System components

Input/output devices

What is an input device?

Input devices are **hardware components that allow users to interact** with a computer system

They **enable the user to input data or commands** into the system, which the computer then processes to produce output

Types of input devices

Name of device	Description
Keyboard	The most common input device. It allows users to input text and commands by pressing keys
Mouse	Allows users to navigate the computer screen, click on items, and perform other functions
Touchscreen	Found on smartphones, tablets, and some computers, touchscreens allow users to interact with the device by touching the screen
Microphone	Captures audio input, which can be used for voice commands, recording audio, or video conferencing
Webcam	Captures video input, often used for video conferencing or recording videos
Scanner	Digitizes physical documents or images, converting them into a format that the computer can process
Game Controller	Used primarily for video games, these devices allow users to control game characters and interact with the gaming environment
Graphics Tablet	Allows artists and designers to draw or sketch directly onto a computer. It's particularly useful for graphic design, 3D modelling, and other visual creative tasks
Biometric Devices	These devices, such as fingerprint scanners or facial recognition systems, are used for security purposes to verify a user's identity
Barcode Reader	Scans barcodes, typically used in retail and inventory management
Joystick	Often used for computer games, especially flight simulators. It allows the user to control movement more fluidly than with a keyboard or mouse

What is an output device?

- Output devices are **hardware components that receive information** from a computer system and present it to the user in a comprehensible form
- They enable the computer to **communicate the results of processed data or commands**

Types of output devices

Name of device	Description
Monitor	This is the most common output device. It displays visual output from the computer, including text, images, and videos
Printer	Produces a hard copy of digital documents or images. There are various types of printers, including inkjet, laser, and 3D printers
Speakers	Output audio from the computer, such as music, sound effects, or voice
Headphones	Similar to speakers, headphones output audio directly to the user, providing a more personal and potentially immersive experience
Projector	Projects the computer's display onto a large screen or wall, useful for presentations or movie viewing
Braille Display	This specialised device outputs information in Braille, allowing visually impaired users to read text from the computer
Plotter	Used for printing large, high-quality diagrams and designs, often used in engineering or architecture
Virtual Reality (VR) Headset	Provides an immersive visual and audio output, primarily used for gaming and virtual simulations
Computer- Controlled Machinery	In manufacturing or robotics, computers often output commands directly to machinery to control their operation

Choosing the right device

When recommending a device for a specific situation, consider the following factors:

User Needs

What tasks will the user be performing? A graphic designer might need a graphics tablet, while a data entry clerk might need a keyboard with a number pad

User Skills

Is the user comfortable with the device? A touch screen might be more intuitive for some users, while others might prefer a mouse and keyboard

Environment

Where will the device be used? A wireless mouse might be suitable for a clutter-free office, while a wired mouse might be better for a public computer lab to prevent theft

Cost

Higher-end devices often have more features but are also more expensive. Consider the budget and whether the extra features are worth the cost

Primary memory

What is primary memory?

- Primary memory is **memory directly accessible by the CPU**
- Has **much faster access times** than secondary storage
- This **speeds up operations** like the **Fetch-Execute Cycle**
- Stores **data and instructions** the CPU needs while the computer is **on and running**
- Acts as **short-term, working memory**
- Found in components like:
  - **RAM** (Random Access Memory) – directly connected to the CPU
  - **Cache and Registers** – built **into the CPU** for even faster access
- Because it's fast, it's also **more expensive**, so we use **less of it**
  - Example: RAM = **16–32 GB**
  - Secondary storage (like HDDs) = **1–2 TB or more**

Secondary storage

What is secondary storage?

Secondary storage provides permanent data storage Hardware components that retain digital data within a computer system

- They provide a means of **storing**, **accessing**, and **retrieving** data, which can include software applications, documents, images, videos, and more
- There are 3 types of storage:
  - **Magnetic**
  - **Optical**
  - **Solid state**

Type of storage	Description	Benefits	Drawbacks
Magnetic (e.g., Hard Disk Drives, Magnetic Tape Drives)	Store data by magnetizing particles on a disk or tape	High storage capacity; relatively low cost per gigabyte; suitable for long-term storage and backup	Slower read/write speeds compared to other types; susceptible to physical damage; moving parts can wear out over time
Optical (e.g., CDs, DVDs, Blu-ray Discs)	Store data using a laser to burn pits into the surface of the disc	Durable and relatively immune to environmental conditions; easy to transport; suitable for distributing software, music, or movies	Lower storage capacity compared to other types; slower read/write speeds; can be easily scratched or damaged
Solid state (e.g., Solid- State Drives, USB Flash Drives)	Store data in flash memory cells	Fast read/write speeds; no moving parts, so less likely to fail due to physical shock; silent operation	Higher cost per gigabyte; flash memory cells can wear out after a certain number of write cycles

Here are some of the **devices commonly used** for storage:

Name of device	Type of device	Typical storage capacity	Affordability	Portability	Durability
Hard Disk Drive (HDD)	Magnetic	500GB - 2TB (consumer-grade)	Low cost per GB	Low (especially for internal HDDs)	Moderate (susceptible to damage from shocks or falls due to moving parts)

Solid-State Drive (SSD)	Flash	120GB - 4TB (consumer-grade)	High cost per GB	High (especially for external SSDs)	High (no moving parts, less susceptible to physical shock)
USB Flash Drive	Flash	8GB - 256GB (common sizes)	Moderate cost per GB	Very High (small and lightweight)	Moderate (can withstand casual handling, but can be lost or damaged if not cared for)
CD/DVD/Blu- ray Disc	Optical	CD: 700MB, DVD: 4.7GB - 9GB, Blu-ray: 25GB - 50GB	Low cost per disc	High (thin and lightweight)	Low (can be scratched or damaged easily)

Choosing the right storage device

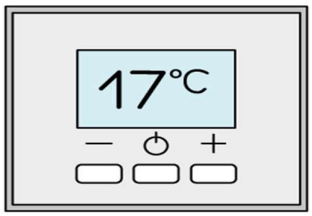
When recommending a storage device for a specific situation, consider the following factors:

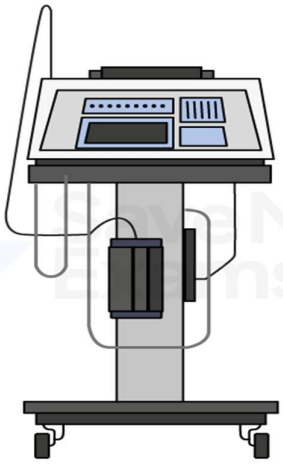
- **Storage needs**
  - How much data does the user need to store? A user with large amounts of data might need a high-capacity HDD, while a user who only needs to store a few documents might be fine with a USB flash drive
- **Performance needs**
  - Does the user need fast access to their data? An SSD might be best for tasks that require high-speed data access, like video editing or gaming
- **Portability**
  - Does the user need to transport the data? USB flash drives and external HDDs or SSDs are portable and can be used to transfer data between different computers
- **Cost**
  - Higher-capacity and faster storage devices are generally more expensive
  - Consider the user's budget and whether their storage and performance needs justify the extra cost

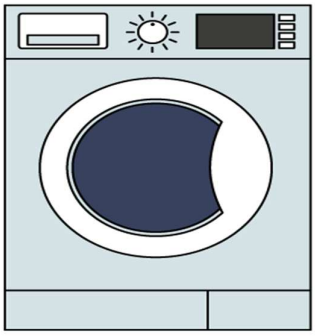
Embedded systems

What is an embedded system?

- An embedded system is a computer system which is used to **perform a dedicated function**, inside a larger mechanical unit
- Examples of embedded systems include
  - **Heating thermostats**
  - **Hospital equipment**
  - **Washing machines**
  - **Dishwashers**
  - **Coffee machines**
  - **Satellite navigation systems**
  - **Factory equipment**
  - **Security systems**
  - **Traffic lights**







Benefits and drawbacks of embedded systems

Benefits	Drawbacks
Small and compact – easy to fit into dedicated devices	**Limited functionality** – only performs specific tasks
Low power consumption – efficient and cost-effective	**Hard to upgrade or repair** – often built into the device
Fast and reliable – designed for quick, repetitive tasks	**Limited memory and processing power**
Cheaper to produce – uses minimal hardware	**Not flexible** – can't easily be reprogrammed for other tasks
Works in real-time – ideal for time- sensitive operations (e.g. alarms)	**May be less secure** – limited protection if connected to other systems

Worked Example

A car has several features. One feature is a lane detection system. This system monitors the lines on either side of the lane. If the car gets too close to one line, the system automatically moves the car away from the line.

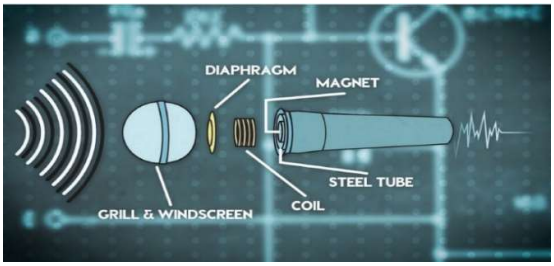
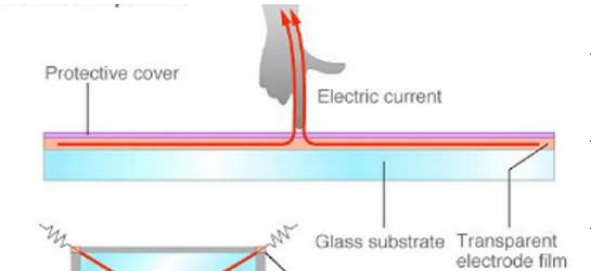
Explain why the lane detection system is an example of an embedded system. **[2]**

Answer

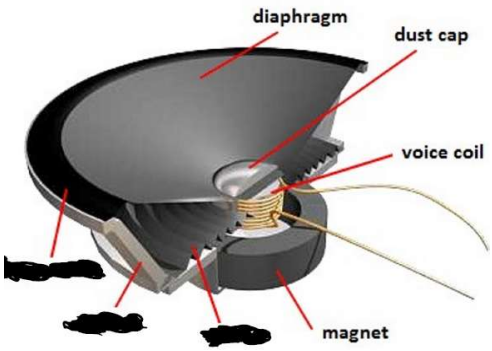
- The lane detection system is built into / integrated into the car [1 mark]
- The lane detection system only performs one task [1 mark]
- The lane detection system is not easily changed/updated by the car owner [1 mark]

Hardware devices

Input devices

Device	Principal operations	Additional information
Microphone	▪ Converts sound waves into electrical signals	▪ Allows users to record voice or send audio into a computer ▪ **Dynamic microphones** – good for loud environments (e.g. concerts) ▪ **Condenser microphones** – more sensitive and accurate, used in studios 
Touchscreen	▪ Detects a user's touch and converts it into an input command	▪ **Capacitive** – responds to electrical charge from your finger (used in smartphones, tablets)  ▪ **Resistive** – responds to pressure (used in ATMs, tills) ▪ First used in ATMs and information kiosks, now used in smartphones, tablets, laptops, smart displays ▪ Popular for direct, easy interaction and improved accessibility 

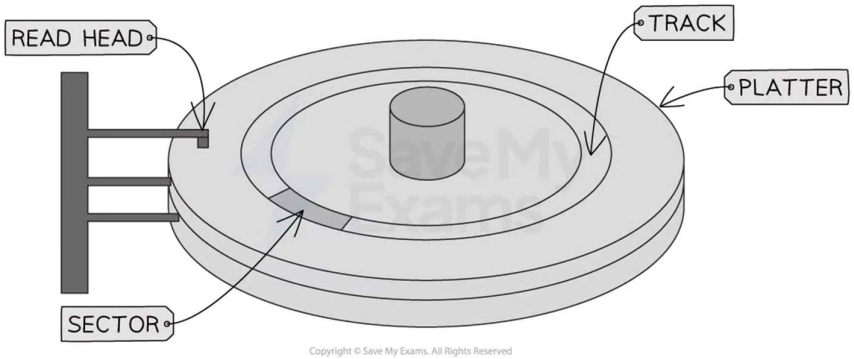
Output devices

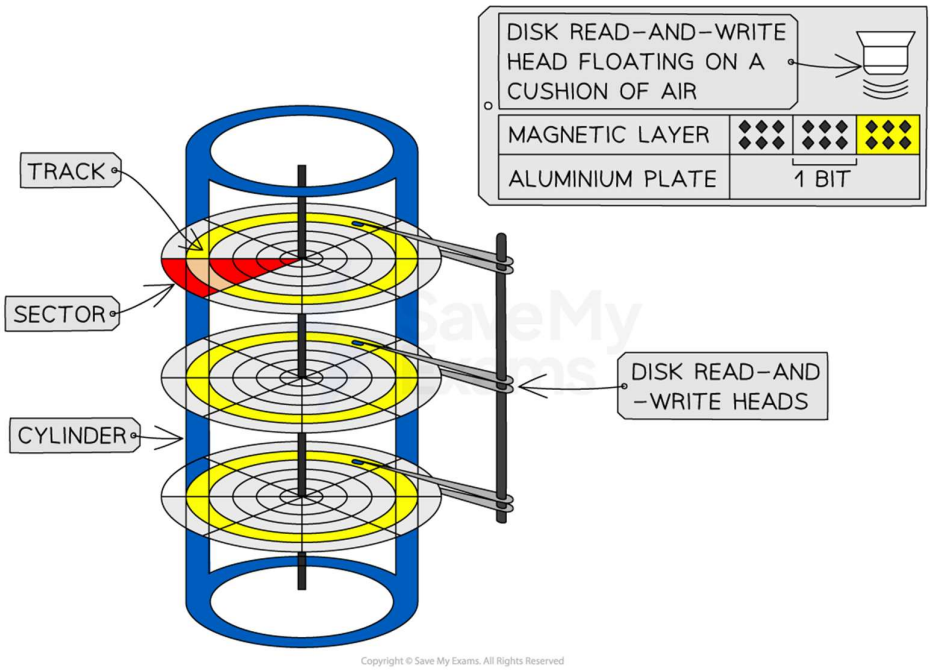
Device	Principal operations	Additional information
Laser printer	Laser beam draws the image of the page onto a photosensitive drum, changing its electric charge Toner is transferred from drum to paper	**Toner sticks to the drum** – toner powder is attracted to charged areas matching text/image shape **Fusing** – paper passes through hot rollers, melting toner onto paper so it doesn't smudge
3D printer	Builds objects layer by layer from the bottom up Uses various materials such as thermoplastics, resins, and metals Allows high customization and rapid prototyping	Handles complex shapes traditional methods can't make easily **FDM** – melts plastic and builds in layers, **SLA** – uses light to harden liquid resin Used in healthcare (prosthetics), automotive/aerospace (custom parts) Can be slow for large/detailed objects, some methods need costly specialist materials
Speakers	Convert electrical signals into sound waves 	Range from basic laptop speakers to high-end multi-driver home theatre systems Found in phones, laptops, studios, smart devices, home theatres Improved with digital sound processing and miniaturized components Support voice commands, calls, and multimedia playback
Virtual reality headset	Creates a fully immersive 360° digital environment Lets users look around and interact with the virtual world 	Uses head tracking, motion sensors, and stereoscopic displays for 3D vision **Uses** – gaming, education/training, architecture/design, medical/therapy **Challenges** – expensive hardware, possible eye strain or motion sickness, time-intensive content creation

Fused Deposition Modeling (FDM) and Stereolithography (SLA).

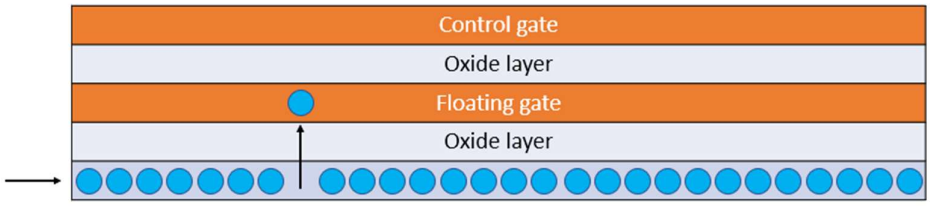
Storage devices

Device	Principal operations	Additional information
Magnetic hard disk	Multiple metal platters coated with magnetic material store data as magnetized iron particles (0s and 1s) Platters spin at high speed (typically 5400–7200 RPM) Data read/written using electromagnet	**Platters** divided into concentric tracks and wedge-shaped sectors, forming track sectors **Read/write arm**, controlled by an actuator, positions the head over the correct track sector Reliable but mechanical – can be slower and more prone to damage than SSDs

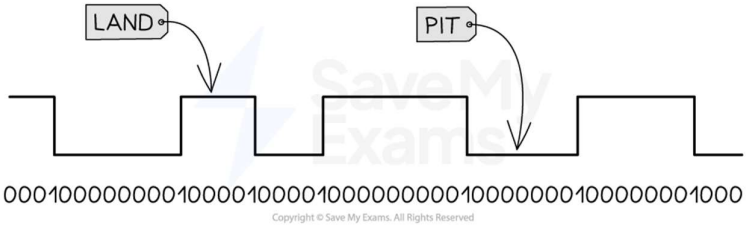




Solid state (flash) memory	Stores data in **cells** using transistors that act as switches Uses **NAND** or **NOR** gates to control flow of electrons Writing: high voltage **pushes electrons** onto floating gate Faster and more durable than magnetic drives	Common examples: SSDs, USB flash drives Each cell contains a **control gate** (controls current) and a **floating gate** (stores charge) Erasing: reverse high voltage pulls electrons off floating gate No moving parts – better shock resistance



Optical disc reader/writer	Uses a **laser** to read and/or write data on optical discs Writing: **laser burns pits and lands** onto the disc surface **Arm** moves the laser across the disc Blu-rays store the most, CDs the least	Examples: CD, DVD, Blu-ray Reading: laser scans surface; changes in reflection indicate 0s and 1s CD-R = write once, CD- RW/DVD-RW = rewriteable Slower than magnetic/solid- state storage but good for archival



Worked Example

Magnetic hard disk is used to store data on the computer. Describe the principal operations of a magnetic hard disk **[5]**

Answer

- The hard disk has (one or more) platter/plate/disk [1 mark]
- Each surface of the platter/disk is capable of being magnetized [1 mark]
- The surface of the platter/disk is divided into concentric tracks / circles [1 mark]
- The disks are rotated (at high-speed) [1 mark]
- (Each surface of the disk) has a read/write head mounted on an arm (positioned just above the surface) [1 mark]

Memory types

RAM vs ROM

What is RAM?

- RAM (Random Access Memory) is **primary storage** that is directly connected to the CPU and holds the **data** and **instructions** that are **currently in use**
- RAM is **volatile** which means the contents of RAM are lost when the power is turned off
- For the CPU to access the data and instructions they must be **copied from secondary storage**
- RAM is **very fast** working memory, much faster than secondary storage
- RAM is **read/write** which means data can be read from and written to
- In comparison to ROM, it has a much **larger capacity**

What is ROM?

- ROM (Read Only Memory) is **primary storage** that holds the **first instructions** a computer needs to **start up** (Bootstrap)
- ROM contains the **BIOS** (Basic Input Output System)
- ROM is a small **memory chip** located on the computers **motherboard**
- ROM is **fast** memory, much faster than secondary storage but **slower than RAM**
- ROM is **non-volatile** which means the contents of ROM are not lost when the power is turned off
- ROM is **read only** which means data can only be read from
- In comparison to RAM, it has a much **smaller capacity**

Differences between RAM & ROM

Feature	RAM	ROM
Speed	Very fast	Fast (slower than RAM)
Capacity	Gigabytes (GB)	Megabytes (MB)
Stores	Programs and data in use	Bootstrap (start-up instructions)
Read/Write	Read & write	Read only
Volatile/Non-volatile	Volatile	Non-volatile

SRAM vs DRAM

What is SRAM?

- SRAM (Static RAM) is a form of RAM that **keeps data** as long as power is on
- SRAM is made from **flip-flops** so there is no need for constant refreshing
- SRAM is used in places where **speed** is more important than storage size
- An example of where SRAM is used is:
  - **Cache memory**, where quick access to data is most important
- **Very fast** – faster than DRAM
- **Uses less power**, good for **low-power devices**
- **Expensive** to make
- **Takes up more space** – lower storage capacity compared to DRAM

What is DRAM?

- DRAM (Dynamic RAM) is a form of RAM that stores each bit in a **tiny capacitor**
- DRAM needs **constant refreshing** to keep the data
- DRAM is commonly used as:
  - **Main memory (RAM)**, where larger amounts of cheaper storage is required
- **Cheaper** to produce than SRAM
- **Higher capacity** – can fit **more memory in less space**
- **Slower** than SRAM, needs time to refresh data
- **Uses more power**, especially during refreshing cycles

PROM vs EPROM vs EEPROM

What is PROM, EPROM & EEPROM?

- PROM, EPROM and EEPROM are all **types of ROM** that are **programmed and reprogrammed in different ways**
- Each type has a **specific application** in difference devices

Feature	PROM	EPROM	EEPROM
Can be reprogrammed?	No – programmed once only	Yes – can be erased and rewritten	Yes – can be erased and rewritten
Erased using	Cannot be erased	UV light	Electric voltage
Must be removed from device?	No	Yes – must be removed from the device	No – can be erased in place
Erased all at once?	Not applicable	Yes – entire chip is erased	No – specific parts can be erased
Common use	Permanent firmware	Reprogrammable chip development	Flash memory, BIOS chips
Examples	Remote controls, basic calculators, early model washing machines	Arcade machines (older models) Early games consoles	BIOS chips in computers, Smart cards, remote key fobs, flash memory like USB sticks and SSDs

Worked Example

A computer has hardware and software.

The hardware includes different types of memory.

Complete the description of computer memory. **[5]**

Random Access Memory (RAM) and Read Only Memory (ROM) are both examples of .....memory.

One item that is stored in RAM is.....One item that is stored in ROM is .....RAM can be either Static RAM (SRAM) or Dynamic RAM (DRAM).

SRAM uses transistors arranged as ..... .
DRAM uses transistors and .....

Answer

Random Access Memory (RAM) and Read Only Memory (ROM) are both examples of primary memory.

One item that is stored in RAM is currently running software/data/part of the OS.
One item that is stored in ROM is the start-up/boot-up instructions/BIOS.
RAM can be either Static RAM (SRAM) or Dynamic RAM (DRAM). SRAM uses transistors arranged as flip-flops. DRAM uses transistors and capacitors.

Monitoring vs control

Monitoring systems

- A monitoring system is used to **collect data continuously** through observation
- It works by **passively gathering data**
- It **does not interact with or change** the environment
- The system **does not take action** based on the data collected
- Designed for **high accuracy** using **precise sensors and measurements**
- Examples of monitoring systems include:
  - **Weather stations**
  - **Patient monitoring in hospitals**

Weather stations

- Collect data like **temperature, wind speed, humidity, and rainfall**
- Used by **meteorologists** to observe and predict weather patterns
- Data is collected **24/7** but the system does **not react or change anything**

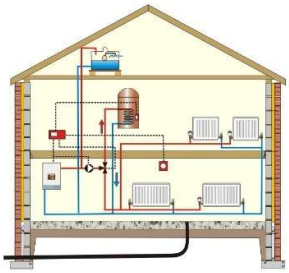
Patient monitoring

- Tracks **heart rate, oxygen levels, and blood pressure** in real-time
- Alerts medical staff if readings go outside safe ranges
- The system itself just **records and displays data**, it doesn't directly treat the patient

Control systems

- A control system is used to **automatically manage or adjust** a process based on data collected from sensors
- It works by **monitoring input**, then **taking action** if certain conditions are met
- Unlike monitoring systems, control systems **do interact with the environment**
- They are designed to keep systems **stable, safe, or working efficiently** without human input
- Examples of control systems include:
  - **Central heating system**
  - **Automatic irrigation system**

Central heating system



- **Monitors room temperature** using a thermostat
- If the temperature drops below the set level, the **boiler is switched on**
- Once the target temperature is reached, the system **turns the heating off** automatically
- The system constantly checks and **adjusts** to maintain the desired temperature

Automatic irrigation system

- **Monitors soil moisture levels** in farmland or gardens
- If moisture drops too low, it **activates sprinklers** to water the plants
- Once the soil reaches the correct level, the system **turns off the water supply**
- Ensures plants are **watered efficiently** without wasting resources

Use of sensors

What are sensors?

- Sensors are **input devices**
- They **measure a physical property of their environment** such as light levels, temperature or movement
- Sensors can be used for both **monitoring and control systems**
- A process where **outputs are recycled and used as inputs**, creating a continuous cycle is called a **feedback loop**

Sensor type	What it measures	Typical use
Acoustic	Sound levels	To detect changes in sound levels of industrial machinery To monitor noise pollution In security system to detect suspicious sounds
Accelerometer	Acceleration rate, tilt, vibration	Detecting sudden changes in vehicle movement and deploy safety features if needed In mobile phones to detect orientation of the device
Flow	Rate of gas, liquid or powder flow	Detect changes in the flow through pipes in water system

Gas	Presence of a gas e.g. carbon monoxide	Detect levels of gas in confined spaces Detect gas levels when fixing gas leaks
Humidity	Levels of water vapour	Monitor humidity in greenhouses
Infra-red	Detecting motion or a heat source	Security systems detecting intruders who break the beam Measures heat radiation of objects - used by emergency services to detect people
Level	Liquid levels	Detects levels of petrol in a car tank Detect levels of water in a water tank Detect a drop in water levels due to a leak
Light	Light levels	Automatically switching on lights when it gets dark (street lights, headlights)
Magnetic field	Presence and strength	Anti-lock braking system Monitoring rotating machinery such as turbines
Moisture	Presence and levels of moisture	Monitoring moisture in the soil Monitoring dampness in buildings
pH	Acidity or alkaline	Monitoring soil to ensure optimum growing conditions Monitor pH levels in chemical processes
Pressure	Gas, liquid or physical pressure	Monitoring tyre pressure Monitoring pressure in pipes during the manufacturing process
Proximity	Distance	Monitoring the position of objects in robotics Used in safety systems to prevent objects from colliding
Temperature	Temperature in Celsius, Fahrenheit or Kelvin	Used to maintain temperature in swimming pools Used to control temperature in chemical processes

Feedback loops

What is a feedback loop?

- A feedback loop is when a control system uses its **output to influence its next input**
- Allows the system to **automatically adjust** and stay within set conditions
- Feedback allows the system to **check if it's working as expected**
- The **output affects the next input**, helping the system make adjustments
- This means the system can **automatically respond to changes** in its environment
- Helps the system **stay within set limits or target values** (e.g. temperature, moisture)
- Makes the system **more accurate and efficient** without needing human control

Example: Central heating system

- The system uses a **thermostat** to monitor the **room temperature**
- If the room gets **too cold**, the system **turns the heating on**
- Once the room reaches the **set temperature**, the system **turns the heating off**
- This process uses **feedback**:
  - The **output** (room temperature) affects the **input** (whether heating is needed)
- Feedback ensures the system **automatically adjusts** to keep the room at the right temperature
- No need for manual control as the system **self-corrects** using feedback

How 3D PRINTER works?

- The object is designed using computer aided design software
- The software splits the object into slices
- The data about the slices is sent to printer
- The solid plastic is melted and transferred to the nozzle.
- A stepper motor moves the nozzle into position.
- The nozzle extrudes the molten plastic
- The previous steps are repeated until the layer is complete.
- A fan cools the layers
- Each layer is printed by following the same steps.

VIRTUAL REALITY HEADSET

- Video is sent from computer to the headset using a cable
- Two feeds are sent to LCD
- Sometimes two screens are used
- Lenses are used for focusing and reshaping the image.
- Most headset use 60 to 120 frame rate and 1100 field of view to make it realistic.
- Gyroscopic or accelerometer are used to detect the head movement
- Headset uses binaural sounds.