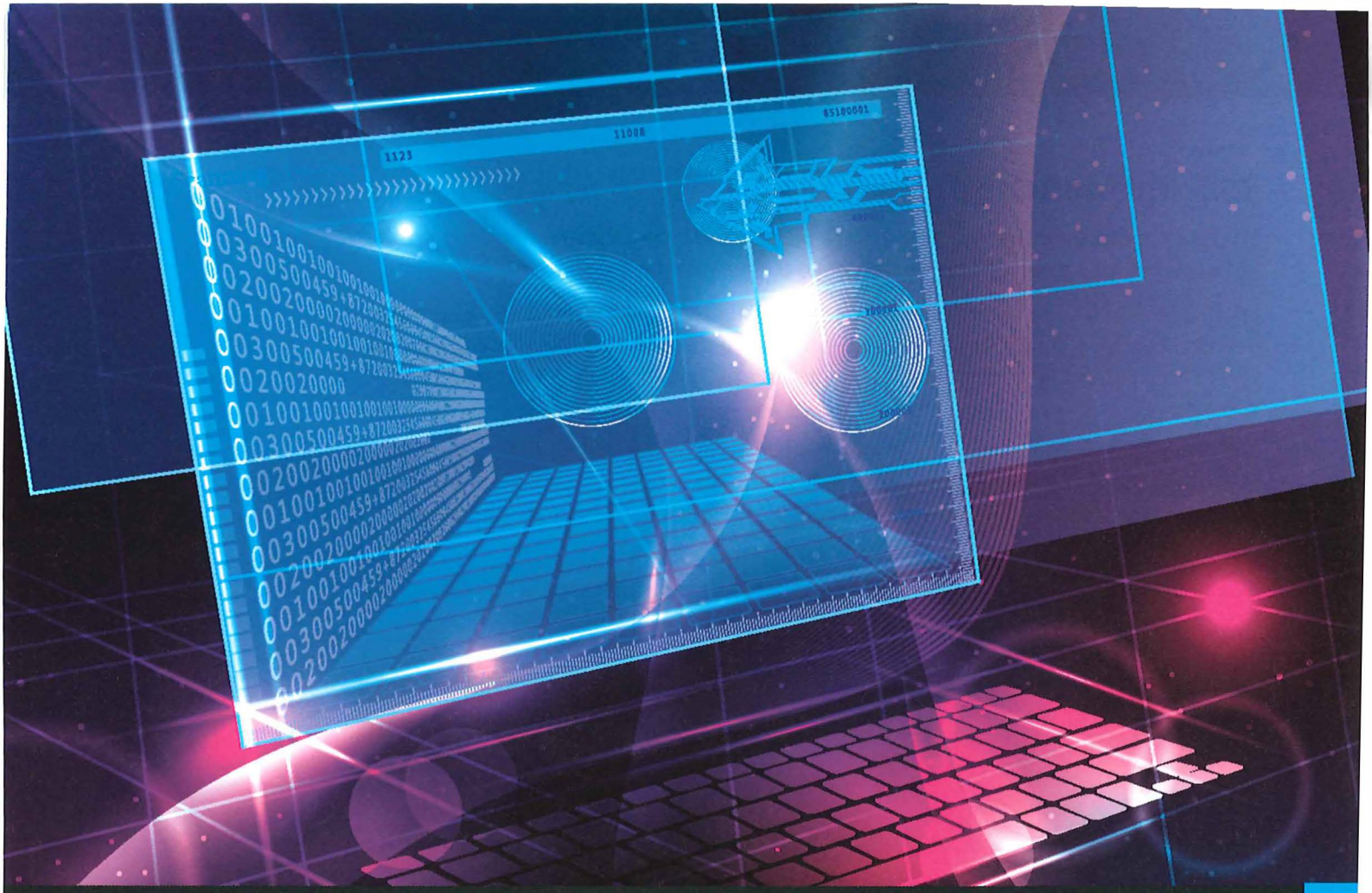

Chapter 7:
Output Devices

Learning objectives

By the end of this chapter you will:

- understand what an output device is and why they are necessary
- understand that different output devices output different forms of information, such as text, images, sound and movement
- understand how flat-panel display screens, liquid crystal display (LCD) and light-emitting diode (LED) screens, touch screens, LCD projectors and Digital light projectors (DLP) operate
- understand what is meant by a printer and a cutter and how different printers and cutters operate
- understand what is meant by speakers and headphones and how they operate
- understand what is meant by an actuator and how they operate.

7.01 Introduction

The function of a computer is to input data, process it and output the resulting information. An output device is a **peripheral** that is used to output information.

Information can be output in many different forms. When designing a computer system we need to know what information it will output, how the output will be presented and the best way to achieve this. Different types of output device exist and they output information in a different way.

The first outputs from computers were cards with holes punched into them. The pattern in which the holes were punched represented the data. Today, the most common forms of output are **soft copies** from displays, **hard copies** from printers and sound from speakers and headphones.

All output devices take up space on a desk, in a cupboard or on the floor. The space taken by a peripheral is called its **footprint**.

KEY TERM

Peripheral – an external device that is connected to a computer.

Soft copy – data and information that is virtual.

Hard copy – data and information that is physical.

Footprint – the space taken up by a peripheral.

TEST YOURSELF

1 How many output devices can you see in your classroom?

2 Do the output devices produce soft copies or hard copies of data?

7.02 Displays

SYLLABUS CHECK

Describe the principles of operation of the following output devices: flat-panel display screens, including Liquid Crystal Display (LCD) and Light-Emitting Diodes (LED); LCD projectors and Digital Light Projectors (DLP).

Describe how these principles are applied to real-life scenarios.

A display is an electronic device that outputs information via a screen or projection. This information can be in the form of text, images or video. As most modern computers, such as laptops, tablets and smartphones, contain a built-in screen, displays are considered to be the most immediate form of output. An external display, for example one used with a desktop PC, is often referred to as a monitor or visual display unit (VDU).

KEY TERM

Pixel – short for picture element; it is an illuminated dot; many pixels together form an image.

Resolution – the number of pixels in a display.

The image on a display is built up of thousands of tiny illuminated dots called **pixels**, short for picture elements. The quality of the image depends on the **resolution** of the display. The resolution of a display is the amount of pixels the display contains. Different screens have different resolutions and larger displays will normally have more pixels. The higher the number of pixels, the higher the resolution of the display, as in Table 7.01.

Table 7.01

Screen type	Resolution (pixels)	Number of pixels
Typical smartphone	800 × 480	84 000
Typical tablet	1280 × 800	1 024 000
Typical 13-inch laptop	1280 × 800	1 024 000
Typical 19-inch desktop PC	1440 × 900	1 296 000
22-inch screen	1920 × 1080	2 073 600
Typical projector	1024 × 768	786 432
Standard-definition TV	1280 × 720	921 600
High-definition TV	1920 × 1080	2 073 600
4k TV	3840 × 2160	8 294 400

A display with a small number of pixels is known as a low-resolution display. A display with a large number of pixels is known as a high-resolution display. Low-resolution displays are suitable when a high level of detail is not necessary, such as displaying text. High-resolution displays provide a clear, detailed image and are required when a high level of detail is essential, such as image editing, video production and graphic design.

Displays produce either monochrome or colour images. Monochrome images have two colours: one foreground colour and one background colour. The two colours are normally black and white. Colour displays produce images by combining the three primary colours: red, green and blue (RGB). Different mixtures and strengths of these primary colours can be combined to create different shades of colour.

Displays have a colour depth. This is the degree to which a particular colour can be represented, for example how bright or pale a colour is. Colour depth is represented as series of bits. The more bits, the greater the colour depth and the closer to a particular shade of colour the display can produce. The higher the number of bits, the greater the number of possible colour shades as in Table 7.02.

Table 7.02

Colour depth	Allows
1-bit monochrome	2 colours – primarily black and white, however, any two colours can be used
8-bit grayscale	256 shades, running from solid white to solid black
8-bit colour	256 colours
16-bit colour (also known as high colour)	65 536 colours
24-bit colour (also known as true colour)	16 777 216 colours
30, 36 or 48-bit colour (also known as deep colour)	Billions of colours

Modern displays commonly offer 24-bit colour, although some smartphones and tablets are restricted to 16-bit colour.

To learn more about pixels and resolution, see Chapter 1.

Displays can be portrait or landscape in orientation:

- Portrait displays are squarer in nature. They have a ratio of width to height of 4:3. Older televisions and monitors normally have a portrait display.
- Landscape displays are rectangular in nature. They have a ratio of width to height of 16:9. Modern televisions and computers, tablets and smartphone displays tend to have landscape screens. Landscape displays are also called widescreen displays.

Some devices, such as tablets and smartphones, have the ability to switch the display between portrait and landscape modes:

- Portrait mode offers more height. It is best suited to viewing documents where the content runs in columns, such as a page of a book or an article.
- Landscape mode offers more width. It is best suited to viewing images and videos.

The size of a display is usually measured from one corner to the diagonally opposite corner, and not its height or width. Therefore, a 22-inch display measures 22 inches from the top left corner to bottom right corner.

Flat-panel displays

For many years the most common form of display was the cathode ray tube (CRT) display. A CRT consists of a sealed glass tube with a fluorescent coating of phosphor dots applied to the inside. Colours are created by mixing various shades of the basic RGB colours. Electrons fired at the tube by three separate electron guns (one each for RGB colour) illuminate the fluorescent coating to create an image. These displays are limited in resolution, bulky in size and use a lot of energy. They also produce flickering images that can strain your eyes.

Today, CRTs have been largely replaced by flat-panel displays. Flat-panel displays are thinner in depth, lighter and use less energy compared with CRTs. They also provide higher resolution, brighter, flicker-free images. Flat-panel displays do have their drawbacks. They are easily damaged if dropped. This means that many people damage the screen on their smartphone or tablet. They can also suffer from 'dead pixels'. This is where a pixel remains constantly illuminated no matter what image is displayed. This degrades the picture. As well as computer monitors, flat-panel displays are ideal for use in devices where size and energy use is important, for example laptops, mobile phones, tablets and digital cameras.

Table 7.03

Advantages of flat-panel displays	Disadvantages of flat-panel displays
They have a high-resolution, bright, flicker-free image. This increases the detail of text, images and video	They can be easily damaged if dropped
They can be made at a size ideal for a portable device	They can suffer from dead pixels that will spoil the display
They have low energy requirements. This is ideal for use with battery-powered devices	

Figure 7.01 Flat-panel displays are thinner, lighter and use less energy than previous types of display

Flat-panel displays come in two main formats: liquid crystal displays (LCD) and light-emitting diode (LED) displays.

Liquid crystal display (LCD)

A liquid crystal display (LCD) is made up of separate red, green and blue coloured pixels arranged together in tiny blocks. Each block is made up of liquid crystals. The crystals can be made to turn solid or transparent by altering the electric current that is supplied to the block. A backlight made up of cold cathode fluorescent lamps (CCFL), similar in nature to fluorescent tubes used in room lighting, shines light behind the pixels. When the crystal is transparent, light is let through and the pixels are illuminated. When the crystal is solid, the pixels remain dark. Colour is created by illuminating sufficient red, green and blue pixels to achieve the desired shade.

LCD displays are thin in size and do not use a lot of energy. This makes them ideal for portable devices such as laptops, tablets, smartphones, PDAs and in-car satellite navigation systems. Additionally, LCDs do not damage our eyes as much because they do not produce glare. However, unless viewed straight on, the image displayed on a LCD can be hard to see.

Light-emitting diode (LED) display

The light-emitting diode (LED) display is a more advanced version of the liquid crystal display. An LED display works the same way as an LCD except that the pixels are backlit with light-emitting diodes. LEDs produce a brighter, more direct light. They are smaller and thinner than the cathode lamps used by LCDs. This means that LED displays can be made thinner and lighter than the equivalent LCDs. The image is also visible over a wider viewing angle.

However, LED screens sometimes suffer from uneven brightness across the display. This happens more with large displays. LED displays can be less energy efficient than LCDs. Although individual LEDs require very little energy, the large numbers required to light a large display can mean more energy is used.

TEST YOURSELF

Another type of LED display is the OLED display. Research OLED technology and find out what advantages OLED offers over LED.

7.03 Digital projectors

A digital projector is a display device connected to a computer that is used to project digital video output onto a flat area such as a wall, projector screen or interactive whiteboard.

To learn more about interactive whiteboards, see Chapter 5.

Projectors are used when an output needs to be shown on a large scale, for example a presentation to a large audience. Due to the nature of light projection, the further away the projector is from the wall or screen, the larger the image. This means that projectors are useful where information needs be presented to large numbers of people, such as in business meetings, classrooms and at conferences. However, the greater the distance, the dimmer the image will be as the projected light is spread.

There are two main types of projector to consider: the liquid crystal display (LCD) projector and the digital light processing (DLP) projector.

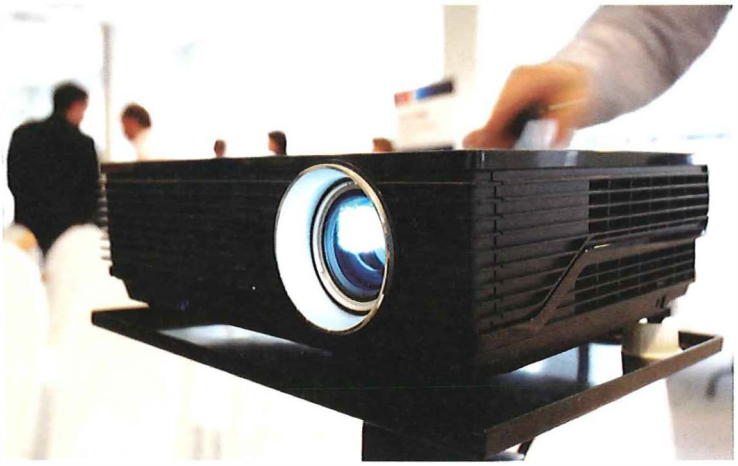

Figure 7.02 Digital projectors can be used to present information to a large number of people

LCD projector

An LCD projector contains three separate LCD glass panels, one for each of the RGB colours in an image. As the light passes through the LCD panels, individual pixels can be opened, to allow light to pass, or closed, to block the light. LCD projectors are useful when contrast and brightness is important.

DLP projector

A DLP projector uses millions of tiny mirrors to reflect light towards the projection lens. This system creates an image with excellent colour reproduction, but one that has less contrast and brightness. As they have fewer internal components, DLP projectors are smaller. This makes them more portable than their LCD equivalents.

7.04 Printers

SYLLABUS CHECK

Describe the principles of operation of the following output devices: inkjet, laser and 3D printers; 2D and 3D cutters; speakers and headphones; actuators.

Describe how these principles are applied to real-life scenarios.

Printers are devices that produce hard copies of information. A hard copy is a physical copy, for example a printout of a typed document or an image. Printouts are made so that users can take a copy of information away to look at, share with others or keep as a permanent record.

Some printers produce monochrome printouts, usually in black and white. Other printers produce colour printouts. However, unlike displays that form all colours from RGB, printers create colours from three base colours: cyan (C), magenta (M) and yellow (Y). To give definition and clarity to the image, black is also used. This is called the key (K). Together these four colours are known as CMYK. Printers create images using ink or toner. CMYK ink or toner colours are mixed together at varying strengths to form different colours. CMY are lighter colours. Mixing them together will produce darker colours. As they are light colours to start with, it takes a lot of ink or toner to achieve much darker colours. The colours RGB are darker colours, a different mixture of them is needed to create colours than is needed for CMYK. This means that colours shown on a printed document will appear different to those presented on a display.

Printers form images by printing tiny dots. Print resolution is measured in **dots per inch (DPI)**. The more dots printed per inch, the higher the resolution. As with displays, printers are available with differing print resolutions. 300 DPI is considered high resolution for a printer. Resolutions of 150 to 200 DPI are suitable for most purposes. Printers can print in many different paper sizes. The footprint of a printer varies according to the size of paper it can print on to.

KEY TERM

Dots-per-inch (DPI) – the resolution of a printed image.

Figure 7.03 Printers use a mixture of cyan, magenta, yellow and key (black) to create different colours

Several types of printer exist and each type produces hard copies in a different way. As a result, some printers are more suitable for certain situations. Printer types include:

- inkjet printer
- laser printer
- three-dimensional (3D) printer.

Inkjet printers

An inkjet printer uses ink to print information. The ink is provided in a cartridge and is sprayed through microscopic nozzles onto paper. Colour inkjet printers often have four cartridges, one for each CMYK colour.

Inkjet technology is relatively cheap, making inkjet printers a popular choice for home use. However, as paper absorbs ink, definition is not always particularly sharp. Ink absorption also prevents printing on both sides of the page, as the image printed on one side may show through to the other. This is known as 'see through'. Definition can be increased if photographic paper is used. This is because ink will not be absorbed in the same way.

Inkjet printers are slow to produce copies. They are usually capable of printing around 5–15 pages per minute. Although inkjet cartridges are cheap, they run out of ink quickly as they need to use a lot of ink. The nozzles can also clog making the cartridge useless. As a result, they are best suited to situations where low levels of printing are required and quality is of less importance. Inkjet printers do produce superior colour to laser printers. This means they are more suitable for printing photographs.

Table 7.04

Advantages of inkjet printers	Disadvantages of inkjet printers
They are cheaper to buy than most other printers	They are expensive to run as they can use a lot of ink, which is expensive to buy
Image quality can be excellent when used with photographic paper	Image quality can be poor when printing on ordinary paper
	It is difficult to print on both sides of paper
	They are slow at printing

Laser printers

A laser printer uses a special powder called toner to print out information. The toner is provided in a cartridge. As with colour inkjet printers, colour laser printers normally have four cartridges, one for each CMYK colour.

Laser printers use a laser to create static electricity on certain areas of the page. These areas correspond to the image or text that is being printed. Toner is then scattered onto the page. The static electricity attracts the toner and causes it to stick to the page. This forms the image or text to be output. Finally, a fusing element makes sure the toner is bonded to the page.

Laser technology is more expensive to buy. This makes laser printers a less popular choice for home use as they are more expensive. Laser printers also tend to have a larger footprint than inkjet printers. However, as toner is not absorbed into paper, the quality of printed text is higher as it is sharper. Laser printers are capable of printing much faster than inkjet printers. They can print up to 60 pages per minute. Although toner cartridges are more expensive than ink cartridges, they last longer and allow many more copies to be printed. Many laser printers

also allow double sided printing (duplex printing), this reduces paper costs. As a result, laser printers are extremely well suited to business use, where cheap, high-speed printing is desirable.

Table 7.05

Advantages of laser printers	Disadvantages of laser printers
They are cheap to run as toner cartridges last much longer	They are expensive to buy as laser technology is expensive
Text printing quality is generally excellent	Image printing quality on photographic paper is not as good as an inkjet printer
They are very quick at printing	They normally have a larger footprint than an equivalent inkjet printer
They are suitable for duplex printing. This reduces paper costs	

TEST YOURSELF

Determine which type of printer would be best suited to these applications and explain why:

- a family wanting to print copies of digital photos
- an accountant wanting to print monthly budget spreadsheets
- a small business wanting to print invoices.

Three-dimensional (3D) printer

3D printing is the process of creating three-dimensional objects. A 3D printer is a device that outputs the 3D objects.

The 3D printing process requires an object to first be drawn up as a 3D model in a digital file. The object can be created using either a **computer-aided design (CAD)** application or by scanning an object with a 3D scanner. The digital object is then split into thousands of extremely thin, horizontal layers. Starting at the bottom, the 3D printer uses a material such as polymers, acrylic or plastic to slowly print each individual layer, one on top of another. 3D printing is also known as additive manufacturing. This is because during the printing process the printed object is added to layer by layer.

KEY TERM

Computer-aided design (CAD) – software that allows a user to design and create an image of an object.

To learn more about 3D scanners, see Chapter 5.

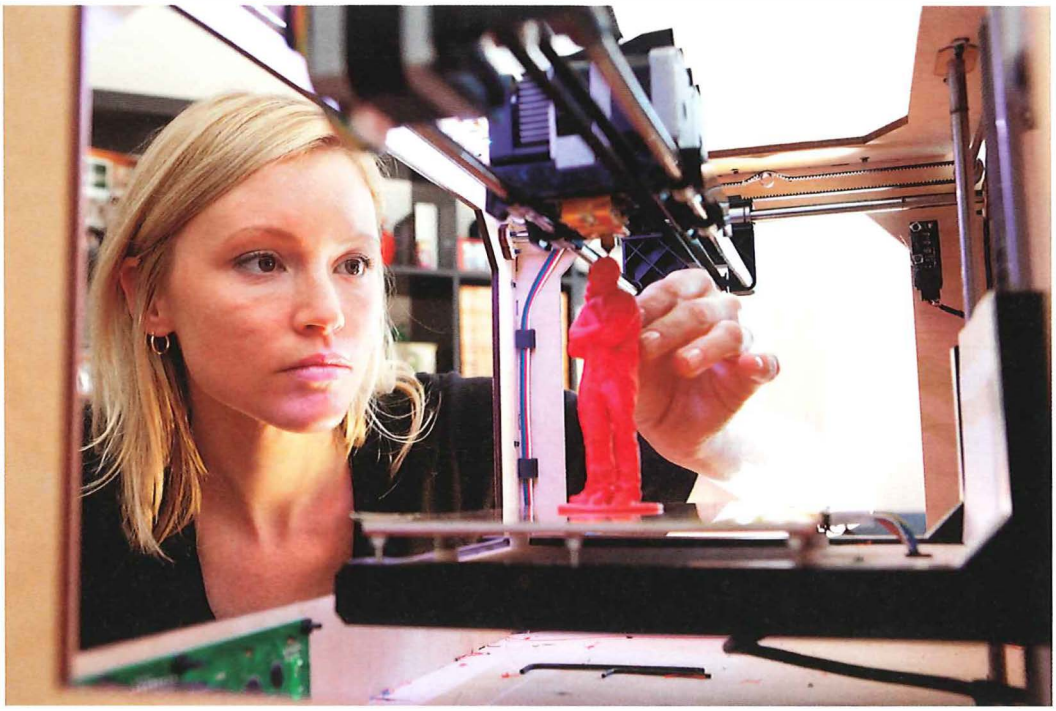

Figure 7.04 3D printers create objects by printing horizontal layers of material, one on top of the other

3D printers are not designed for mass production of objects. They are more suitable for creating individual items. The process allows an engineer to quickly build and test an object design without having to wait for a prototype to be manufactured. They can also be used to produce bespoke items fairly quickly. 3D printing technology is expensive but it has become much more affordable. This has meant some schools, small businesses and homes now have 3D printers.

3D printers can be used in many ways:

- In China, a large-scale 3D printer was used to print a five-storey apartment building.
- Astronauts on the International Space Station have printed tools.
- People who make models can print replacement parts for broken or missing pieces.
- Archaeologists and palaeontologists have printed replicas of ancient objects such as fossils.
- In the United Kingdom, students at Sheffield University used a 3D printer to print bespoke parts to build a telescope that took images using a Raspberry Pi.

3D printing can have issues as well as benefits. The materials used to printed objects may not be as strong or as durable as traditionally manufactured items. 3D printers can also allow the creation of dangerous items such as weapons, making these items accessible to anyone who has access to the design and a 3D printer. Copyright issues could also exist if users replicate and print a copyrighted design.

Table 7.06

Advantages of 3D printers	Disadvantages of 3D printers
Bespoke items or prototypes can be made quickly	3D printing is quite expensive
Just about any shape can be printed	Printed items might not be as durable as a similar manufactured product
Costs to a designer can be reduced as they can easily change a design, re-print it and test it without having to have the object manufactured	Dangerous items may be printed
Designs can easily be shared by sharing the digital file	Copyright issues may exist if a copyrighted design is printed

7.05 Computer-aided manufacturing (CAM)

Computer-aided manufacturing (CAM) is a process where computers and machinery work together to manufacture products. CAM uses computer-aided design (CAD) software to design a product. Additional software then takes the design and controls machine tools to create the product. First, a workflow is determined by the user. This dictates which machine tools are to be used and when. The CAM software then controls and monitors the machine tools to make sure the product is manufactured correctly.

KEY TERM

Computer-aided manufacturing (CAM) – a computer controls machinery to manufacture an object.
Computer-numerical control (CNC) – the method of control used by CAM.

Machine tools involved in CAM include lathes, cutters, drills and conveyors. CAM software works by issuing a series of numbers to the machine tools it controls. The numbers are information the machine needs.

- A cutting machine needs to know what depth the material needs to be cut and at what angle.
- A conveyor needs to know what speed the material needs to be moved along the belt.
- A drill needs to know what depth a hole needs to be drilled and what speed to operate at.

Controlling machines using numbers is known as **computer numerical control (CNC)**. CNC allows precision manufacturing that is more accurate than we can achieve by hand. Once a machine has been programmed and controlled using CNC, many items can be manufactured. High-quality bespoke items and prototypes can also be produced.

CAM requires training. Engineers need to understand how machinery works, how to control the machinery using numbers and how to design a workflow to manufacture the product. CAM is expensive to introduce, but once set up can be cheaper to run than employing a workforce.

Table 7.07

Advantages of CAM	Disadvantages of CAM
Items can be manufactured to a higher precision than by hand	Training is required to use CAM
High production quality can be maintained when making many products	Bespoke items and prototypes may be expensive to produce
It can produce high-quality bespoke items and prototypes	CAM is expensive to introduce because of the hardware and software costs involved

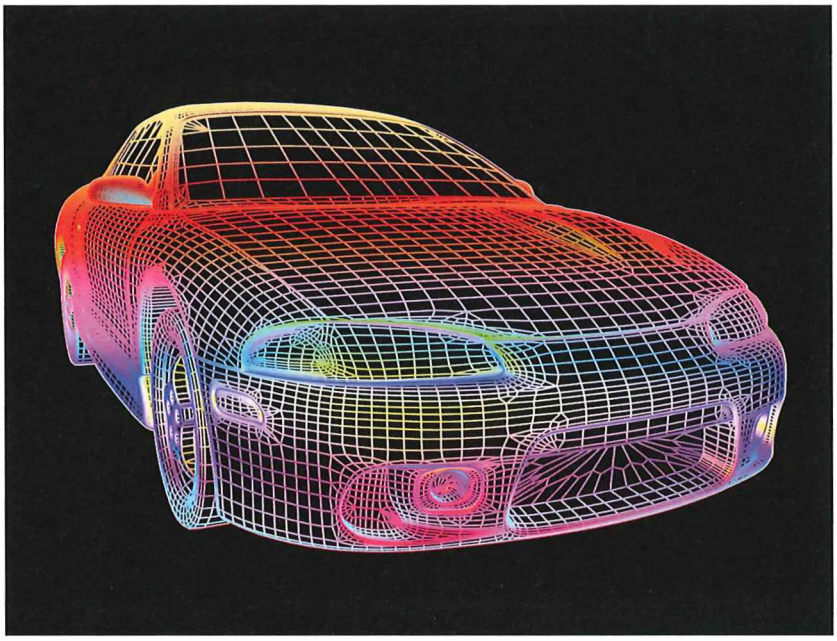

Figure 7.05 CAD software can be used to design many products

Figure 7.06 CAD can be used in CAM to create the product

2-dimensional (2D) CAM machines

2D CAM machines are also known as 'cutters'. They manipulate materials in two dimensions. Various types of cutter exist, for example blade, laser and water jet cutters. Cutters vary in size and the size of the cutter determines the size of the material that can be cut.

- Blade cutters use a blade to cut and trim materials such as paper, card and vinyl. They are often used to create signs and some advertising materials, for example billboards. Blade cutters are cheaper than other types of cutter. They can be noisy.
- Laser cutters use a laser to cut or etch into materials. They are typically used for industrial manufacturing. A high-powered laser enables precise shapes to be cut out of sheets or blocks. The excess material after the shape has been cut is drawn out of the machine by an extractor. 2D laser cutters can cut a variety of materials such as wood, plastic, metal and textiles. Lasers can also allow designs to be etched into materials as well as cutting them. Laser cutters are quick, accurate and quiet.
- Water jet cutters use a pressurised stream of water mixed with an abrasive element. The abrasive element that is used in most water cutters is the gem stone garnet. These types of cutter enable precision cutting of polished and reflective materials, for example a mirror, without spoiling the materials coating or finish.

3-dimensional (3D) cutters

2D CAM machines only allow cutting in two dimensions. 3D machines such as millers or routers have tools that rotate on six axes. This means a shape can be cut in 3 dimensions. 3D cutters are commonly used for cutting wood, MDF, wax, plastics and acrylics. As well as producing bespoke products, they are used to test and modify prototype designs. This helps reduce errors whilst saving time and money.

Although different in nature, 3D cutters and 3D printers produce similar final products.

7.06 Speakers and headphones

Speakers are a device used to output sound. For sound to be output, the digital sound file needs to be converted to an analogue signal via the use of a **digital-to-analogue convertor (DAC).** This is usually in the form of a sound card. The speaker translates this signal into a sound wave by moving a cone to vibrate air.

KEY TERM

Digital-to-analogue convertor (DAC) – a device that converts digital signals to analogue.

To learn more about analogue signals see Chapter 1.

Speakers can be used to output sound for many different purposes, including:

- listening to music for entertainment
- alerting us to a message or reminder
- giving feedback to a user to tell them an action has been carried out
- as an alarm to warn of an intruder
- to aid a disabled person in completing tasks.

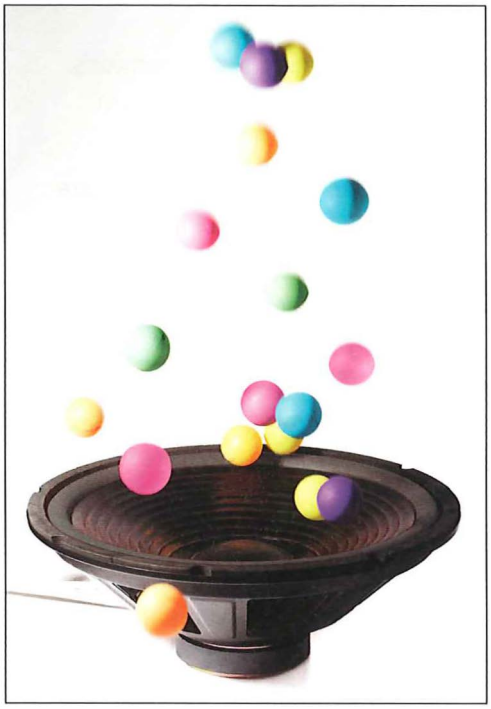

Figure 7.07 A speaker translates an analogue signal into a sound wave by moving a cone to vibrate air

Many devices, such as laptops, tablets, smartphones and televisions have built-in speakers. The quality of these devices is generally fairly low. Higher quality external speakers are available that give a much higher quality sound reproduction. Devices without internal speakers, for example a desktop PC, often have a sound card with a socket to connect speakers.

Speakers are useful but the sound output they produce can disturb other users. Headphones can be used in place of speakers so that only one person can hear the output. Headphones contain a small pair of speakers that cover the ear, sending sound only towards the ear.

Table 7.08

Advantages of speakers	Disadvantages of speakers
They allow a variety of information to be provided to the user	Built-in speakers often give low quality sound reproduction
They can aid a disabled user when operating a device	The sound produced may disturb other users
They are useful to warn a large amount of people at once about an emergency	A sound card with a digital-to-analogue convertor is needed to convert information to a form a speaker can output

7.07 Actuators

Sometimes outputs can be a movement or an action. An actuator is a mechanical output device that produces movement. The moving part of an actuator is usually connected to another device in order to move that device. Actuators can rotate, open, close, push and pull an object. They apply movement through the use of energy and the energy is converted into motion.

Actuators are used for tasks such as:

- controlling a robotic arm
- spinning a fan
- pumping water.

Figure 7.08 Actuators are used to produce the movement of a robot arm

TEST YOURSELF

Think of a device that may use an actuator in your home?

Summary

- Computers need to be able to output information. Information can take the form of text, images, video, sound or action.
- Output devices are peripherals that allow information to be output.
- A display is an electronic device that outputs information via a screen or projection.
- Flat-panel displays are thin in depth and are fairly lightweight. Flat-panel displays are ideal for use in devices where size and energy use are important, such as laptops, mobile phones and digital cameras.
- LCDs consist of separate red, green and blue coloured pixels arranged together in tiny blocks. LCDs are ideal for portable devices such as laptops, tablets, smartphones, PDAs and in-car satellite navigation systems.
- LED displays are a more advanced version of LCDs. They work in the same way except that the pixels are backlit with LEDs, which produce brighter displays.
- A digital projector is a display device connected to a computer that is used to project digital video output onto a flat area such as a wall, projector screen or interactive whiteboard.
- A printer is a device for outputting hard copies of information.
- 3D printers print solid objects. They are not designed for mass production of objects, but more for creating individual items.
- CAM is a process where computers and machinery perform together to manufacture products. CAM utilises 2D and 3D cutters.
- Speakers are a sound outputting device. For sound to be output, the digital sound file needs to be converted to an analogue signal via the use of a DAC.
- An actuator is a mechanical output device that produces movement.

Exam-style questions

1 Explain what is meant by an output device. (2 marks)

2 Explain why LCD screens are more suited to portable devices than CRTs. (2 marks)

3 Explain why printers do not print in RGB. (2 marks)

4 Vikram wants a new printer to take to university. He will be printing mainly essays and reports. State which type of printer would be most suitable and say why. (2 marks)

5 Explain what is meant by the resolution of a display. (3 marks)

6 Discuss how and why 3D printing may become a more common technology in the home. (4 marks)