films, music, etc.), special effects (films).
- They are used in voice recognition software, which can have a number of purposes, for example:
  - conversion of speech into text that can be used in, for example, a word processor
  - recognition of commands (e.g. some cars now have voice-activated systems to switch on the lights, turn up the radio volume, etc.).

Advantages

- It is faster to read in text than to type it in using a keyboard.
- Using special software, it is possible to manipulate sound in real time rather than working on a recording done at some earlier stage.
- If used in a voice activation system, this has the advantage of improving safety since, for example, car drivers don't need to take their hands off the wheel to operate a switch or alter the radio station etc.

Disadvantages

- Sound files can use up a lot of computer memory.
- Voice recognition software isn't as accurate as typing in manually (for example, the software can't distinguish the difference between 'their' and 'there').

Sensors

This section deals with **analogue sensors**. A sensor is a device which inputs data to a computer, where the data is a measurement of some physical quantity which is continuously changing (e.g. temperature, light, moisture, etc.). These physical quantities are analogue in nature. Since computers only understand digital data (i.e. 1s and 0s), the information from the sensors needs to be converted into a digital form. This is done using an analogue to digital converter (ADC).

Uses

Sensors are used in monitoring and control applications – the type of sensor depends on the application (see Table 2.1). When monitoring, the data sent to the computer is often transferred directly to a spreadsheet package (e.g. taking measurements in a scientific experiment, measuring atmospheric pollution, etc.).

Type of sensor	Applications
Temperature	Automatic washing machines, central heating systems, automatic greenhouses, ovens
Pressure	Burglar alarm systems, washing machines, robotics, environmental monitoring
Light	Automatic greenhouses, automatic doors, burglar alarm systems, street lighting control
Sound	Burglar alarm systems, monitoring liquid and powder flow in pipes
Humidity/moisture	Automatic greenhouses, environmental monitoring, factories where moisture levels are crucial (e.g. manufacture of microchips, paint spraying)
pH	Automatic greenhouses, chemical processes, environmental monitoring

Table 2.1 Applications of different types of sensors

Advantages

- Readings taken using sensors are generally more accurate that those taken by human operators.
- Readings are continuous, so there is no break in the monitoring.
- Because it is a continuous process, any necessary action (control system) or warning (monitoring system) will be initiated immediately.
- The system can be automatic, removing the need for human intervention. This is particularly important if the process is hazardous or needs precise control/monitoring.

Disadvantages

- Faulty sensors can give spurious results (e.g. if the sensors on the rear bumper of a car which monitor for obstacles become dirty, they may either not identify an obstacle or give a continuous alarm).

Graphics tablets

A **graphics tablet** is used with a stylus to produce freehand drawings for example. The images produced can then be stored in a file on a computer.

Uses

- Graphics tablets are used to produce drawings, computer graphics, etc.
- In countries where characters are complex (e.g. China, Japan), they are used as a form of input since it is faster than typing in the characters using a keyboard.
- They are used in **computer aided design (CAD)** work.

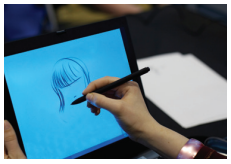
Advantages

- It is possible to modify drawings before they are input.
- They offer a very accurate method of drawing, which is better than using a mouse or trackerball.

Disadvantages

- They are more expensive than other pointing devices, such as a mouse.

Light pens



Light pens contain sensors that send signals to a computer whenever light changes are detected. At the moment, the devices only work with **cathode ray tube (CRT) monitors** (see Section 2.1) because they rely on the screen image being built up row by row by an electron beam. The screen is refreshed 50 times every second, so the computer is able to determine the pen's position by noting exactly when the light pen detected the electron beam passing its tip. Systems to operate with **thin film transistor (TFT) monitors** are still at the development stage.

Uses

- Light pens are used for selecting objects on CRT screens.
- They are also used for drawing on screen (e.g. with CAD packages).

Advantages

- Light pens are more accurate than touch screens.
- They are small, so can be used where space is an issue.
- They are easy to use.

Disadvantages

- There are problems with lag when drawing on screen.
- At the moment, they only work with CRT monitors.
- They are not very accurate when drawing.

2.2 Output devices

As the name suggests, output devices are hardware devices that allow data to be output from a computer. Some devices hold the data temporarily (such as a printer) whereas other devices produce permanent output in the form of a hard copy (such as a printer producing output on paper). There is a third type of output device which is used to control processes in conjunction with sensor input devices. These are covered separately in Section 1.3.

CRT monitors

CRT monitors are the least expensive type of monitor, although they are becoming increasingly rare as TFT monitors are now taking over. They come in various sizes. They use an electron gun to fire against a phosphor screen, which creates a picture that is made up of tiny dots. Each dot is coloured red, green or blue – the intensity of each coloured dot makes up the vast range of colours interpreted by the eye.

Uses

- CRT monitors are used as the primary output device for computers so the user can see immediately what they are typing in.
- They are used with light pens, for example to allow designs to be created on screen.

Advantages

- CRT monitors still produce a higher quality image than TFT monitors.
- The angle of viewing is still better than with a TFT monitor.
- They work with light pens in computer-aided design and computer-aided manufacturing (CAD/CAM) applications.

Disadvantages

- CRT monitors tend to be rather heavy and are a weight hazard if not supported properly.
- They run very hot and can cause fires if left unattended (especially as they get older).
- They consume considerably more power than the modern TFT monitors.
- They can flicker, which can lead to headaches and eyesight problems with prolonged use.

TFT monitors

TFT monitors are taking over from CRT monitors as the main output device. One of the reasons for the rapid development of laptop computers can be attributed to the advancements made in TFT technology. The screen is made up of thousands of tiny pixels, which are made up of transistors controlled by a microprocessor. Each pixel has three transistors, coloured red, green or blue; the intensity of each governs the effective colour of the pixel seen by the eye.

Uses

- TFT monitors are used as the primary output device for computers so the user can see immediately what they are typing in.
- They are an integral part of laptop computers.

Advantages

- TFT monitors are lightweight, so do not pose the same risks as CRT monitors.
- They produce less glare than CRT monitors and also emit less radiation.
- They consume much less power and do not generate as much heat as a CRT monitor.

Disadvantages

- The angle of viewing a TFT monitor is fairly critical, with the image appearing unclear when viewed slightly from the side. This can be an issue if several people are looking at a screen at the same time.
- The definition is sometimes not as good as CRT monitors.
- TFT monitors cannot yet be used with light pens, so these monitors cannot be used in CAD if light pens are used to create and edit drawings.

Laser printers

Laser printers produce very high-quality hard copy output. The print rate per page is very quick if a large number of pages are being printed. They rely on large buffer memories, where the data for the whole document is stored before the pages can be printed out.

Uses

- Laser printers are used where noise levels need to be kept low (e.g. in an office).
- They are the best option for fast high quality high volume printing.

Advantages

- Printing is fast for high volumes. If only a few pages are to be printed they are little faster than inkjet printers.
- They can handle very large print jobs.
- The quality is consistently high.
- Toner cartridges last for a long time, so laser printers can be a cost effective option, particularly if colour outputs are not required.

Disadvantages

- Laser printers are expensive to buy.
- They are only really fast if several copies are being made.
- Colour laser printers tend to be expensive to run, since four cartridges (three colours plus black) are needed as well as diffuser kits, etc.
- They produce ozone and volatile organic compounds because of their method of printing and type of toner/ink used. These have been linked to health hazards in the office.

Inkjet printers

Inkjet printers are used to produce good quality hard copies. Although the quality is not quite as good as that from laser printers, it is far better than that from dot matrix printers. Unlike laser printers, inkjet printers do not have large buffers, so printing is done a bit at a time. This is why printing is sometimes paused, since the whole page can't be stored in the buffer and it has to wait for the computer to send more data.

Uses

- Inkjet printers are used where low output volumes are required.
- If high-quality printing is required for single pages (or only a small print job) then these printers are ideal, for example they are very good at producing photo quality printouts.
- 3D inkjet printers are now being used in industry to produce prototypes (see below).

Advantages

- The output is of high quality.
- Inkjet printers are cheaper to buy than laser printers.
- They are very lightweight and have a small footprint (i.e. take up little space).
- They do not produce ozone and volatile organic compounds, unlike laser printers.

Disadvantages

- The output is slow if several copies needed, as there is little buffer capacity to store the pages.
- The ink cartridges run out too quickly to be used for large print jobs.
- Printing can 'smudge' if the user is not careful.
- Inkjet printers can be expensive to run if they are used a lot, since original ink cartridges are expensive.

3D inkjet printers

These are a new type of printer that produce solid 3D models using modified inkjet technology. In this technology, known as 'tomography', thin layers of fine powder (plaster, resin and starch) are bonded together as a 3D model is slowly built up (each layer is only about 0.25 mm thick). Figure 2.7 shows some items produced on a **3D inkjet printer** – these are known as prototypes.

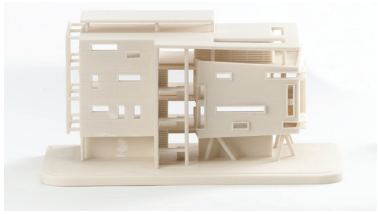


Figure 2.7 A prototype produced on a 3D inkjet printer

Uses

- Inkjet printers are used to produce prototypes which actually work from CAD packages, photograph images, stored drawings, etc.
- Scale models are produced in colour before the real thing is manufactured.
- The ultimate objective is to produce organic objects (such as replacement human organs) using this layering technology.

Advantages

- 3D inkjet printers save a lot of money, since making prototypes by other methods is very time consuming and expensive.
- Physical scale models are produced with working parts, which gives a better idea of how the end product will look.
- The powders used can often be ground up and re-used.

Disadvantages

- 3D inkjet printers are expensive to buy.
- They are slow at producing their output.
- The end product can sometimes be a little rough and often needs further work to be done on it.

Dot matrix printers

Dot matrix printers are a type of impact printer, where a printhead (made up of a matrix of pins) presses against an inked ribbon. They tend to be slow, noisy and the output is not good quality. They are still useful, however, where multi-part or continuous stationery (e.g. long reams of perforated paper) is being used.

Uses

- They can be used in noisy environments (e.g. garage workshops) and in applications where print quality is not very important.

Advantages

- Dot matrix printers can be used in environments which would be a problem for laser or inkjet printers (e.g. dusty, dirty or moist atmospheres).
- Carbon copies or multi-part outputs can be produced.
- They are very cheap to run and maintain.
- They are easy to use if continuous stationery is required (e.g. long print jobs such as wages slips).

Disadvantages

- They are very noisy and so not good in an office environment.
- They cost more than an inkjet printer to buy.
- They are very slow and the printing is of poor quality.

Plotters

Plotters (also known as graph plotters) are devices that produce hard copies, but operate in a different way to printers. They are not limited to normal printer paper size and are capable of producing highly accurate, very large drawings and posters. The most common types are pen plotters (which use coloured pens to draw), electrostatic (similar method to laser printers) and inkjet plotters. With pen plotters the coloured pens are controlled by a computer and the paper can move backwards and forwards to allow accurate shapes to be drawn.

Uses

- Plotters are used to produce large drawings (e.g. blueprints of buildings, factories, etc.) and are often used with CAD applications.
- They are used to produce large pictures for use on billboards or giant posters. They can also print on plastic-coated paper.
- If the pens are replaced with cutting tools, it is also possible to make large signs.

Advantages

- They can produce huge printouts.
- The print quality is extremely high.

Disadvantages

- They are slow in operation.
- They are expensive, both to buy and to maintain.

Speakers

Speakers can be connected directly to a computer or are built into the monitor or casing (as in a laptop computer). Digital data from the computer is converted into analogue form, using a digital to analogue converter (DAC). The signal is then amplified through the speakers.

Uses

- Speakers are used to output sound from multimedia presentations.
- They are used in home entertainment centres.
- They can help blind people (together with speech generation software) through audio output of text on the screen.
- They are used to play downloaded sound files.

Multimedia projectors

Multimedia projectors receive signals that can be either analogue or digital, although most modern projectors only work with digital inputs. The signal source is usually from a computer, television or DVD player. The image from the source is magnified and projected onto a large screen. The devices usually work with a remote control, but can also use virtual mouse technology which actually becomes a cordless PC mouse with the same features as a mouse. It is then possible to direct the computer presentation without being tied to the computer. Another feature of the virtual mouse is the laser pointer. Most multimedia projectors take input from various types of video format such as NTSC, PAL or SECAM.

Uses

- Multimedia projectors are used for training presentations (to allow the whole audience to see the images from a computer).
- They are also used for advertising presentations (large images showing product features of, for example, a new car, can be shown at exhibitions, shopping malls, etc.).
- Home cinema systems (projecting the images from a DVD or television) use multimedia projectors.

Advantages

- They enable many people to see a presentation rather than all of them crowding round a small computer screen.
- They avoid the need for several networked computers. For example, when looking at a video clip on an internet site, everybody can see the video on the large screen rather than logging on to a number of computers.

Disadvantages

- Images can sometimes be fuzzy.
- Multimedia projectors are expensive to buy.
- Setting up projectors can be a little difficult.

2.3 Control devices

Control devices are another type of output device. They are used to control processes in conjunction with sensor input devices. This section gives an overview of actuators and the devices that they operate, but the use of sensors and actuators are covered in more depth in Section 7.7.

Actuators

Actuators are **transducers** and are used to take signals from a computer and convert them into some form of motion, for example operating motors, pumps, switches and valves. As part of the control process, digital signals are sent from the computer to an actuator to operate a device. Usually, conversion of the digital signal to analogue is required first (using a DAC).

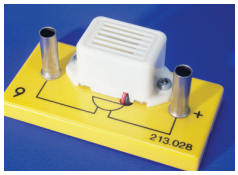
Motors

The motor is turned on or off by the actuator.

Uses

- Motors are used in many domestic appliances, such as automatic washing machines (to make the drum rotate), cookers (to switch on fans), water pumps in central heating systems and automatic greenhouses to open windows and switch on fans.
- In industry, they are used to control robot arms.
- In computers, they operate fans, disk drives and DVD drives.

Buzzers



The buzzers are switched on or off by the actuator.

Uses

- Buzzers are used in cookers and microwave ovens to tell the operator when the cooking process is complete.
- They are used in burglar alarm systems to warn if intruders are present.

Lights

The actuator is connected to the switch that turns the lights on or off.

Uses

- They are used for security lights.
- Lights are used in greenhouses to control the lighting conditions.

Heaters

Actuators are connected to switches which turn the heater on or off.

Uses

- Heaters are used in automatic washing machines, cookers and central heating systems.
- Heaters are used in automatic greenhouses to control the temperature.

CHAPTER 3

Storage devices and media

In this chapter you will learn about:

- back-up storage
- why it is necessary to back up data and files
- the types of access used by the backing stores
- the types of internal and external backing storage devices:
  - magnetic
  - optical
  - solid state.

3.1 Backing up data

The first two sections in this chapter consider the need for backing up data and the different ways of storing and accessing data. Section 3.3 then discusses many forms of **backing storage** and compares the advantages and disadvantages of each type. The comparative performance and main uses for each type of store are also discussed in some depth.

What is backing up of data?

Backing up refers to the copying of files and data to a different medium (disk, tape, flash drive, etc.) in case of a problem with the main storage device. Backing up files and data on a regular basis is seen as good computing practice and many computer systems can be set to back up files automatically on a regular basis.

The backups are often stored in a different place to the main storage. This is in case of fire or some other situation which could lead to irretrievable loss of key data and files.

Why back up data?

There are various reasons why backups are made. Some of the more common reasons are considered below:

- Data could be lost due to failure of the original storage device. This could be due to hardware failure (e.g. head crash on a hard drive unit), problems caused by files being over-written accidentally (or otherwise) or possible corruption of files (e.g. caused by power surges).
- Hackers could be responsible for the corruption or even loss of data. This may not be their intention (they may only want to gain access to the information for other purposes, e.g. to find personal information such as bank account details). However, the very act of hacking into files could cause problems such as corruption or data loss.
- Backups are also made in case the files need to be used elsewhere. The original files are then protected against possible corruption or loss.

However, backups do not necessarily guard against the effect of a virus. The virus could attach itself to the files which could mean that the backups were also affected. If the computer was 'cleaned' of the virus and then the backup files were re-loaded

there would remain the risk that the same virus could infect the computer system again. The best protection is not to get a virus in the first place (discussed in Chapter 6).

3.2 Types of access

The way data is stored and read by different backing storage devices varies considerably. This section briefly describes the two main methods of accessing data.

Serial access

With this system, to access data it is necessary to start at the beginning and then access each piece of data in turn until the required information is found.

It is primarily used on magnetic tape systems and is a very slow form of access. It is used in applications where speed of access or where the order in which the data is accessed is not important, for example in utility billing, clearing bank cheques or producing pay slips.

When a magnetic tape needs **updating**, an additional tape is required so that the old information can be **merged** with the new data (itself often on another tape, but the new data could be stored in various ways) to produce the updated tape (see Figure 3.1).

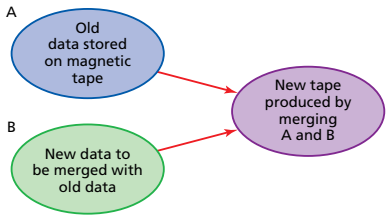


Figure 3.1 Updating the data on a magnetic tape

Direct access

This method is used with magnetic disks and with optical media (such as CDs and DVDs). The computer uses a key field to calculate where data has been stored. It is then able to access the data directly from the calculated position. Consequently, access is much faster than with serial access.

It is used in applications where access speed is vital (e.g. in **real-time process control** systems such as controlling a chemical plant or **online** systems such as booking air tickets or automatic stock control).

When updating media which uses direct access, the new data is written to the next available location and its position is calculated using the built-in algorithm.

3.3 Backing storage media

Dating back to the development of the personal computer, all computer systems have come equipped with some form of backing storage. When a user types data into a computer, the information is stored temporarily on the **RAM** – however, this information would be lost as soon as the computer was turned off. Backing storage devices ensure that data is stored permanently and can be used at a later date. This section will be considering various types of backing storage and the media used.

Backing storage devices are either internal or external (i.e. plug-in devices) to the computer, and are one of three types:

- magnetic
- optical
- solid state.

Fixed hard disk

Fixed hard disk drives are available on all computers and are the main method used for data storage. On a PC this is usually a fixed hard disk with read/write heads allowing data to be written to or read from the disk surface. The disk surface is coated in a magnetic film which allows data to be stored by altering the magnetic properties to represent binary 1s or 0s (the fundamental units of computer memories). The hard drive disks usually store the **disk operating system (DOS)** and other important software and files. Applications software (e.g. spreadsheets and word processors) need a hard drive to allow them to quickly retrieve and save data.

Uses

- Fixed hard drives are used to store the operating system and working data.
- They are used for storing applications software that needs fast retrieval and storage of data.
- Real-time systems (e.g. robots, control of a chemical plant) and online systems (e.g. booking airline tickets, automatic stock control (using EPOS)) used fixed hard drives.
- They are used in file servers for computer networks.

Advantages

- They have a very fast data transfer rate and fast access times to data.
- They have very large memory capacities.

Disadvantages

- They can be fairly easily damaged (e.g. if the correct shut-down procedure on a laptop computer has not been correctly carried out and the computer is then moved).
- They lack portability unless a portable hard disk drive is used (see next sub-section).

Portable hard disk drives

These devices work in much the same way as fixed hard disk drives but are usually connected to the computer via a **universal serial bus (USB)** port and can be disconnected and used on different computers. The disks are generally capable of storing more data than the equivalent optical disk (CD, DVD and so on).

Uses

- Portable hard disks can be used as back-up systems to prevent loss of data.
- They can be used to transfer data, files and software between computers.

Advantages

- The data access time and data transfer rate is very fast.
- They have large memory capacities.
- They can be used as a method of transferring information between computers.

Disadvantages

- As with fixed drives, a portable hard disk can be easily damaged if the user accidentally drops it or does not shut it down correctly after use.

Floppy disk drives

Floppy disks are still used on some computer systems. They consist of a thin disk of plastic which is housed in a plastic case with a window where the disk can be accessed. As the disk rotates, a read/write head is used to add or read data stored on the surface.

Uses

- They are still used where small files need to be transferred/stored (e.g. word-processed documents).
- Some older computer systems still make use of this method of storage.

Advantages

- Using a CD to store a small file (e.g. a word-processed document) is often regarded as wasteful – especially if CD-R is used.
- It is a very simple technology. Floppy disk drives are also extremely low cost items to buy.

Disadvantages

- Floppy disks have a very low memory capacity when compared to CD/DVDs, for example.
- Very few modern computers have floppy disk drives.
- The data transfer rate is slow compared to more modern data storage devices.
- Floppy disks are not very robust.

Magnetic tapes

A **magnetic tape** is a very thin strip of plastic which is coated in a magnetic layer. They are read and written to by a read/write head. The data is stored in magnetic areas which represent 1s and 0s. Data is written to and read from the tape in sequence (i.e. in order) – for example, if five records A, B, C, D and E were stored they would be in the order E D C **B** A on the tape; so if record **B** was to be read it would be necessary to read E, D and C first *before* getting to the required record. This is known as **serial access**. This type of storage is useless in a real-time or online application (due to the very slow access speeds) and is best suited to offline or batch processing.

Uses

- Magnetic tapes are used in applications where batch processing is used, for example in clearing bank cheques, utility billing (gas, electricity, water) and producing pay slips. In these applications, there is no need for any specific processing order and speed of data access is not important).
- They are used as a back-up media since all the data needs to be stored.

Advantages

- They are generally less expensive than the equivalent-capacity hard disk.
- It is a very robust technology.
- The data transfer rate is fast.

Disadvantages

- Access time is very slow.
- When updating, another tape is needed (i.e. original tape + tape with the changes produces an updated tape).

Optical storage media

Optical storage devices, such as CD and DVD, all use optical (i.e. light) read/write methods, unlike tapes and floppy/hard drive disks which are magnetic media. A laser beam is used to write to and read from the optical media.

The CDs and DVDs are manufactured either from a single polycarbonate disk or from two polycarbonate disks bonded together. A very thin layer of metal or organic dye is used as the recording media. The big advantage of these storage media is that they are portable and can store large data files (e.g. films, music or multimedia files) which would be too large for a floppy disk.

CD-ROM and DVD-ROM

CD-ROMs and DVD-ROMs are read only memory (ROM), which means they cannot be written over and can only be read. The data is stored as a series of **pits** (equivalent to a binary value of 1) and **lands** (equivalent to the binary value of 0) in the metallic optical layer. The pits are formed by a laser beam etching the surface at the manufacturing stage. Only a single track exists which spirals out from the centre of the disk.

The pits and lands are read by a low-powered laser beam which follows the data stream and reads from the centre outwards in a spiral. The light reflects differently off a pit than it does off a land and this is interpreted as 1s and 0s (i.e. data) – hence the term digital media.

Uses

- CD-ROMs are used by manufacturers to store music files and software, computer games and reference software (such as an encyclopedia).
- DVD-ROMs have much larger storage capacity than CD-ROMs and are used to store films. They are now increasingly used to store computer data and ever-more sophisticated computer and arcade games.

Advantages

- They hold far more data than floppy disks, so one CD/DVD could replace several floppy disks in some applications.
- They are less expensive than hard disk drive systems.

Disadvantages

- The data transfer rate and data access time are slower than for hard disks.

CD-R and DVD-R

The letter 'R' here means the disk is recordable *once* only and then it becomes a CD-ROM or DVD-ROM. These use a thin layer of an organic dye as the recording media; DVDs also use an additional silver alloy or gold reflector. A laser beam produces **heated spots** and **unheated spots**. On reading the disk, a laser beam is

capable of distinguishing between the two types of spots and effectively reads the data stream from the centre outwards in a spiral action. This data is then interpreted as 1s and 0s.

Uses

- They are used for home recordings of music (CD-Rs) and films (DVD-Rs).
- They are used to store data to be kept for later use or to be transferred to another computer.
- They are used in applications where it is necessary to prevent the deletion or over-writing of important data).

Advantages

- CD-Rs and DVD-Rs are cheaper than RW disks.
- Once burned (and **finalised**), they are like ROM disks.

Disadvantages

- They can only be recorded once, so if an error occurs then the disk has to be thrown away.
- Not all CD/DVD players can read CD-R/DVD-R.

CD-RW and DVD-RW

The 'RW' means that these disks are a re-writable media and can be written over several times. Unlike CD-R/DVD-R, they don't become ROMs. The recording layer uses a special phase-changing metal alloy. The alloy can switch between crystalline and amorphous (non-crystalline) phases, thus changing its reflectivity to light, depending on the laser beam power. **Spots** are produced which can be read by a laser and then interpreted as 1s and 0s. The system allows data to be written, erased and re-written many times.

Uses

- CD-RWs and DVD-RWs are used to record radio and television programmes, but can be recorded over time and time again.
- They are used in closed circuit television (CCTV) systems.

Advantages

- CD-RWs and DVD-RWs can be re-used many times.
- They can use different file formats each time they are used.
- The RW format is not as wasteful as the R format since files or data can be added at a later stage.

Disadvantages

- CD-RWs and DVD-RWs can be relatively expensive media.
- It is possible to accidentally overwrite data.

DVD-RAM

DVD-RAM is a recent addition to the optical media group. Unlike other CD and DVD formats, DVD-RAMs have several discrete concentric tracks rather than a single spiral track. This gives them the advantage that writing and reading can occur at the same time. This makes it possible to watch an already recorded television

programme at the same time as a different programme is being recorded. DVD-RAMs can be written to many times.

Figure 3.2 compares the single spiral track found on normal CDs and DVDs with the discrete single tracks found on a DVD-RAM.

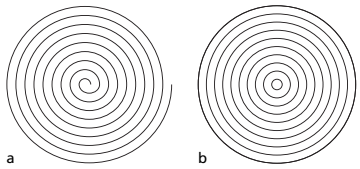


Figure 3.2 **a** Spiral tracks on a normal CD or DVD **b** Discrete tracks on a DVD-RAM

The recording layer is made from a similar phase-changing material to that used in RW technology. When writing, a laser heats the phase-changing alloy on the disk to about 500–700°C, changing the reflective properties from shiny to dull (i.e. pits). If the disk needs to be erased, a laser heats the surface to about 200°C to return the disk to its original shiny state. A low power laser is used to read the written marks on the surface. The shiny and dull (pits) marks represent data to a computer where they are interpreted.

Uses

- DVD-RAMs are used in recording devices such as satellite receivers to allow simultaneous recording and playback.
- They are used in camcorders to store films.

Advantages

- DVD-RAMs have a long life – minimum life is estimated to be 30 years.
- It is possible to do a re-write operation over 100,000 times, compared with the RW format which only allows about 1,000 re-writes.
- Writing on DVD-RAMs is very reliable, as they have in-built verification software to ensure the accuracy of the data.
- Access is very fast if the files are fairly small.
- There is no need to finalise the disk.
- They have a very large capacity (about 10 Gbyte if double-sided format is used).
- They offer the ability to read data at the same time as data is being written.

Disadvantages

- DVD-RAMs are not as compatible as R or RW format, as many systems will not recognise their format.
- They are relatively expensive, costing about 4 times as much as a DVD-RW disk.

Blu-ray disks

Blu-ray disks have the largest capacity of all the optical media available and go up to 100 Gbyte (at the present time). The laser beam used is at the blue/violet end of the spectrum, rather than red which is the colour of the lasers used in other optical media. Consequently, the light used has a shorter wavelength, allowing more data to be stored/read on the disk.

Uses

- Blu-ray disks are used in home video consoles.
- They are used for storing and playing back films: 1 high-definition film of two hours duration uses 25 Gbyte of memory.
- PCs can use this technology for data storage or backing up hard drives.
- Camcorders can use this media (in cartridge form) to store film footage.

Advantages

- They have a very large storage capacity, and so are ideal for storing high definition films.
- The data transfer rate is very fast.
- The data access speed is also greater than with other optical media.

Disadvantages

- The disks are relatively expensive .
- At the time of writing, blu-ray systems still have encryption problems (which are used to stop piracy) when used to store video.

Solid state backing store

Solid state technology is being developed to the point where solid state drives will soon replace hard disk drives in laptop computers. This is due to their inherent thinness, their much faster data access time and the fact that they are extremely robust.

They are similar to magnetic and optical media in that data is still stored as 1s and 0s. However, instead of changing the magnetic properties on the thin film surface of a rotating disk, these solid state systems control the movement of electrons within a microchip. The 1s and 0s are stored in millions of miniature transistors within the microchip: if the transistor conducts a current, this is equivalent to a 1, otherwise it is a 0.

They consequently have no moving parts, consume much less power and are extremely robust.

They are used primarily as removable storage devices and are collectively known as flash memory. The most common examples are memory sticks/pen drives and memory cards.

Memory sticks/pen drives

Memory sticks/pen drives can store several Gbytes of data and use the solid state technology described above. They are usually connected to a computer through the USB port and power to operate them is drawn from the host computer. They are extremely small and very portable. Most operating systems recognise these storage media, which means that no additional software is needed to operate them.

Some expensive software increasingly use these storage methods (sometimes referred to as portable flash drives) as a form of security. They plug into the computer using the USB port and are known as **dongles**. The software installed on a computer sends out a request (in encrypted form) to the dongle asking for an encrypted validation key. Thus a person trying to commit **software piracy** would have to crack the code on the dongle first before they could use the software. Some systems go one stage further and have key bits of software stored on the dongle in encrypted form. The software looks for these pieces of encrypted code to enable it to run. This gives an added security benefit to the software.

Uses

- Memory sticks and pen drives are used for transporting files between computers or as a back-up store.
- They are used as a security device – a dongle – to prevent software piracy.

Advantages

- They are very compact and portable media.
- They are very robust.

Disadvantages

- It is not possible to write protect the data and files.
- Their small physical size means that they are easy to lose.

Flash memory cards

These are a form of **electrically erasable programmable read only memory (EEPROM)** and are another example of solid state memories.

Uses

- Flash memory cards are used to store photos on digital cameras.
- Mobile phones use them as memory cards.
- They are used in **MP3** players to store music files.
- They are used as a back-up store in handheld computer devices.

Advantages

- Flash memory cards are very compact, so they can be easily removed and used in another device or used for transferring photos directly to a computer or printer.
- Since they are solid state memories, they are very robust.

Disadvantages

- They are expensive per Gbyte of memory when compared to hard drive disks.
- They have a finite life in terms of the number of times they can be read from or written to.
- They have a lower storage capacity than hard disks.