

2

Input and output devices

In this chapter you will learn about:

- ★ input devices
- ★ direct data entry (DDE) devices
- ★ output devices.

For each device you will learn about:

- ★ characteristics
- ★ uses
- ★ advantages and disadvantages.

As the name suggests, these 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 more specialist devices, such as barcode readers. Some of these are described in this section.

2.1 Input devices and their uses

2.1.1 Keyboards

Keyboards are by far the most common method used for data entry. They are used as the input device on computers, tablets, mobile phones and many other electronic items.

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).

When the character on the keyboard is pressed, it is converted into a digital signal, which the computer interprets.

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.

Ergonomic keyboards can help to overcome this problem – these have the keys arranged differently, as shown in Figure 2.2. They are also designed to give more support to the wrists and hands when doing a lot of typing.

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.

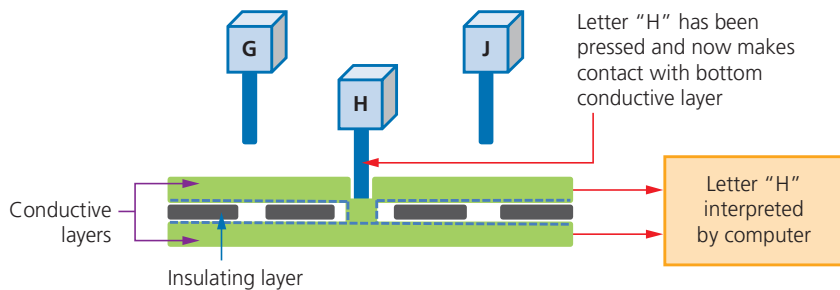


▲ Figure 2.1 Keyboard



▲ Figure 2.2 Ergonomic keyboard

- » 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 (for example, text into word processors, numbers into spreadsheets, and so on).
- » Typing in commands to the computer (for example, Prnt Scrn, Ctrl+P to print out, and so on).

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 (can immediately compare the source document with typed data on the screen).

Disadvantages of keyboards

- » Can be difficult to use if the user has limited arm/wrist use.
- » Slow method when compared to direct data entry (for example, Optical Mark Recognition – see Section 2.2).
- » Fairly large device that uses up valuable desk space.

Exercise 2a

Find out about a number of applications that use input/output devices and discuss the reasons why they were chosen (that is, their advantages and disadvantages).

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.



▲ **Figure 2.4** Numeric keypad

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- » 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 user controls the position of a pointer on the screen by moving the mouse around. There are usually two buttons which have different functions; the left button is used to select items by double clicking, while the right button brings up drop-down menus.

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

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. The advantage of an optical mouse is it has no moving parts and it also does not pick up any dirt. This makes it more robust and improves its performance because the older type of mouse can 'skid' on certain surfaces reducing the control of the pointer.

Uses of a mouse

Almost anything, depending on the software, but includes:

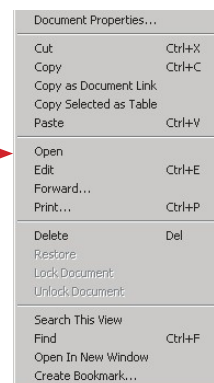
- » opening, closing and minimising software
- » grouping, moving and deleting files
- » image editing, for example, controlling the size and position of a drawing pasted into a document
- » controlling the position of a pointer on the screen to allow selection from a menu or selecting an icon, and for 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 2.5 Mouse



▲ 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). They also have buttons under the touchpad which serve the same function as the left and right buttons on a mouse.



▲ Figure 2.7 Touchpad

Use of a touchpad

Their uses are the same as those of a mouse.

Advantages of a touchpad

- » Same as the mouse (faster than a keyboard for choosing options, used to navigate applications and the internet, etc.).
- » 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.

Trackerball

Trackerballs 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 trackerballs have two buttons, which have the same function as the left- and right-hand mouse buttons. If they have a third button, it is equivalent to a double click. Because trackerballs do not physically move, there is no need for a large amount of desk space.



▲ Figure 2.8 Trackerball

Uses of a trackerball

- » 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.



▲ Figure 2.9 Trackerball used in a luxury car

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Advantages of a trackerball

- » 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.
- » 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 trackerball

- » 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.

The buttons on the keypad are used to select options (such as television channels, sound levels on a Hi-Fi, timings on a DVD recorder, etc.).

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, for example, a wired mouse which is restricted by the length of the wire. Some industrial processes are hazardous, so it is a big advantage to be able to select operations from a distance.

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. Often they have another button on the top of the stick that is used for gaming purposes for example to fire a weapon.



▲ **Figure 2.10** Remote control



▲ **Figure 2.11** Joystick

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. The wheel allows you to simulate the turning of a steering wheel, and there are associated devices (such as buttons or pedals) which allow you to accelerate and brake. Sensors are used to pick up left/right movement so that the user gets the sensation of steering a car around a circuit or on the road.



▲ Figure 2.12 Driving wheel

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.

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. The selection is automatically made without the need for any pointing device.

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.



▲ Figure 2.13 Touch screen

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- » 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 (straining of arm muscles, RSI, etc. are all possible).
- » The screen can get very dirty with constant touching (giving a risk of spreading infections, and reduce its responsiveness which makes it more difficult to read in strong sunlight).

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. 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 of text can also be used with optical character recognition (OCR) software to produce editable text documents (see Section 2.2). There are also specialist scanners which are designed to carry out a specific task, for example, barcode scanners (see later).

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 (this is also known as archiving).
- » Scan in photographs (not all cameras are digital and therefore photographs are still printed on paper, requiring conversion to computer format for storage).
- » 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 fairly 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).

The images are uploaded from the camera and stored in a file in the computer; the user can select which photos to upload and which to discard. The images are then available for printing out as photos, can be used in a 'slide show', imported into software such as a word processor, or uploaded on to the internet.

Uses of digital cameras

- » Taking photographs; they still take better photographs 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.



▲ Figure 2.15 Digital camera

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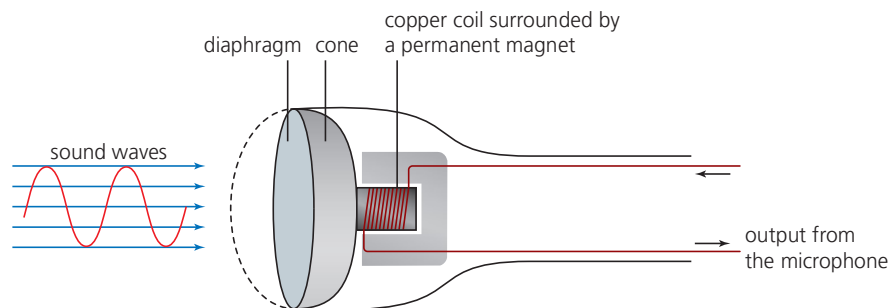
Disadvantages of digital cameras

- » 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 (for example, incorrect exposure, removal of red eye, etc.).
- » Images often need to be compressed to reduce the amount of memory used (a single image can use more than 12 MB of memory, for example).

Many smartphones and tablets are now capable of taking photographs of a very high quality. Some of the latest smartphones are essentially making cameras almost obsolete for the casual photographer. Because the quality of the lens is an important feature, professional photographers will continue to use digital cameras for a number of years. However, it is now possible to get special attachments for many smartphones to allow special effects, zooming functions and even light filters.

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. The current produced is converted to a digital format so that a computer can process it or store it (for example, on a CD).



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

- » 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.
- » A copper coil is surrounded by a permanent magnet and the coil is connected to the diaphragm using a cone. As the diaphragm vibrates, the cone moves in and out causing the copper coil to move backwards and forwards relative to the magnet.
- » 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.

The electric current output from the microphone can also be sent to a computer where a sound card converts the current into a digital signal which can then be stored in the computer.

Uses of microphones

- » To input speech/sounds to be used in various applications, for example, in presentations, sampling (in films, music, etc.) and special effects (films).
- » 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 (because the car driver, for example, does not need to take their hands off the wheel to operate a switch or alter the radio station, etc.).

Disadvantages of microphones

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

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 (for example, temperature, light, moisture, etc.). These physical quantities are analogue in nature. 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)**.

Sensors are used in monitoring and control applications – various types of sensors are used depending on the application (see Table 2.1). When monitoring, the data sent to the computer is often transferred directly to a spreadsheet package (for example, taking measurements in a scientific experiment, measuring atmospheric pollution, etc.).

Link

For more on the differences between analogue and digital data see Section 1.13.

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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 (very important if the process is hazardous or needs precise control/monitoring).

Disadvantages of using sensors

- » Faulty sensors can give spurious results – for example, sensors on the rear bumper of a car that monitors obstacles; if these become dirty, they may either not identify an obstacle or give a continuous alarm.
- » 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. The screen is refreshed 50 times every second; because of this, the computer is able to determine the pen's position by noting exactly when the device detected the electron beam passing its tip. Systems to allow light pens to operate with LCD monitors are still at the development stage.

Uses of light pens

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



▲ **Figure 2.17** Light pen

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. For example, barcode readers are DDE and the only human involvement is to point a reader at the barcode. The transfer of the data to the computer is done automatically.

2.2.1 Card readers

Magnetic stripe readers

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

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.

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 (information not in human readable form and, because there is no typing, removes the risk of somebody observing your key strokes).
- » 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 (for example, due to exposure to a strong magnetic field) 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.

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. All contactless cards have



▲ **Figure 2.18** Magnetic stripe reader



▲ **Figure 2.19** Contactless debit card

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a small chip that emits radio waves embedded in them. The card is held within a few centimetres of the payment terminal to pay for an item; 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.

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; it does not simply transmit the consumer's account number; this number is also encrypted.

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 (the third point above reduces this risk considerably however; because you do not have to type in a PIN, somebody standing behind you could not steal your PIN and use it).
- » Can take money twice if the customer uses it as a chip and PIN card (one is contactless and the other is chip and PIN).
- » Transactions are usually limited to a small maximum value (for example, \$50).
- » Transactions have been carried out, in some countries, without the card holder being aware of this while they were just standing in the payment queue (although it should be pointed out that this is much rarer today with new technologies in most countries).

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. The reader also has a small screen which gives instructions to the operator. They are similar to 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.



▲ **Figure 2.20** Contactless card reader

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

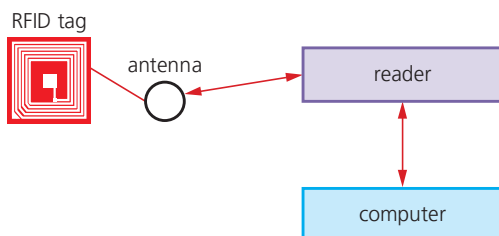
- » Fraud – need to be careful to ensure PIN is not read by somebody else while typing it in.

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 a distance of several metres, which is one of its advantages over the barcode system. 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.

The tags can be passive or battery-powered. Passive tags use the reader's radio wave energy to relay back the information; battery-powered tags use a small embedded battery to power the RFID.



▲ **Figure 2.21** RFID

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 (it is similar to barcodes, but does not require any scanning; details such as price can be stored on the tag and then automatically read at a checkout – a big advantage is that several tags can be read at the same time, thus speeding up the checkout process).
- » Admission passes (for example, in theme parks RFID cards eliminate the need to scan or swipe people before 'rides', reducing the waiting time; it also allows the tracking of people in the theme park and certain information, such as height or age, can be stored to prevent entry to certain rides on safety grounds).
- » Libraries (books can be tracked in and out automatically by readers at the library entrance; no need to scan barcodes or use magnetic stripe cards, making the process quicker and more accurate).

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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. 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 option 1. The position of the mark is stored in the computer's memory after being read by the OMR device.

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.



▲ Figure 2.22 OMR

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. OCR software converts this electronic data into a form that can then be used in various application packages, such as word processors or presentation software.

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. What features of OCR or OMR need to be considered when designing the data-capture form? This comparison is needed before the form is designed and the appropriate input method chosen. Table 2.2 summarises the features of both methods.

▼ **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



▲ **Figure 2.23** Using OCR to process a passport

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).

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 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).

Uses of barcode systems

- » 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.
- » 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 (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 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 (for instance electrical components) they can help improve safety.
- » They allow automatic stock control.
- » They are a tried and trusted technology.

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. For example, the QR code in Figure 2.26 is a website advertising rock music merchandise. It includes a web address in the code.

QR codes can hold considerably more information than the more conventional barcodes described earlier.

Description of QR codes

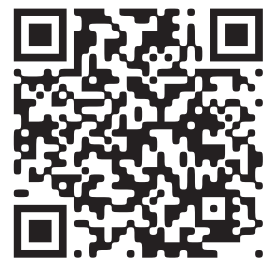
A QR code consists of a block of small squares (light and dark) known as pixels. It can presently hold up to 4296 characters (or up to 7089 digits) and allows internet addresses to be encoded within the QR code. This compares to the 30 digits which is the maximum for a barcode. However, as more and more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



▲ **Figure 2.24** Sample barcode



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




▲ **Figure 2.26** Sample QR code

The three large squares at the corners of the code function as a form of alignment; the remaining small corner square is used to ensure the correct size and correct angle of the camera shot when the QR code is read.

Because of modern smartphones and tablets, which allow internet access on the move, QR codes can be scanned anywhere. This gives rise to a number of uses:

- » advertising products (for example, the QR code in Figure 2.26)
- » giving automatic access to a website or contact telephone number
- » storing boarding passes electronically at airports and train stations (Figure 2.27).

By using the built-in camera on a mobile smartphone or tablet and by downloading a QR app (application), it is possible to read QR codes on the move using the following method:

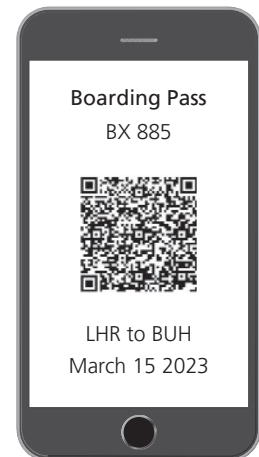
- » Point the phone or tablet camera at the QR code.
- » The apps will now process the image taken by the camera converting the squares into readable data.
- » The browser software on the mobile phone or tablet automatically reads the data generated by the apps; it will also decode any web addresses contained within the QR code.
- » The user will then be sent to a website automatically (or if a telephone number was embedded in the code, the user will be sent to the phone apps .
- » If the QR code contained a boarding pass, this will be automatically sent to the phone/tablet.

Uses of QR codes

- » Used in advertising to contain data such as business addresses, phone numbers, email addresses and website addresses; scanning the QR code gives all the necessary data on the smartphone screen, or the user is sent automatically to the website embedded in the QR code.
- » 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 – when the QR code is scanned using a smartphone/tablet, it will be able to automatically join that network.
- » QR codes can be used to deliver **augmented reality** (see Chapter 1) 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, for example, on a train station wall. The customers scan the QR codes, and the products are automatically delivered to their homes.

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; normal barcodes



▲ **Figure 2.27** Sample boarding pass

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contain almost no data redundancy (that is, data which is duplicated) therefore it is not possible to guard against badly printed or damaged barcodes.

- » 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. When the code is scanned, it is possible the creator of the malicious code could gain access to everything on the user's smartphone/tablet (for example, photographs, address book, stored passwords, etc.). The user could also be sent to a fake website, or it is even possible for a virus to be downloaded.

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). However, some output devices are part of a control system. In these examples, the computer is controlling a process and sends signals to these output devices.

2.3.1 Monitors (screens)

In this section we will consider two types of monitor:

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

While CRT monitors have just about been phased out everywhere, they are included here because these are the only type of device which allows the use of light pens (see Section 2.1.11). Consequently, some companies using CAD still use large CRT monitors to enable the use of light pens as part of the drawing environment.

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. The picture is made up of tiny dots which are coloured red, green or blue – the intensity of each coloured dot makes up the vast range of colours interpreted by the eye.



▲ **Figure 2.28** CRT monitor

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.

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 cover about ten times the area of an LCD monitor).
- » 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.

This type of screen tends to be used for large outdoor displays, due to the brilliance of the colours produced. Recent advances in LED technology have led to the introduction of OLED (organic LED) screens.

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.

Modern LCD screens are backlit using light emitting diode (LED) technology and must not be confused with pure LED screens. When LEDs are used, a matrix of tiny blue-white LEDs is used behind the LCD screen. The use of LED backlighting gives a very good contrast and brightness range.

Before the use of LEDs, LCD screens used cold cathode fluorescent lamps (CCFL) as the back lighting method. Essentially, CCFL used two fluorescent tubes behind the LCD screen to supply the light source.

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).

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- » 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

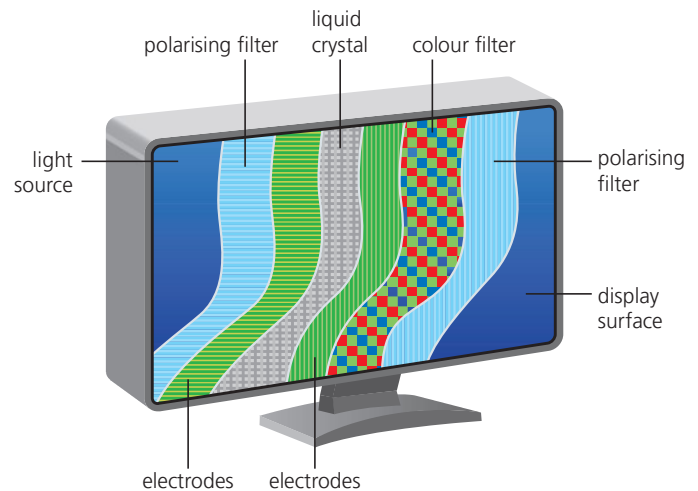
- » Very efficient, low power consumption.
- » Lightweight devices.
- » Unlike CRT monitors, do not suffer from screen image burn-in (that is, a permanent image burned into the screen due to unchanging images over a period of time).
- » Screens can be made in large variation of sizes.
- » Do not suffer 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, for example a food selection at a fast food outlet, a user can make a selection by touching the screen (this is the input). Another set of options then appear on the screen, such as choosing another drink – this is the output produced based on the previous input.



▲ **Figure 2.29** Inside an LCD 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 (giving a risk of spreading infections, as well as reducing its responsiveness and making it more difficult to read in strong sunlight).
- » Easier for a third party to track a user's interactions, which is a security risk (for example, entering credit card details).

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. The devices work with a remote control which acts like a cordless mouse when interfacing with the screen. 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.



▲ **Figure 2.30** Multimedia projector

Uses of multimedia projectors

- » Training presentations (to allow the whole audience to see the images from a computer).
- » Advertising presentations (large images showing product features, for example a new car; can be shown at exhibitions, shopping malls, etc.).
- » 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 (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).

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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 printer:

- » 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.

Let us briefly consider how a page is printed:

- » The start of the printing process involves a printing drum being given a positive charge; as this drum rotates, a laser beam is scanned across it removing the positive charge in certain areas; this leaves negatively charged areas which exactly match the text/images of the page to be printed.
- » The drum is then coated with positively-charged toner (powdered ink); because the toner is positively charged, it only sticks to the negatively charged parts of the drum.
- » A negatively-charged sheet of paper is then rolled over the drum.
- » The toner on the drum now sticks to the paper to produce an exact copy of the page sent to the printer.
- » To prevent the paper sticking to the drum, the electric charge on the paper is removed after one rotation of the drum.
- » The paper finally goes through a fuser, which is a set of heated rollers; the heat melts the ink so that it fixes permanently to the paper.
- » At the very end, a discharge lamp removes all the electric charge from the drum, making it ready to print the next page.

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 (and the printers can sometimes be a cost-effective option, particularly if colour outputs are not required).



▲ **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 (four-colour/black cartridges are needed, plus diffuser kits, which are expensive to purchase).
- » 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. Unlike laser printers, inkjet printers do not have large buffer memories, therefore printing is done a bit at a time. This is why printing is sometimes paused – the whole print job cannot be stored in the buffer, and it has to wait for the computer to send more data.

Inkjet printers are essentially made up of:

- » a print head, which consists of nozzles which spray droplets of ink on to the paper to form characters
- » an ink cartridge or cartridges; either one cartridge for each colour (blue, yellow and magenta) and a black cartridge, or one single cartridge containing all three colours plus black (note: some systems use six colours)
- » a stepper motor and belt, which moves the print head assembly across the page from side to side
- » a paper feed which automatically feeds the printer with pages as they are required.

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. This continues until the printing cycle is completed.
- » **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 (high-volume jobs are difficult to do because the ink cartridges tend to be used up very quickly).
- » 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 Section 2.3.6).

Advantages of inkjet printers

- » High-quality output.
- » Cheaper to buy than laser printers.



▲ **Figure 2.32** Inkjet printer

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- » 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. They are still useful, however, where multi-part stationery (carbon copies) or continuous rolls of paper (rather than individual sheets) are being used. They also work well in dirty atmospheres (such as on a factory floor), unlike inkjet or 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 (for example, when producing physical 'carbon copies' such as when producing wage slips).
- » Still widely used in till receipts.

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. The size of the paper can be anything from A4 up to several metres. They produce vector graphic drawings and are often used in conjunction with CAD and CAM (computer aided manufacturing).



▲ Figure 2.33 Dot matrix printer



▲ Figure 2.34 (Graph) plotter

Some plotters are used to cut out material by replacing the pen with a cutting blade. However, in general, plotters are being phased out, as wide-format inkjet printers are being produced at lower cost.

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 actually work. The solid object is built up layer by layer using materials such as powdered resin, powdered metal, paper or ceramic.

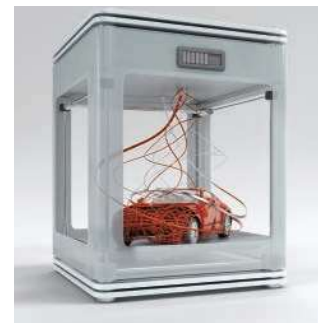
The alloy wheel in Figure 2.36 was made using an industrial 3D printer.

It was made from many layers of powdered metal (0.1 mm thick) using a technology known as binder 3D printing.

Other examples are discussed below.

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** (i.e. the object is built up layer by layer); this is in sharp contrast to the more traditional method of **subtractive manufacturing** (i.e. removal of material to make the object). For example, making a statue using a 3D printer would involve building it up layer by layer using powdered stone until the final object was formed. The subtractive method would involve carving the statue out of solid stone (i.e. removing the stone not required) until the final item was produced. 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

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- » **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.
- » Newer technologies are using lasers and UV light to harden liquid polymers; this further increases the diversity of products which can be made.

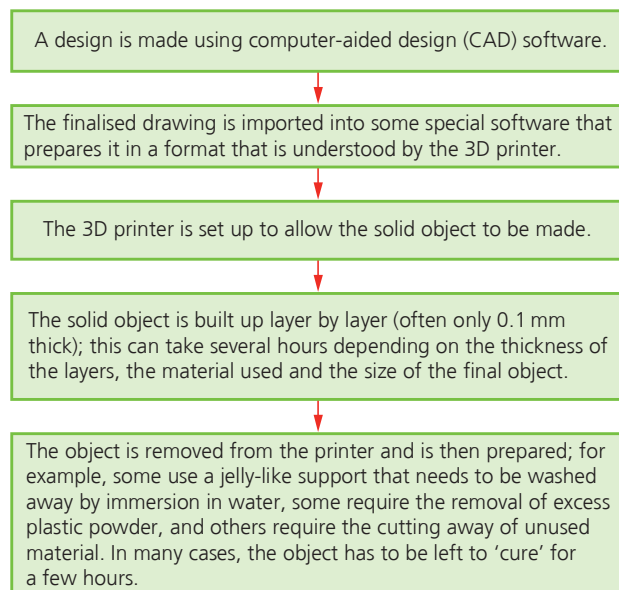
Uses of 3D printers

3D printing is regarded as being possibly the next ‘industrial revolution’ because it will change the manufacturing methods in many industries. 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 (for example, facial reconstruction following an accident); 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.



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

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. This has led the way for customised products, as it allows a user to create their own designs in 3D and have them printed in solid form.
- » 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. The fact that the cost of manufacturing using 3D printers is the same for both small-scale and mass production is also a very useful benefit.
- » 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. A car made in the 1930s, for example, will no longer have parts available off-the-shelf. By scanning the broken part (using a 3D scanner), or by obtaining its blueprint, it will be possible to simply email the file to a company and have the part made on an industrial 3D printer. This clearly has many benefits in a number of applications.

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. Thus, it could become very difficult to trace the source of fake items; copyright holders would also have great difficulty in protecting their rights.
- » 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.

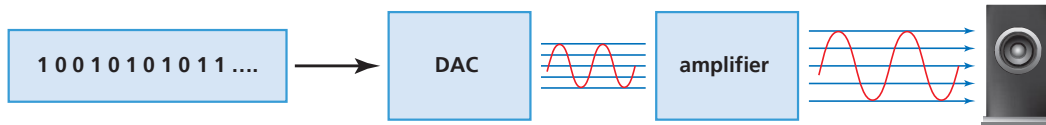
2.3.7 Speakers

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.

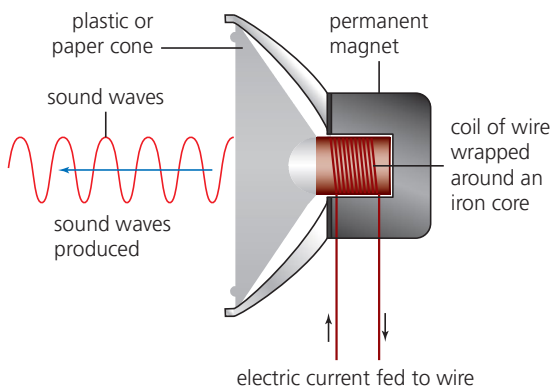
2 INPUT AND OUTPUT DEVICES

The schematic in Figure 2.38 shows how this is done.



▲ **Figure 2.38** Digital to analogue conversion

As Figure 2.38 shows, if the sound is stored in a computer file, it must pass through a digital to analogue converter (DAC) to convert binary (digital) data into an analogue form (electric current) which can then drive the loudspeaker. Figure 2.39 shows how the loudspeaker converts the electric current into sound.



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

- » 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. This causes the iron core to be attracted or repelled from the permanent magnet and as the current varies this will cause the iron core to vibrate.
- » 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 in to most computers.
- » Outputs sound from multimedia presentations.
- » Helps visually impaired people (together with speech generation software) 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, for example, can hear the output from a computer.
- » It can create a good atmosphere when making a presentation.

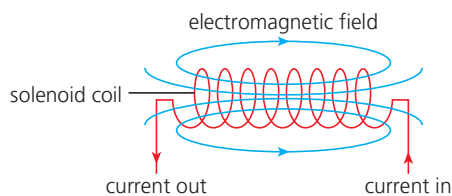
- » They can help visually impaired people as discussed.
- » Very simple technology.

Disadvantages of speakers

- » Speaker output can be disturbing to others in, for example, an office environment.
- » 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. An actuator is a mechanical or electromechanical device such as a relay, solenoid or motor. We will consider a solenoid as the example; this converts an electrical signal into a magnetic field producing linear motion:



▲ **Figure 2.40** Solenoid

If a plunger (for example, a magnetised metal bar) is placed inside the coil, it will move when a current is applied to the coil (see Figure 2.40). This would allow the solenoid to operate a valve or a switch, for example. There are also examples of rotary solenoids, where a cylindrical coil is used. In this case, when a current is supplied to the coil, it would cause a rotational movement of the plunger.

Uses of actuators

- » They are used to control motors, pumps, switches, buzzers and so on.
- » 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 be converted using a DAC to enable computer control.

Exam-style questions

- 1 a State one suitable application for each of the following printers. A different application should be given in each case.
» inkjet printer
» 3D printer [2]
- b Name another type of printer and describe one way in which it is different from the two printers named in part a. [3]
- 2 Contactless debit cards are replacing standard debit cards. Some countries are introducing contactless debit card transactions at ATM machines. Give **three** disadvantages to the customer of using these cards at an ATM. [3]

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- 3 In each of the following questions, only one of the responses is correct. Choose one of the five options given. [10]
- a Which one of the following is the most suitable device for inputting a short report into a computer?

a	trackerball
b	scanner
c	keyboard
d	optical mark reader (OMR)
e	joystick

- b Which one of the following would you use to produce a digital image of a hard copy photograph?

a	touch screen
b	keyboard
c	optical character reader (OCR)
d	scanner
e	QR scanner

- c Which one of the following is **NOT** a suitable use for an optical mark reader?

a	reading barcodes
b	multiple-choice exam papers
c	choice of candidate in voting forms
d	opinion poll survey
e	data collection with limited options

- d Which one of the following is the most appropriate device for printing out wage slips, where carbon copies are also required?

a	laser printer
b	(graph) plotter
c	inkjet printer
d	actuator
e	dot matrix printer

- e Which one of the following devices could be used to produce a very large drawing on plastic sheeting?

a	(graph) plotter
b	laser printer
c	dot matrix printer
d	3D printer
e	touch screen

- f Which one of the following printers is most suitable for printing a very large number of high-quality black and white leaflets?

a	(graph) plotter
b	laser printer
c	dot matrix printer
d	inkjet printer
e	computer-aided design (CAD)

- g Which one of the following **cannot** be **directly** measured using a sensor?

a	temperature
b	light intensity
c	heat
d	air humidity
e	pressure

- h Which one of the following devices allows the use of a light pen?

a	CRT monitor
b	LCD monitor
c	barcode reader
d	QR reader
e	touch screen

- i Which one of the following cannot be used as an output device?

a	touch screen
b	(graph) plotter
c	actuator
d	speaker
e	mouse

- j Which one of the following cannot be used as an input device?

a	touch screen
b	3D printer
c	optical mark reader (OMR)
d	QR reader
e	(graph) plotter

2 INPUT AND OUTPUT DEVICES

- 4 Five devices are shown on the left and five descriptions are shown on the right. By drawing lines, connect each device to its correct description. [4]

Inkjet printer	Display that uses light modulating properties of crystals
LCD screen	Image from a source is magnified and shown on a large screen
3D printer	Droplets of ink are ejected onto a sheet of paper
Digital projector	Electrically-charged powdered toner is melted onto paper
Laser printer	Produces solid objects using CAD software

- 5 Which ten computer terms are being described below? [10]

- a A matrix of filled-in dark squares on a light background; read using a smartphone camera or tablet using an app.
- b A device that can read marks written in pen or pencil; the pencil or pen marks must be made in the correct position.
- c An input device that takes physical readings from the surroundings and sends the data back to a computer.
- d An input device that converts sound into electric signals that can be stored digitally on a computer.
- e A device that converts a photograph or document into a computer-readable file.
- f A device used to control the operation of other electronic devices using infrared signals.
- g A direct data entry device that uses radio waves to read and capture information stored on an electronic tag.
- h A device that produces very high-quality hard copy output; uses dry ink cartridges and an electrically charged drum.
- i A device that prints by impacting a print head made up of an array of pins against an inked ribbon.
- j A pointing device that moves around on a surface in an X-Y direction to control a cursor on a computer screen.

- 6 a i Describe how a QR reader works. [4]
ii What are QR codes used for? [4]
- b Give two advantages and two disadvantages of using QR codes. [4]
- c A touch screen can be used as both an input device and an output device. Explain how this is possible. [2]

- 7 Give a use for each of the following input and output devices. [10]
- | | |
|-----------------------------|-----------------------|
| a Keyboard | f Touch screen |
| b Driving wheel or joystick | g 3D printer |
| c QR code reader | h Dot matrix printer |
| d Barcode reader | i RFID |
| e Microphone | j chip and PIN reader |

- 8 A home is fitted with a microprocessor-controlled burglar alarm system. It is not connected to a police station. Tick (✓) **three** sensors which would be used in such a system. [3]

	(✓)
Pressure sensor	
Oxygen level sensor	
Wind speed sensor	
Sound sensor	
Body sensor	
Moisture sensor	
Infra-red sensor	
Touch sensor	

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- 9 A school is holding an athletics competition. The timings of each running event will be measured electronically using sensors at the start and finish. Runners begin a race in starting blocks. When the starting pistol is fired the electronic timing starts. The winner of the race is the first to break the light beam at the end of the race.

- a Complete the table using the most appropriate words from the list below.

Infra-red sensor Light sensor Moisture sensor Motion sensor
pH sensor Pressure sensor Sound sensor Temperature sensor

	Device
Data from the starting pistol is read by this device	
This device detects that the athlete has left the starting block	
When the light beam is broken the data is read by this device	

[3]

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October/November 2017

- b A member of the sports department will use a computer to produce a magazine of the competition. He will include photographs stored in a digital camera as well as printed photographs.

Identify the methods he would use to transfer the photographs to the computer.

[2]

- 10 Tick (✓) whether the following statements are True or False. [2]

	True (✓)	False (✓)
Answers to multiple-choice examination papers can be read using an optical mark reader (OMR)		
The PIN is stored on the magnetic stripe on a credit card		
The chip on a credit card is read by a PIN reader		
An RFID chip can be used to track stock		