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Chapter 02

Input and output devices

2.1 Input devices and their uses

2.1.1 Keyboards

The keyboard is connected to the computer through a USB or wireless connection. In the case of tablets and mobile phones, the keyboard is often **virtual** or a type of **touchscreen** technology (see later).

They are a relatively slow method of data entry and are also prone to errors. But keyboards are probably still the easiest way to enter text into a computer. However, frequent use of these devices can lead to injuries, such as **repetitive strain injury (RSI)** in the hands and wrists.

Figure 2.3 and the following description summarises how the computer can recognise a letter pressed on the keyboard:
» There is a membrane or circuit board at the base of the keys.

» In Figure 2.3, the 'H' key is pressed, and this completes a circuit as shown.

» The CPU in the computer can then determine which key has been pressed.

» The CPU refers to an index file to identify which character the key press represents.
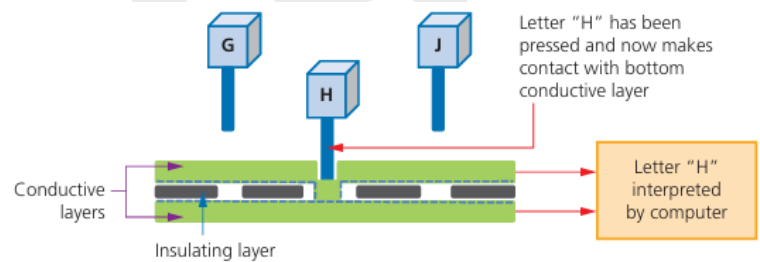
▲ **Figure 2.3** Diagram of a keyboard

Uses of keyboards

» Input of data into applications software
» Typing in commands to the computer

Advantages of keyboards

» Fast entry of new text into a document.
» Well-known method. » Easy to use for most people.
» Easier to do verification checks as data is entered

Disadvantages of keyboards

» Can be difficult to use if the user has limited arm/wrist use.
» Slow method when compared to direct data entry
» Fairly large device that uses up valuable desk space.

2.1.2 Numeric keypads

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

Uses of numeric keypads

» **Automatic teller machines (ATMs),** where the customer can key in their PIN, amount of money, etc.
» Mobile phones to allow phone numbers, etc. to be keyed in.

» **Point of sale terminals (POS)** in case the barcode reader fails to read the barcode – the number has to be keyed in manually by the operator.

» Chip and PIN devices when paying by credit/debit cards (key in PIN, amount of money, etc.).

» Fast entry of numeric data into a spreadsheet.

Advantages of numeric keypads

» Faster than standard keyboards when entering numeric data.
» Because many are small devices (for example, mobile phones) they are very easy to carry around.

Disadvantages of numeric keypads

» Sometimes have small keys which can make input more difficult.
» Sometimes the order of the numbers on the keypad is not intuitive.

2.1.3 Pointing devices

Mouse

The **mouse** is an example of a **pointing device**. The **optical mouse** (where movement is detected by reflected light rather than the position of a moving ball) and the **cordless** or **wireless mouse** (which transmits signals to a USB wireless receiver plugged into the computer) are in use on modern computers.

Uses of a mouse

Almost anything, depending on the software, but includes:
» Opening, closing and minimising software » grouping, moving and deleting files
» Image editing, for example, controlling the size and position of a drawing pasted into a document
» 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 and right.

Advantages of a mouse

» Faster method for choosing an option rather than using a keyboard.
» Very quick way of navigating through applications and the internet.
» Does not need a large desk area when compared to a keyboard.

▲ **Figure 2.6** Example of a drop-down menu
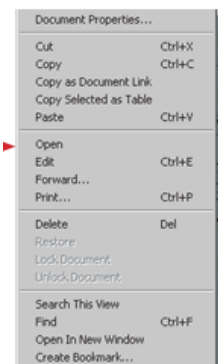
Disadvantages of a mouse

» Can be more difficult for people with restricted hand/wrist movement than using a keyboard for data entry.
» Easy to damage, and the older type of mouse quickly becomes clogged up with dirt.
» Difficult to use if no flat surface readily available (for example, on an aeroplane).

Touchpad

Touchpads are used as a pointing device in many laptop computers. 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 (that is, selection).

Use of a touchpad

Their uses are the same as those of a mouse.

Advantages of a touchpad

» Same as the mouse
» Because the touchpad is integrated into the laptop computer there is no need for a separate mouse – this aids the portability and is a big advantage if there are no flat surfaces available.

Disadvantages of a touchpad

» People with limited hand/wrist movement find the device difficult to use.
» Can be more difficult to control the pointer when compared to a normal mouse.
» More difficult to use when doing certain operations such as drag and drop.

Tracker ball

Tracker Balls are similar to a mouse, except that a ball is on the top or the side of the device; the user controls the pointer on the screen by rotating the ball with their hand. It is easier to use for people with limited hand/wrist movement. Some tracker balls have two buttons, which have the same function as the left- and right-hand mouse buttons.

▲ **Figure 2.8** Trackerball

Uses of a tracker ball

» Can be a good alternative to a mouse for people with conditions such as RSI.

» Used in an industrial control room environment where it is faster than a mouse to navigate through process screens.

» Used in some luxury cars to select functions such as radio, telephone, music, satnav and so on.

Advantages of a tracker ball

» Does not need the same fine control as a mouse.

» Easier to use than a mouse if the operator has problems with their wrist or hand.

▲ **Figure 2.9** Trackerball used in a luxury car

» More accurate positioning of the pointer on screen than a mouse.

» They are more robust than a mouse.

» Needs less desk space than a mouse or keyboard.

Disadvantages of a tracker ball

» Not supplied with the computer as standard, therefore more costly.

» User may need training because it is not standard equipment

2.1.4 Remote control

A remote control is used for the operation of other devices using infrared signals.

Uses of a remote control

» Televisions, satellite systems, DVD/Blu-ray players and Hi-Fi systems all use remote controls to alter functions such as sound volume, on/off, change channels, open the disc drawer, and so on.

» Used to control multimedia systems.

» Used in industrial applications to remotely control processes, stop and start machinery, etc.

Advantages of a remote control

» Can be operated from any reasonable distance, unlike,

Disadvantages of a remote control

» Difficult to use if the operator has limited hand/wrist movement.
» It is easier to block the signal if, for example, the walls in the building are very thick.

2.1.5 Joysticks and driving wheels

Joystick

Joysticks have similar functions to a mouse and a trackerball. By gripping the stick, a pointer on the screen can be controlled. Buttons are used to make selections.

Uses of a joystick

» Used in video/computer games.

» Used in simulators (for example, flight simulators) to mimic actual controls

Advantages of a joystick

» Easier than a keyboard to navigate the screen.

» Control is more realistic for some applications than, for example, using a mouse.

Disadvantages of a joystick

» More difficult to control the on-screen pointer than with other devices, such as a mouse.

Driving wheel

A **driving (steering) wheel** is an example of an input device that is similar to a joystick in many ways. It connects to a computer (or games machine), usually through a USB port.

Uses of a driving wheel

» Used in video/computer games (for example, car racing games).

» Used in simulators (for example, car-driving simulators) to mimic actual vehicle controls.

▲ **Figure 2.11** Joystick

Advantages of a driving wheel

» Easier than a keyboard or joystick to control steering movements; it is more natural.

» The 'driving experience' is nearer to how an actual steering wheel and other controls operate in real life.

Disadvantages of a driving wheel

» It can be a rather expensive input device compared to mouse or joystick.

» Movements in the steering can be too sensitive, giving an unrealistic 'feel'.

» Unless it is an expensive simulator, feedback to the driving wheel is non-existent.

2.1.6 Touch screens (as an input device)

With a **touch screen** the user can choose an option by simply touching a button/icon on the screen.

Uses of touch screens

» Self-service tills, for example, petrol stations, where the user just touches the screen to select the fuel grade and payment method.

» Automatic teller machines (ATMs) to choose from on-screen options.

» Point of sale terminals such as in restaurants. » Public information systems at airports, railway stations, tourist offices, etc.

» Mobile phones, tablets and satellite navigation systems.

» Interactive white boards in education. » Computer-based training (CBT) where answers are selected during on-screen testing.

» They can obviously also be used as an output device because they also work as a flat-screen monitor (see Section 2.3.2).

Advantages of touch screens

» Faster entry of options than using keyboard or mouse.

» Very easy method for choosing options.

» User-friendly method – no training necessary in its use.

» Option to expand the size of the display if necessary.

Disadvantages of touch screens

» Limited number of input options available.

» Can lead to problems if an operator has to use the system frequently

» The screen can get very dirty with constant touching.

2.1.7 Scanners

Scanners are used to enter information from hard copy (for example, text documents, photographs) into a computer. The most common type is the flatbed scanner (see Figure 2.14), which is made up of a glass panel and lid.

Uses of scanners

» Scan in documents and convert into a format for use in various software packages.

» Scan in old/valuable documents/books, thus protecting the originals, as well as producing records in case the paper copies are lost/destroyed

» Scan in photographs

» Scan in barcodes at POS terminals.

▲ **Figure 2.14** Flatbed scanner

Advantages of scanners

» Images can be stored for editing at a later date.

» When used with OCR, much faster and more accurate (no typing errors) than typing in documents again.

» It is possible to recover damaged documents and photographs by scanning in and then using appropriate software to produce an acceptable copy.

Disadvantages of scanners

» Quality can be limited depending on how good a resolution the scanner is capable of (most scanners have a range of resolutions you can choose from).
» They can be slow at scanning, especially if the colour scanning mode is chosen or if the chosen scanning resolution is high.

2.1.8 Digital cameras

Digital cameras have largely replaced traditional film-based cameras. The images are stored on a memory card (solid-state memory) and can be transferred to a computer by:

» Directly reading the memory card (by slotting it into a card reader attached to a computer or a printer)

» Connecting the camera to the computer using a USB port

» Using wireless data transfer (Wi-Fi or Bluetooth).

Uses of digital cameras

» Taking photographs; they still take better photgraphs than smartphones or tablets due to the use of expensive lenses and dedicated software.

» Used as a data-capture device; for example, as a reversing aid in a car where small cameras (in the bumpers) help the driver to see their immediate surroundings.

» Dentists use digital cameras to take photos of a patient's teeth to help them diagnose any problems; they are also used to improve colour matching when doing dental fillings.

» The creation of virtual reality tours around houses, historical buildings, industrial plants, and so on.
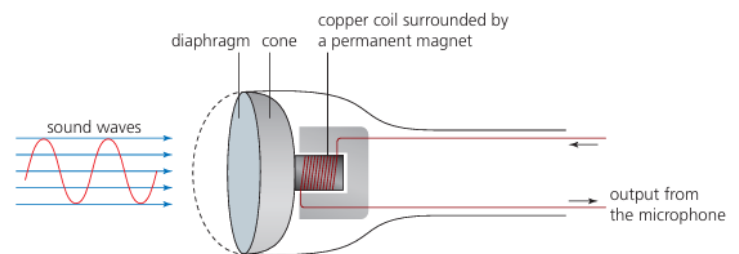
Advantages of digital cameras

» Easier to produce better-quality photographs than with a traditional camera.

» Easier and faster to upload photographs to a computer rather than having to scan in hard copies when using traditional methods.

» No need to develop film and print out photographs anymore – this saves money and is also environmentally more acceptable (saves paper and reduces the use of the chemicals used in developing traditional film).

» Memory cards can store many thousands of photographs.

Disadvantages of digital cameras

» Need 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 because clever software now corrects errors in the photographs

» Images often need to be compressed to reduce the amount of memory used

2.1.9 Microphones

Microphones are either built into the computer or are external devices connected through the USB port or using Bluetooth connectivity. Figure 2.16 shows how a microphone can convert sound waves into an electric current.

» When sound is created, it causes the air to vibrate.

» When a diaphragm in the microphone picks up the air vibrations, the diaphragm also begins to vibrate.

▲ **Figure 2.16** Diagram of how a microphone works

» A copper coil is surrounded by a permanent magnet and the coil is connected to the diaphragm using a cone.

» This forwards and backwards motion cuts through the magnetic field around the permanent magnet, inducing an electric current.

» The electric current is then either amplified or sent to a recording device. The electric current is analogue in nature.

Uses of microphones

» To input speech/sounds to be used in various applications,

» Input in voice-recognition software: – the software converts the speech into text that can be used in, for example, a word processor or to input commands into a computer

– to recognise commands; for example, some cars now have voice-activated systems to switch on the lights, turn up the radio volume, etc. (see Chapter 1).

» Microphones can also be used as a sensor to pick up sound (for example, in an intruder alarm system).

» Used in video conferencing or Voice over Internet Protocol (VoIP) applications.

Advantages of microphones

» Faster to read in text than to type it in using a keyboard.

» It is possible to manipulate sound in real time using special software rather than work on a recording done at some earlier stage.

» If used in a voice activation system, it has the advantage of improving safety

Disadvantages of microphones

» Sound files can use up a lot of computer memory.

» Voice-recognition software is not as accurate as typing in manually

2.1.10 Sensors

This section deals with **analogue sensors**. A sensor is a device that inputs data to a computer; the data is a measurement of some physical quantity that is continuously changing.

Because computers only understand digital data (1s and 0s), the information from the sensors needs to be converted; this is done using an **analogue to digital converter (ADC).**

Uses of sensors

▼ **Table 2.1** Uses of sensors

Type of sensor	Applications
Temperature	Used in automatic washing machines, central heating systems, automatic glasshouses, ovens
Pressure	Used in intruder alarm systems, washing machines, robotics, environmental monitoring
Light	Used in automatic glasshouses, automatic doors, intruder alarm systems, street lighting control
Sound/acoustic	Used in intruder alarm systems, monitoring liquid and powder flow in pipes
Humidity/moisture	Used in automatic glasshouses, environmental monitoring, in factories where moisture levels are crucial (for example, manufacture of microchips, paint spraying)
pH	Used in automatic glasshouses, chemical processes, environmental monitoring

Advantages of using sensors

» More accurate readings taken when compared to human operators.
» Readings are continuous – no break in the monitoring.
» Because it is a continuous process, any necessary action (control system) or warning (monitoring system) will be initiated immediately.
» Systems can be automatic, removing the need for human intervention

Disadvantages of using sensors

» Faulty sensors can give spurious results

» Most sensors are analogue; therefore, they require conversion using an ADC

2.1.11 Light pens

Light pens are used with computers as an input device. They contain sensors that send signals to a computer whenever light changes are detected. The devices only work with CRT monitors (see Output devices section as they rely on the screen image being built up row by row by an electron beam.

Uses of light pens

» Selecting objects on CRT screens.
» Drawing on screen (for example, with CAD packages).

Advantages of light pens

» Greater accuracy than touch screens.
» Small (can be used where space is an issue).
» Easy-to-use technology.

Disadvantages of light pens

» Problems with lag when drawing on screen.
» Only works with CRT monitors (at the moment).
» Not that accurate when drawing.
» Rather dated technology.

2.2 Direct data entry (DDE) devices

Direct data entry (DDE) devices are used to input data into a computer without the need for very much, if any, human interaction.

2.2.1 Card readers

Magnetic stripe readers

These are used to read information on the **magnetic stripe** found on.

Uses of magnetic stripe readers

» On credit/debit cards for use at ATMs or EFTPOS (electronic funds transfer at point of sale) terminals.
» Security devices to allow entry to buildings, hotel rooms, etc.

▲ **Figure 2.18** Magnetic stripe reader

Advantages of magnetic stripe readers

» Fast data entry, rather than keying in with a keyboard or keypad.

» Error-free (because no typing is involved).

» Secure

» Prevents access to restricted/secure areas.

» Not affected by oil, water, moisture, etc.

» No moving parts – so physically very robust.

Disadvantages of magnetic stripe readers

» If the magnetic stripe gets damaged the data is lost.

» Does not work at a distance (card needs to be in close contact with reader).

» Because the information is not human readable, this can be a disadvantage in some applications

▲ **Figure 2.19** Contactless debit card

Contactless debit card readers

Contactless debit or credit cards allow customers to pay for items worth up to a certain amount of money without entering their PIN. the terminal picks up the signal from the chip and allows the transaction to be processed. The steps taken are;

1. Customers look out for the contactless symbol (((on the payment terminal.
2. The shop assistant enters the amount for payment.
3. The card reader informs the customer to present their contactless card.
4. The customer holds their card close to the front of the card reader.
5. The terminal display will indicate that the card has been read successfully.

▲ **Figure 2.20** Contactless card reader

Advantages of using contactless cards

» Faster transactions (typical transaction takes 10 seconds as opposed to 30 seconds using magnetic stripe reader).

» The contactless card system uses 128-bit encryption systems to protect the data.

» Customers do not have to worry about typing errors (such as incorrectly typing in a PIN).

» Retailers no longer have access to the customer's credit/debit card information.

» The chip in the contactless credit card responds to the payment terminal reader with a unique number used for that transaction only.

Disadvantages of using contactless cards:

» They are more expensive than normal credit/debit cards.

» A thief with a suitable reader could monitor your contactless card transaction while standing at the counter with you, or just behind you

» Can take money twice if the customer uses it as a chip and PIN card

» Transactions are usually limited to a small maximum value

» Transactions have been carried out,

Chip and PIN readers

Chip and PIN readers are like 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. They are like the contactless system, except for two points:

1. The customer has to key in their PIN to make a transaction.

2. These cards do not make use of radio frequency technology.

Uses of chip and PIN readers

» Where payments are made using cards (restaurants, supermarkets, travel agents, etc.).

Advantages of chip and PIN readers

» More secure system than contactless payments (PIN typed in must match up with PIN stored on chip).
» More robust system than magnetic stripe cards.

Disadvantages of chip and PIN readers

» Fraud – need to be careful to ensure PIN is not read by somebody else while typing it in.

2.2.2 Radio frequency identification (RFID) readers

Radio frequency identification (RFID) readers use radio waves to read and capture information stored on a **tag**. In some applications, the tag can be read from several metres, which is one of its advantages over the barcode system.
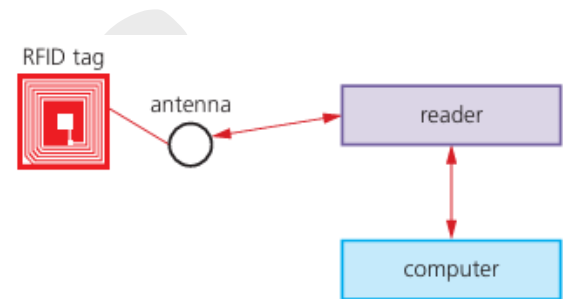
▲ Figure 2.21 RFID

The RFID tag is made up of two components:
» A microchip that stores and processes information
» An antenna which is used to receive and transmit data/information.

Uses of RFID

» Livestock tracking (so that the whereabouts of each animal on a farm is known; it also identifies which farm owns the animal).

» Retail   » Admission passes   » Libraries

Advantages of RFID

» No line-of-sight contact is necessary; the tags can be read from a distance.
» It is a very robust and reliable technology.
» Very fast read rate (typically less than 100 milliseconds to respond).
» Bidirectional data transfer (that is, it allows read and write operations to take place).
» Bulk detection is possible (that is, it can detect several RFID tags at the same time).

Disadvantages of RFID

» Tag collision (this is when the signals from two or more tags overlap, interfering with each other).
» Because RFID uses radio waves, they are relatively easy to jam or interrupt.
» It is relatively easy to hack into the data/signal transmitted by the tag.
» RFID is more expensive than a comparable barcode system.

2.2.3 Optical mark recognition/reader (OMR)

Optical mark recognition (OMR) is a device which can read marks written in pen or pencil on a form.

▲ Figure 2.22 OMR

Uses of OMR devices

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

Advantages of OMR devices

» Very fast way of inputting the results of a survey, etc. The documents are fed in automatically and there is no user input.

» Because there is no typing, they are more accurate than keying in the data.

» They are more accurate than OCR methods.

Disadvantages of OMR devices

» The forms need to be carefully designed to make sure the marks/shading are correctly positioned to gather accurate information.

» There can be problems if they have not been filled in correctly; sometimes they have to be manually checked before being read, which is both time consuming and expensive.

2.2.4 Optical character recognition/reader (OCR)

Optical character recognition (OCR) is the name given to a device that converts the text on hard copy documents into an electronic form.

Uses of OCR

» One of the most recent uses is the processing of passports and identity cards.

» Converting hard copy documents into electronic form which can be stored on a computer.

» Used in automatic number plate recognition (ANPR) systems in car parks.

» Digitising historic newspapers and rare books so they can be archived and used by researchers, preventing damage to the originals.

Advantages of OCR

» It is a much faster data entry system than manually keying in data.

» Because there is no manual data entry, the number of errors is also reduced. Disadvantages of OCR

» The system still has difficulty reading some handwriting.

» Still not a very accurate technique.

Comparison of OMR and OCR features

A company has decided to produce a questionnaire to gain information from customers.

▼ **Table 2.2** Comparison of OCR and OMR

OCR	OMR
Because this method reads handwriting, it is possible for customers to extend their answers to questions	Because this involves shading in lozenges to answer set questions, the information obtained is limited to the choices offered in each question
This method can read handwriting – but if the handwriting is poor it may cause reading errors	OMR relies on simply detecting where marks have been made on a page; the position of the marks is compared to a template stored in memory
OCR is used for converting printed documents to an editable electronic format	OMR simply reads the position of marks so it is ideal for multiple-choice exam papers
OCR requires a complex recognition system	This method requires complex (and expensive) forms to be completed; but the recognition system is simpler than OCR
Fewer 'how to fill in' instructions are needed for forms designed to be completed and then read by OCR	While this method requires more 'how to fill in' instructions, it is easier and faster for customers to complete OMR forms than to complete OCR forms
While OCR is more accurate than data entered into a computer by keyboard, there are still problems recognising all types of handwriting leading to inaccuracies	OMR is essentially a more accurate method for reading data than OCR

2.2.5 Barcode readers

Barcode readers are used to read information in the form of a bar code (see barcode example in Figure 2.24). **Handheld scanners** or **wands** (as shown in Figure 2.25) are also very common for reading barcodes if portability is required (for example, if the barcodes are on large or fixed objects).

▲ **Figure 2.24** Sample barcode

Uses of barcode systems

» Used in supermarkets and other shops where the goods are marked with a barcode
» Used in libraries to keep track of books on loan.
» Used as a safety function in many companies to ensure that electrical equipment is checked on a regular basis.

Advantages of barcode systems

» Much faster than keying in data manually and fewer mistakes will be made.
» If used as a way of recording safety testing of components
» They allow automatic stock control.
» They are a tried and trusted technology.

▲ **Figure 2.25** Portable barcode reader (scanner)

Disadvantages of barcode systems

» Relatively expensive system to administer.

» Not fool-proof (barcodes can be swapped around on items).

» Can be more easily damaged than RFID tags or magnetic stripes

2.2.6 Quick response (QR) code scanners (readers)

Another type of barcode is the **quick response (QR)** code. This is made up of a matrix of filled-in dark squares on a light background.

Description of QR codes

A QR code consists of a block of small squares (light and dark) known as pixels. It can presently hold up to 4296 characters (or up to 7089 digits) and allows internet addresses to be encoded within the QR code. This compares to the 30 digits which is the maximum for a barcode.

Uses of QR codes

» Used in advertising to contain data such as business addresses, phone numbers, email addresses and website addresses.

» Contain links to apps (for example, they can be found in app stores to enable the appropriate apps to be quickly downloaded onto a user's device).

» Wi-Fi authentication; QR codes can be used to store Wi-Fi network authentication (proof of identity) details, including passwords and type of encryption used.

» QR codes can be used to deliver augmented reality experiences, by helping an AR system to determine the positions of objects in three-dimensional space.

» QR codes have been used to establish virtual online stores, where a gallery of product information and QR codes are presented to the customer,

Advantages of QR codes

» They can hold much more information than normal barcode.
» There will be fewer errors than with barcodes; the higher data capacity of the QR code allows the use of built-in error-checking systems.
» QR codes are easier to read; they do not need expensive laser or LED (light emitting diode) scanners like barcodes – they can be read by the cameras used on smartphones and tablets.
» It is easy to transmit QR codes either as text messages or images.
» It is also possible to encrypt QR codes, which gives them greater protection than traditional barcodes.

Disadvantages of QR codes

» More than one QR format is available.
» QR codes can be used to transmit malicious codes; known as **attagging**. Because there are a large number of free apps available to a user for generating QR codes, that means anyone can do this. It is relatively easy to write malicious code and embed this within the QR code.

2.3 Output devices and their uses

As the name suggests, these are devices that usually show the result of computer processing in a format that can be understood by a human (for example, on a monitor or printed on paper).

2.3.1 Monitors (screens)

In this section we will consider two types of monitors:

» The cathode ray tube (CRT) monitor
» LCD (or TFT) screen (TFT means 'thin film technology'; a general term for modern thin screens)

CRT monitors

Cathode ray tube (CRT) monitors are the least expensive type of monitor, although they are becoming increasingly rare as LCD monitors are now taking over. They come in various sizes and make use of an electron gun firing against a phosphor screen.

Uses of CRT monitors

» They are only used in specialist areas, such as computer-aided design (CAD); the screens are usually very large to enable complex diagrams to be created or modified.

» They are used with light pens to allow designs to be created on screen.

▲ **Figure 2.28** CRT monitor

Advantages of CRT monitors

» The screen can be clearly seen at a wider range of viewing angles than with most LCD monitors.

» They allow the use of light pens in, for example, CAD/CAM applications.

Disadvantages of CRT monitors

» They tend to be rather heavy and present a weight hazard if not supported properly; they also have a very large footprint on a desk

» They run very hot and can cause fires if left unattended (especially as they get older).

» They consume considerably more power than LCD monitors.

» They can flicker, which can lead to headaches and eyesight problems with prolonged use.

LED and LCD screens

LED screens

An LED screen is made up of tiny light emitting diodes (LEDs). Each LED is either red, green or blue in colour. By varying the electric current sent to each LED, its brightness can be controlled, producing a vast range of colours.

Many monitors and television screens are advertised as LED when in fact they are LCD screens which are backlit using LEDs.

LCD screens

 LCD screens are made up of tiny liquid crystals. These tiny crystals make up an array of pixels which are affected by changes in applied electric fields. How this works is outside the scope of this book, but the important thing to realise is that for LCD screens to work, they require some form of backlighting.

The reason that LEDs have become increasingly more popular as the method of backlighting is due to a number of advantages over older CCFL technology:

» LEDs reach their maximum brightness almost immediately (there is no need to 'warm up' before reaching full efficiency).

» LEDs give a whiter light, which sharpens the image and makes the colours appear more vivid; CCFL had a slightly yellowish tint.

» LEDs produce a brighter light which improves the colour definition.

» Screens using LED technology are much thinner than screens using CCFL technology.

» LEDs last almost indefinitely; this makes the technology more reliable and makes for a more consistent product.

» LEDs consume very little power which means they produce less heat as well as using less energy.

Uses of LCD screens

» Used as the main output device for most modern computers.
» Many LCD screens offer touch-screen input.
» Mobile phones, tablets, laptops and portable video games all use LCD screens

Advantages of LCD screens

» Very efficient, low power consumption.
» Lightweight devices.
» Unlike CRT monitors, do not suffer from screen image burn-in
» Screens can be made in large variation of sizes.
» Do not suffer from a flickering image, unlike CRT monitors.
» Very sharp image resolution (allow a vast range of colours).
» Produce low electromagnetic fields compared to CRT monitors.

Disadvantages of LCD screens

» Colour and contrast from various viewing angles can be inconsistent.
» Motion blur is a common issue.
» Lower contrast than CRT monitors, because it is harder to produce a deep, rich level of black.
» LCDs can have weak or stuck pixels, which are permanently on or off; some pixels may be improperly connected to adjoining pixels, rows or columns.
» The LCD panel may not be uniformly illuminated by the back light, resulting in uneven intensity and shading over the screen.

2.3.2 Touch screen (as an output device)

Touch screens can work as both an input device (see Section 2.1.6) and as an output device. This is one of the few devices that can be used in this way. When options appear on the screen,

Uses of touch screens (acting as both input and output)

» Smartphones and tablets (allowing interaction with apps).

» ATMs at banks (where screen options displayed depend on previous input response).

» Ticket collection machines at theatres, cinemas and railway stations (again on-screen outputs will depend on previous inputs).
» Information kiosks at museums or art galleries.

Advantages of touch screens

» Faster entry of options than using a keyboard or mouse.

» Very easy method for choosing options. » User-friendly method – no training necessary in its use.

» Option to expand the size of the display if necessary.

Disadvantages of touch screens

» Limited number of options available.

» Not very good if large amounts of data are being input or output because they are not very accurate and the interface is not fast.

» The screen can get very dirty with constant touching

» Easier for a third party to track a user's interactions, which is a security risk

2.3.3 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.

Uses of multimedia projectors

» Training presentations (to allow the whole audience to see the images from a computer).

» Advertising presentations

» Home cinema systems (projecting the images from a DVD or television).

Advantages of multimedia projectors

» Enables many people to see a presentation rather than crowding around a small computer screen.

» Avoids the need for several networked computers

Disadvantages of multimedia projectors

» Images can sometimes be fuzzy.
» Expensive to buy.
» Setting up projectors can be a little difficult.

2.3.4 Printers

This section will consider the use of the three most common types of printers:
» Laser printer
» Inkjet printer
» Dot matrix printer

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 pages can be printed out.

Uses of laser printers

» They are used where low noise is required (for example, in an office).
» If fast, high-quality, high-volume printing is required then laser printers are the best option.

Advantages of laser printers

» Printing is fast (unless only a few pages are to be printed, in which case 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

▲ **Figure 2.31** Laser printer

Disadvantages of laser printers

» Only really fast if several copies are being made.
» Colour laser printers tend to be expensive to run
» They produce ozone and volatile organic compounds because of their method of printing and type of toner/ink used

Inkjet printers

Inkjet printers are used to produce good-quality hard copies. Unlike laser printers, inkjet printers do not have large buffer memories, therefore printing is done a bit at a time.

The ink droplets are produced using two different technologies:

» **Thermal bubble** – tiny resistors create localised heat which makes the ink vaporise. This causes the ink to form a tiny bubble; as the bubble expands, some of the ink is ejected from the print head onto the paper. When the bubble collapses, a small vacuum is created which allows fresh ink to be drawn into the print head.

▲ **Figure 2.32** Inkjet printer

» **Piezoelectric** – a crystal is located at the back of the ink reservoir for each nozzle. The crystal is given a tiny electric charge which makes it vibrate. This vibration forces ink to be ejected onto the paper; at the same time more ink is drawn in for further printing.

Uses of inkjet printers

» 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;

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Advantages of inkjet printers

» High-quality output.

» Cheaper to buy than laser printers

» Very lightweight and have a small physical footprint.

» Do not produce ozone and volatile organic compounds, unlike laser printers.

Disadvantages of inkjet printers

» Slow output if several copies are needed (little buffer capacity to store the pages).

» Cannot do large print jobs (ink cartridges run out too quickly).

» Printing can 'smudge' if the user is not careful.

» Can be expensive if used a lot (original ink cartridges are expensive to buy).

Dot matrix printers

Dot matrix printers are a type of impact printer where a print head (made up of a matrix of pins) presses against an inked ribbon. They tend to be slow, noisy and the output is not that good compared to inkjet and laser printers.

Uses of dot matrix printers

» They can be used in noisy or dirty environments (for example, garage workshops) and in applications where print quality is not that important.

» They are used in applications where multi-part stationery or the fact that they are an impact printer is of value

» Still widely used in till receipts.

▲ **Figure 2.33** Dot matrix printer

Advantages of dot matrix printers

» They can be used in environments which would be a problem for laser or inkjet printers (for example, dusty/dirty or moist atmospheres).

» Carbon copies or multi-part outputs can be produced.

» Very cheap to run and maintain.

» Easy to use if continuous stationery is required (for example, long print jobs such as wages slips).

Disadvantages of dot matrix printers

» Very noisy – not good in an office environment.

» Actually, cost more than an inkjet printer to buy initially.

» Very slow, poor-quality printing.

2.3.5 (Graph) plotters

A (graph) **plotter** is an output device. Although they print on paper, they work very differently to printers. Instead of toner or ink cartridges, plotters use a pen, pencil or marker pen to draw multiple continuous lines, rather than a series of dots like a printer.

Uses of plotters

» Producing architectural drawings.

» Producing engineering drawings.

» Drawing animation characters (cartoon characters).

Advantages of plotters

» Very high-quality output. » Able to produce large, monochrome and colour drawings to a high accuracy.

» Able to print on a variety of materials (for example, aluminium, cardboard, plastic, steel and wood) as well as paper.

Disadvantages of plotters

» Very slow at printing.

» Expensive equipment (and software) to purchase initially; although running costs are low once purchased.

» Have a very large physical footprint compared to a printer

2.3.6 3D printers

3D printers are primarily used in **computer-aided design (CAD)** applications.

They are primarily based on inkjet and laser printer technology and can produce solid objects that work. The solid object is built up layer by layer using materials such as powdered resin, powdered metal, paper or ceramic.

The following information describes some of the features of 3D printing:

» Various types of 3D printers exist; they range from the size of a microwave oven up to the size of a small car.

» 3D printers use **additive manufacturing** this is in sharp contrast to the more traditional method of **subtractive manufacturing.** Similarly, **CNC** (computer-controlled machine – a type of lathe) removes metal to form an object; 3D printing would produce the same item by building up the object from layers of powdered metal.

▲ **Figure 2.35** 3D printer

▲ **Figure 2.36** Alloy wheel made by 3D printing

» **Direct 3D printing** uses inkjet technology; a print head can move left to right as in a normal printer. However, the print head can also move up and down to build up the layers of an object – each layer being less than a tenth of a millimetre (less than 0.1 mm).

» **Binder 3D printing** is similar to direct 3D printing, but this method uses two passes for each of the layers; the first pass sprays dry powder, then, on the second pass, a binder (a type of glue) is sprayed to form a solid layer.

Uses of 3D printers

The following list is just a glimpse into what we know can be made using these printers; in the years that follow, the applications list could probably fill an entire book:
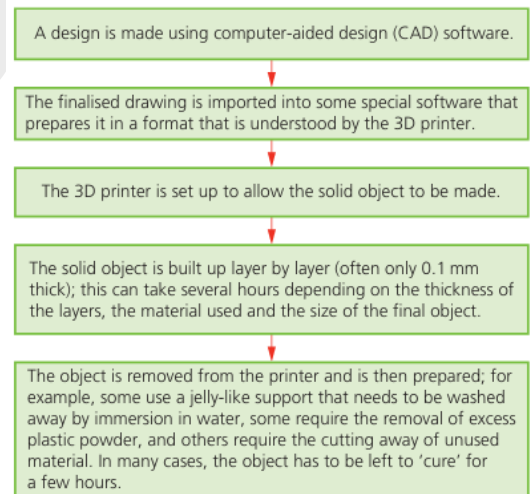
» Prosthetic limbs can be made to fit exactly on the injured body part.

» Making items to allow precision reconstructive surgery the parts made by this technique are more precise in their design as they can be made from an exact scan of the skull.

» In aerospace, manufacturers are looking at making wings and other aeroplane parts using 3D technology; the bonus will be lightweight, precision parts.

» Fashion and art – 3D printing allows new creative ideas to be developed.

» Making parts for items no longer in production, for example, parts for a vintage car.

How to create a solid object using 3D printers

The steps in the process of producing an object using 3D printers is summarised in Figure 2.37

Advantages of 3D printers

» The manufacturing of items has become much easier than ever before. It is now theoretically possible to manufacture any product a user wants using only a 3D printer.

» Because 3D printers can manufacture items relatively quickly, it allows rapid prototyping. This means that it will take a really short length of time for designs to be converted into working prototypes.

» Even though the cost of 3D printing is very high, it is still less when compared to labour costs and other costs involved in manufacturing a product in the more conventional way.

A design is made using computer-aided design (CAD) software.

The finalised drawing is imported into some special software that prepares it in a format that is understood by the 3D printer.

The 3D printer is set up to allow the solid object to be made.

The solid object is built up layer by layer (often only 0.1 mm thick); this can take several hours depending on the thickness of the layers, the material used and the size of the final object.

The object is removed from the printer and is then prepared; for example, some use a jelly-like support that needs to be washed away by immersion in water, some require the removal of excess plastic powder, and others require the cutting away of unused material. In many cases, the object has to be left to 'cure' for a few hours.

▲ **Figure 2.37** Creating a solid object using 3D printers

» Medical benefits are emerging, such as producing artificial organs, prosthetics and precision-made items for reconstructive surgery.

» Parts for machinery that are no longer made could now be manufactured using 3D printers.

Disadvantages of 3D printers

» The biggest possible drawback of 3D printers is the potential to make counterfeit items or items that infringe others' copyright. 3D printing technology essentially turns every owner of one of these printers into a potential manufacturer.

» All new technologies in the hands of the wrong people can lead to dangerous or illegal activities. With the possibility of creating almost anything with the use of a 3D printer, this technology could be used to manufacture dangerous items by almost anyone.

» There is the potential for job losses if this technology takes over from some types of manufacturing. Of course, this could also be seen as a benefit by some companies as it could lead to lower manufacturing costs for certain items.

2.3.7 Speakers

Speakers (or loudspeakers) are output devices that produce sound. When connected to a computer system, digitised sound stored on a file needs to be converted into sound as follows:

» The digital data is first passed through a digital to analogue converter (DAC) where it is changed into an electric current.

» This is then passed through an amplifier (because the current generated by the DAC will be very small); this creates a current large enough to drive a loudspeaker.

» This electric current is then fed to a loudspeaker where it is converted into sound

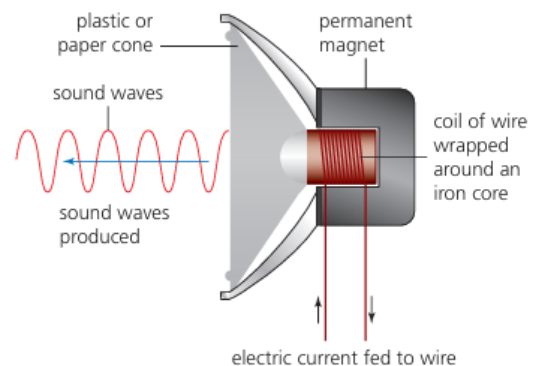The schematic in Figure 2.38 shows how this is done.
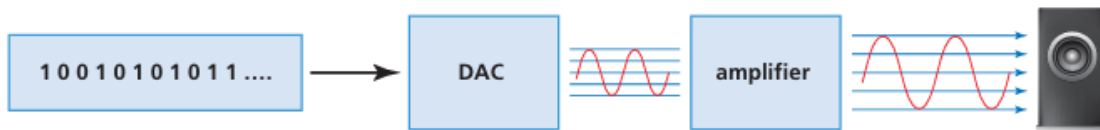
▲ **Figure 2.38** Digital to analogue conversion

Figure 2.39 shows how the loudspeaker converts the electric current into sound.

» When an electric current flows through the coil of wire that is wrapped around an iron core, the core becomes a temporary electromagnet; a permanent magnet is also positioned very close to this electromagnet.

» As the electric current through the coil of wire varies, the induced magnetic field in the iron core also varies.

▲ **Figure 2.39** Diagram showing how a loudspeaker works

» Because the iron core is attached to a cone (made of paper or thin synthetic material), this causes the cone to vibrate, producing sound waves

Uses of speakers

» Used in all phones and built into most computers.
» Outputs sound from multimedia presentations.
» Helps visually impaired people through reading aloud text on the screen.
» Plays downloaded sound files.

Advantages of speakers

» Sounds amplified through speakers can be much louder than the original sound – this is important whenever more than a few people need to listen to something.
» Everyone in a conference,
» It can create a good atmosphere when making a presentation
» They can help visually impaired people as discussed.
» Very simple technology.

Disadvantages of speakers

» Speaker output can be disturbing to others in
» To get high-quality sound, the required speakers can be quite expensive.
» Speakers can take up a lot of desk space.

2.3.8 Actuators

When a computer is used to control devices, such as a conveyer belt or a valve, it is usually necessary to use an **actuator** to, for example, start/stop the conveyer belt or open/close the valve.

Uses of actuators

» They are used to control motors, pumps, switches, buzzers and so on.

▲ **Figure 2.40** Solenoid

» They allow a computer to control physical devices that normally require analogue inputs.

Advantages of actuators

» They allow remote operation of many devices (for example, pumps in a nuclear reactor where remote operation is a big safety factor).

» They are relatively inexpensive devices.

Disadvantages of actuators

» They are an additional device in the system that could go wrong.

» Because they are usually analogue devices, computer signals need to converted using a DAC to enable computer control.
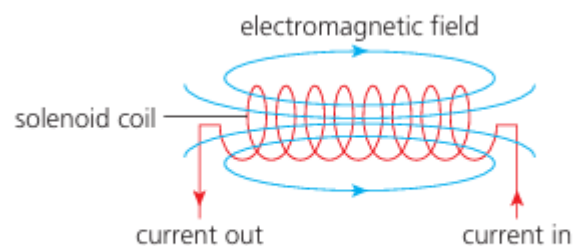
Revision questions

1. March/2023/Paper_0417/12/No.6
Bluetooth is a method of wireless communication.
State two devices found in the home which could be connected via Bluetooth.

2. March/2023/Paper_0417/12/No.10
Some computers have touch screens.
Describe three benefits of using a touch screen.

3. June/2023/Paper_0417/11/No.8
(a) Compare Optical Mark Readers (OMRs) with Optical Character Readers (OCRs). Your answer must include similarities and differences.
(b) Identify two uses of Optical Mark Recognition (OMR).

4. June/2023/Paper_0417/11/No.11
Portable hard drives can be Solid State Drives (SSDs) or Hard Disk Drives (HDDs).
Explain why the SSD may be better to use than the HDD.

5. June/2023/Paper_0417/12/No.2
Identify the most appropriate hardware from the descriptions given:
(a) non-volatile internal memory used to store the start-up instructions
(b) an internal component that provides the input and output of audio signals
(c) an internal component that is composed of the main memory, the control unit and the arithmetic logic unit.

6. June/2023/Paper_0417/12/No.3
A headteacher is producing a web page about the history of her school. She has been given some old hard-copy photographs which she will include on the web page. She has a digital camera and a scanner to use to convert the hard-copy photographs into a digital format.
Compare the use of a digital camera with a scanner in this scenario. Your answer must include similarities and differences.

9. June/2023/Paper_0417/12/No.9
(a) The products in a warehouse contain either a bar code or a Radio Frequency Identification (RFID) tag.
The data about each product is read electronically.
Compare bar code readers and RFID readers. Your answer must include similarities and differences.
(b) Identify two other uses of RFID.

10. June/2023/Paper_0417/12/No.13(b, c)
Weather forecasters use computer modelling.
(b) Data is collected by different types of sensor and then input to the computer model to be processed.
Identify two sensors that could be used to collect weather data.
(c) The processed data is then output.
Identify two output devices that could be used.

11. June/2023/Paper_0417/13/No.2(b, c)

Identify the most appropriate hardware from the descriptions given.

(b) An external device that retains a computer's data even after the computer is turned off.

(c) An input device that is attached to a monitor.

12. June/2023/Paper 0417/13/No.3

A group of students are producing a class newsletter which they will email to parents of students in the class. They are deciding whether to use a laptop computer or a smartphone to type the newsletter.

(a) Discuss the advantages and disadvantages of using a laptop computer rather than a smartphone for this purpose.

(b) The students have decided to use a smartphone. Data for the newsletter will be input, stored and output by the smartphone.

(I) Identify two devices that are part of the smartphone that could be used to input the data for the newsletter.

(ii) Identify two devices that are part of the smartphone that could be used to output data from the newsletter.

(iii) Identify two appropriate devices that could be used to store data for the newsletter.

(c) The newsletter is to be saved as a PDF and sent as an email attachment to parents. Describe two benefits of saving the newsletter as a PDF.

(d) Describe the features that the students must include to make the newsletter appeal to the parents.

13. Nov/2023/Paper_0417/11/No.2

State the most appropriate word or phrase to complete each sentence.

(a) The type of data output from a sensor is

(b) The type of data read by a microprocessor is

(c) The item of hardware that converts data from a sensor so a microprocessor can read it is

(d) The type of sensor that is used in a refrigerator is

14. Nov/2023/Paper_0417/11/No.3

A group of students are carrying out a study of the quality of river water for a project. They can either use a tablet computer or a smartphone to monitor and record their findings.

(a) Discuss the advantages and disadvantages of using a tablet computer rather than a smartphone for this project.

(b) Identify two devices that could be used by the students to enter data.

15. Nov/2023/Paper_0417/11/No.4

A headteacher is considering setting up a card system for students to buy food in the school canteen.

The headteacher is trying to decide whether to install a system that uses magnetic stripe card readers or one that uses chip and PIN card readers.

Compare the use of magnetic stripe card readers with the use of chip and PIN card readers. Your answer must include similarities and differences.

17. Nov/2023/Paper_0417/13/No.3(b)

A teacher is setting up a school shop. The teacher is setting up a spreadsheet to keep the accounts of the shop.

(b) Each box delivered to the school shop includes a QR code.

Explain why QR codes are used.

18. Nov/2023/Paper_0417/13/No.7(b)

Rockit Aircraft manufactures and flies aeroplanes.

(b) Some of the components used in the manufacture of aircraft are produced using a 3D printer.

Analyse the use of a 3D printer to make the components rather than making the components by hand.

19. Nov/2023/Paper_0417/13/No.8(a, b)

Many devices in the home can be connected to the internet so they can be controlled remotely. These devices are called smart devices. A house contains a smart security system.

(a) Describe the benefits and drawbacks of using a smart security system.

(b) Identify two sensors that could be used with the smart security system.

20. March/2024/Paper_0417/12/No.11

More people use desktop computers rather than tablet computers when working at home.

(a) Discuss the advantages and disadvantages of using desktop computers rather than tablet computers for doing work at home.

(b) Desktop computers use input and output devices.

(i) State two input devices that can be used in a desktop computer for working at home.

(ii) State two output devices that can be used in a desktop computer for working at home.