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Cambridge IGCSE

Computer Science

Paper 1

- 3

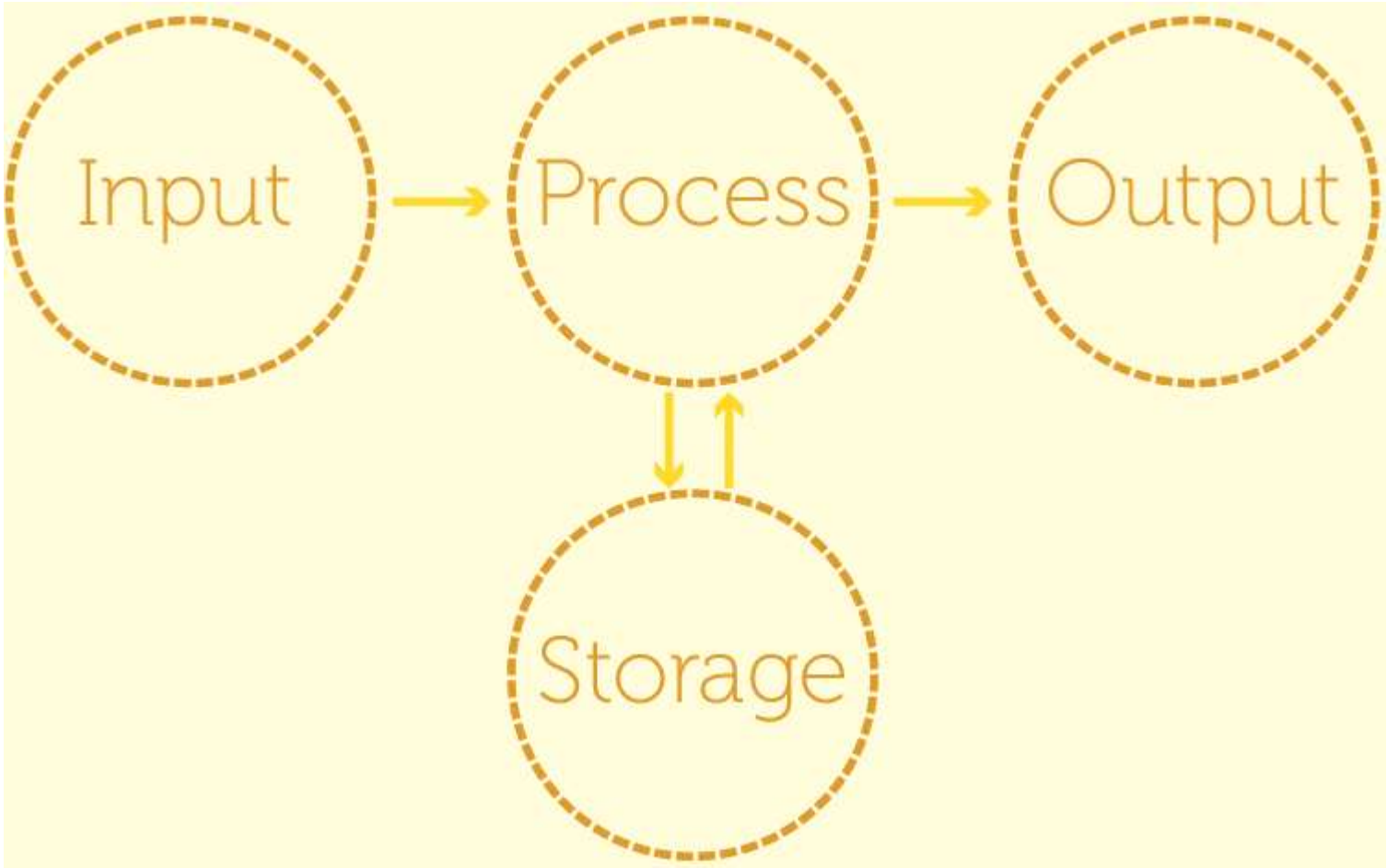
Sensors

Unit 3: Input and output devices

Objectives:

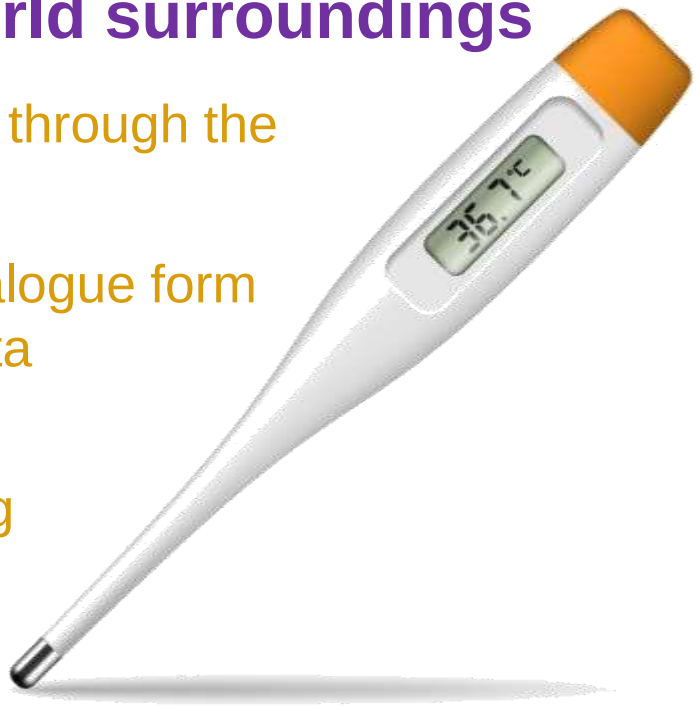
- Describe how a range of sensors can be used to input data into a computer system
- Describe how these sensors are applied to real-life scenarios
- Describe the principles of operation of an actuator

Where are sensors in the model?



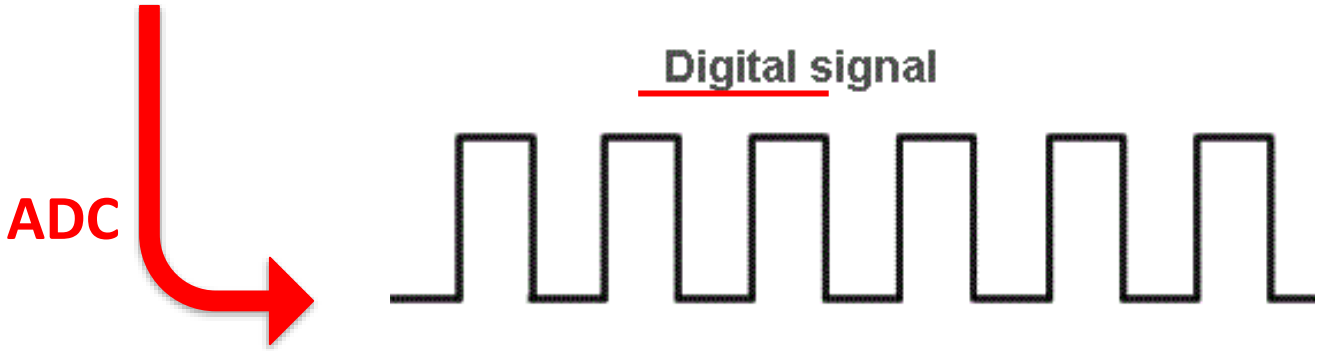
Sensors

- Input devices transfer data from the source in the outside world to the computer.
  Sensors are input devices that read or measure physical properties such as temperature, pressure, pH etc from real world surroundings
  - Some data can be obtained directly through the use of sensors
  - Sensors often collect data in an analogue form and require conversion to digital data to be processed
  - Sensors are used in both monitoring and control applications

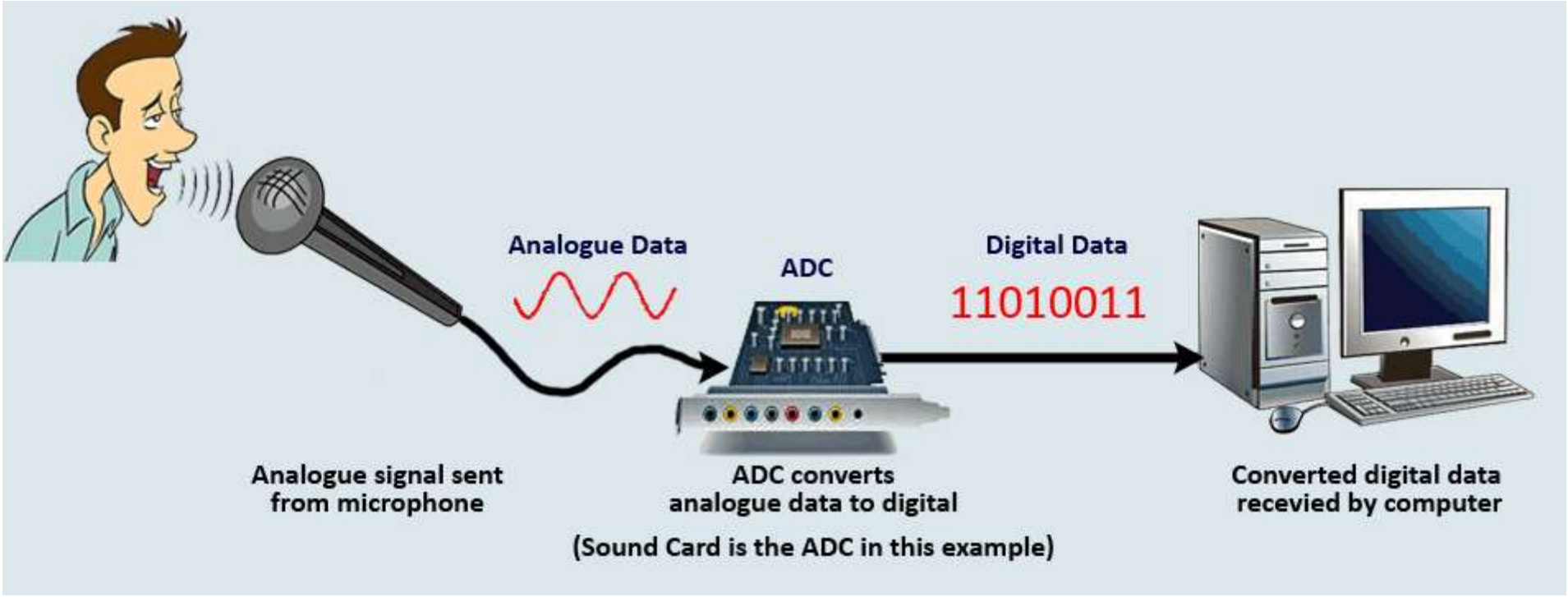


Sensors

- Data taken by sensors is usually in **analogue** form
- This will need to converted into **digital** by an **analogue to digital converter** - **ADC**



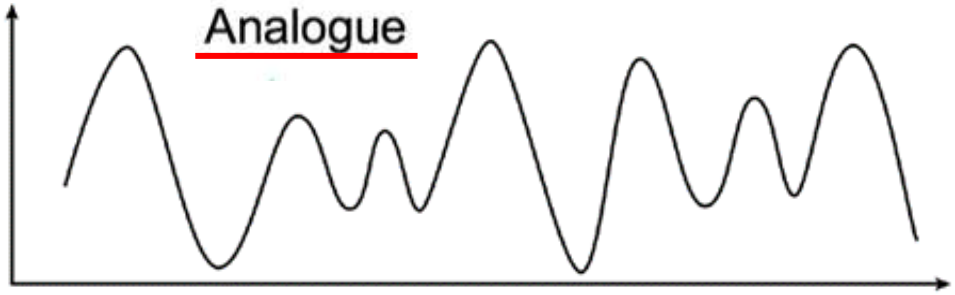
Analogue to Digital example

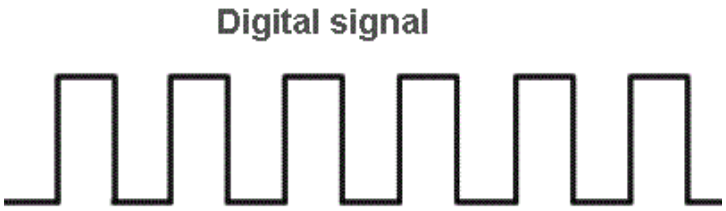


Analogue and digital

Analogue means that data has no discrete value. It can be any value (for example between 1 and 0) and changes smoothly (continuous wave) rather than in exact jumps

Digital data is discrete 离散数据, it can only be a 1 or 0.





Analogue measurements

Analogue means that data has no discrete value and the data changes smoothly rather than in exact jumps

- Examples include:
  - A thermometer where temperature is represented by the height of the mercury
  - A speedometer showing speed represented by a needle on a gauge
  - A seismometer recording the force and duration of ground movement by visualising the motion of a weight on a string using a pen

Types of sensor

There are many types of sensor designed to carry out specific tasks. These include:

- **Gas (e.g. oxygen, carbon dioxide)**
- **Infra-red (e.g. motion or heat source)**
- **pH (i.e. acid or alkalinity)**
- **Light**
- **Temperature**
- **Magnetic field**
- **Pressure**
- **Moisture/humidity**
- **Acoustic (i.e. sound)**

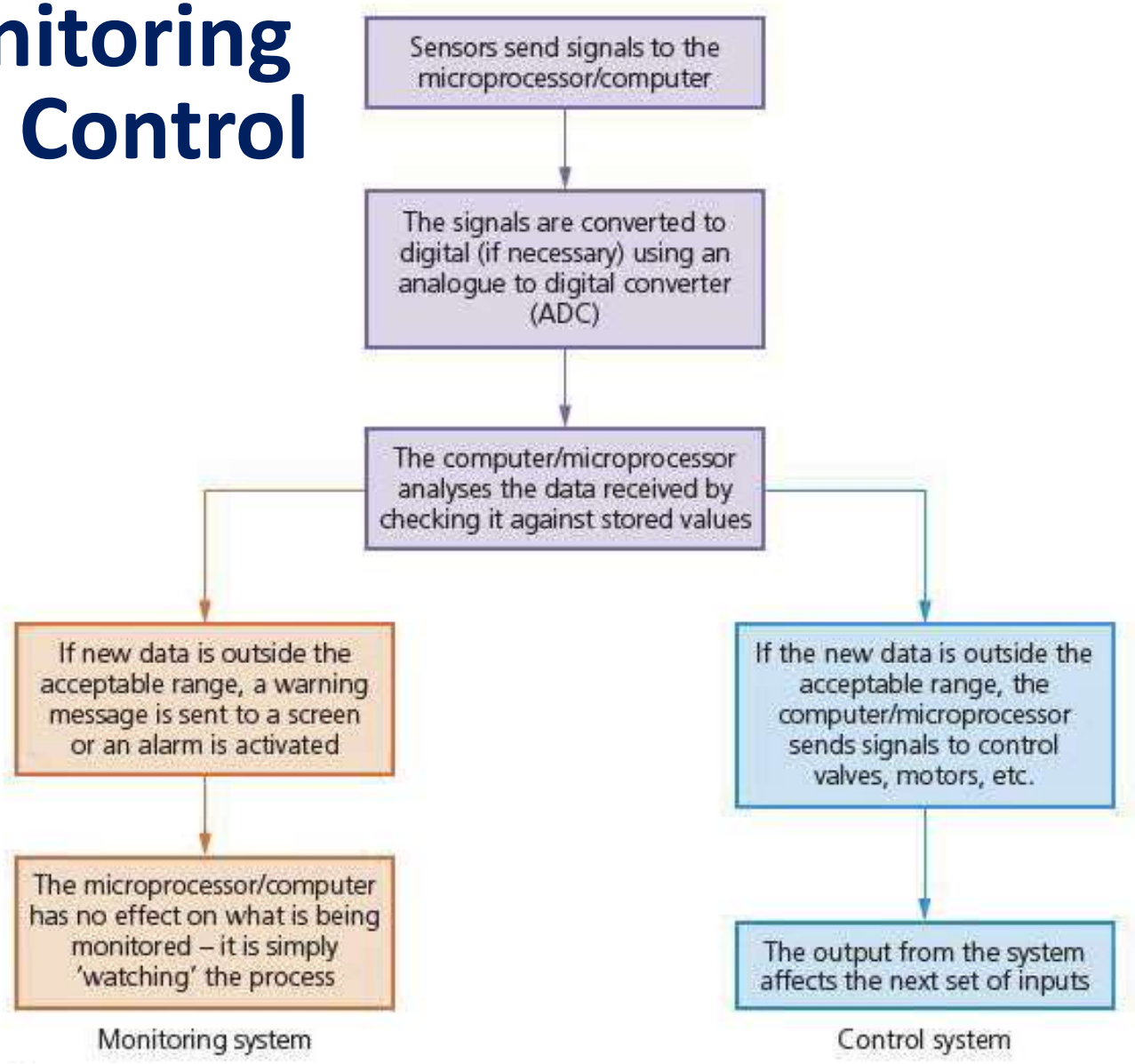
Activity

- Now complete **Sensors Worksheet**

Types of sensor

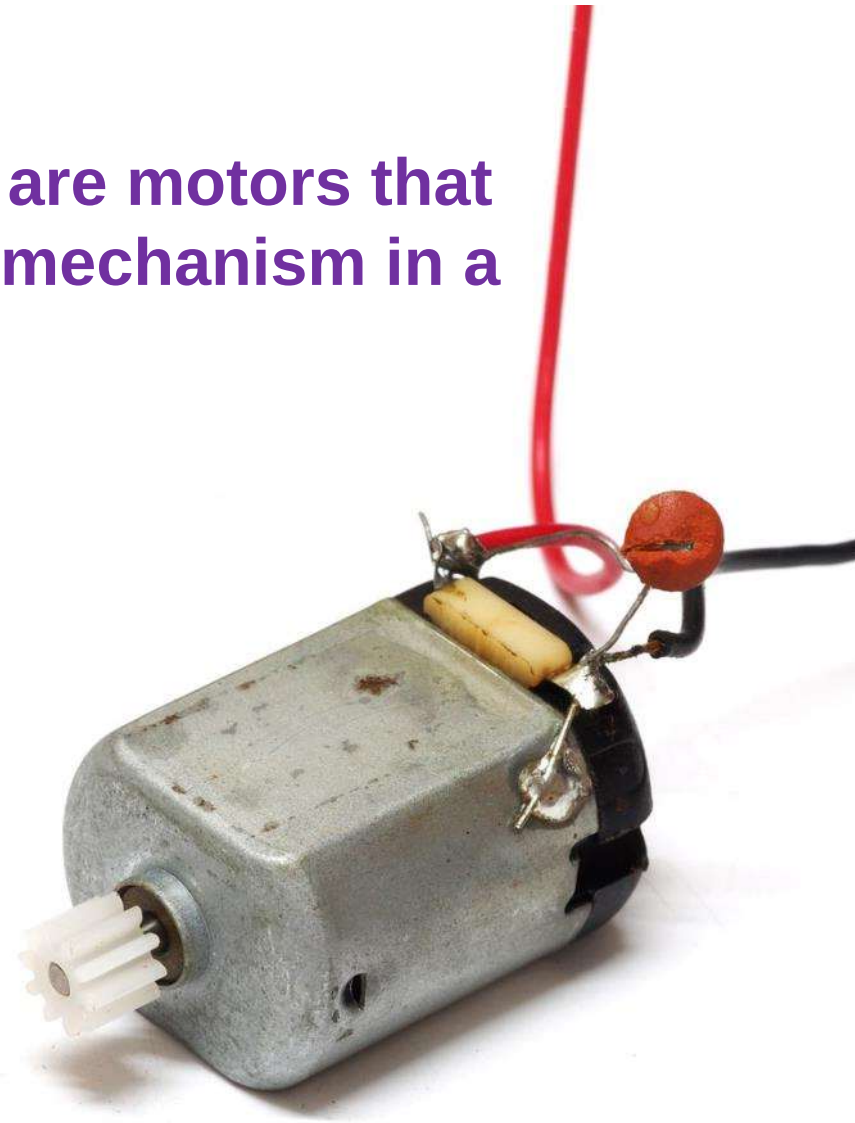
Type of sensor	Applications
Temperature	• control the central heating system in a house • control or monitor the heat output in a chemical process • control or monitor the environmental temperature in a greenhouse
Moisture/humidity	• control or monitor the dampness of soil in a greenhouse • control or monitor the dampness of the air in a greenhouse • monitor the dampness levels in a factory making microchips
Light	• switch street lighting on at dusk and switch street lighting off at dawn • automatically switch a car's headlights on when it gets dark • to close or open the window blinds in a greenhouse to maintain light levels
Infra-red	• turn on a car's windscreen wipers automatically when it starts to rain • detection of intruders in a burglar alarm system • count the number of people entering or leaving a supermarket
Pressure	• detection of intruders in a burglar alarm system • checking the weight of a vehicle on a weigh bridge • measurement of air pressure to forecast weather
Acoustic	• pick up noise levels (e.g. footsteps) in a burglar alarm system • detect the noise of liquids dripping from a pipe in an oil refinery • monitor the sound levels in a car factory
Gas	• monitor CO_2/O_2 levels in a river • monitor CO_2/O_2 levels in the air in a greenhouse • check for the carbon monoxide levels in a car exhaust system
pH	• monitor or control the acidity levels in a chemical process • measurement of pollution levels in a river • check acidity levels in the soil in a greenhouse
Magnetic field	• used in smart phones so they know which direction it is pointing • used in the motors of CD players • used in vehicle anti-lock braking systems

Monitoring and Control



Actuators

- **Actuators (output devices) are motors that are often used to control a mechanism in a computer control system**
- Examples include:
  - Opening a valve or door
  - Starting a pump
  - Turning a wheel or fan
  - Moving an aircraft aileron



Monitoring and control systems

- Monitoring: ⇨ **Watching**
  - With these applications, the computer or microprocessor will make no changes to the actual process; it will simply report the values and inform users of the status of the process being monitored
- Control ⇨ **Changing**
  - The output from the computer or microprocessor can alter how the process is operating; in other words, it can change the value of the next input received by, for example, opening a valve, switching off a heater or changing the speed of a pump (essentially the output from the computer or micro processor can affect the next input it receives)

Examples of monitoring and control

Application	Monitoring	Control
Automatically turning street lights on at night and off during the day		
Changing the traffic lights at a junction to control the traffic flow		
Keeping track of a patient's vital signs (e.g. heart rate, temperature) in a hospital		
Regulating the temperature in an air conditioning system		
Checking for intruders in a burglar alarm system		
Keeping track of the pollution levels in a river		
Ensuring that the anti-lock braking system in a car works effectively		

Monitoring and Control

1 Sensor is continuously sending data to the microprocessor / computer.

2 An Analogue to Digital Convertor (ADC) is used to change any analogue signals to digital.

3 The microprocessor / computer checks the data against stored / pre-set values.

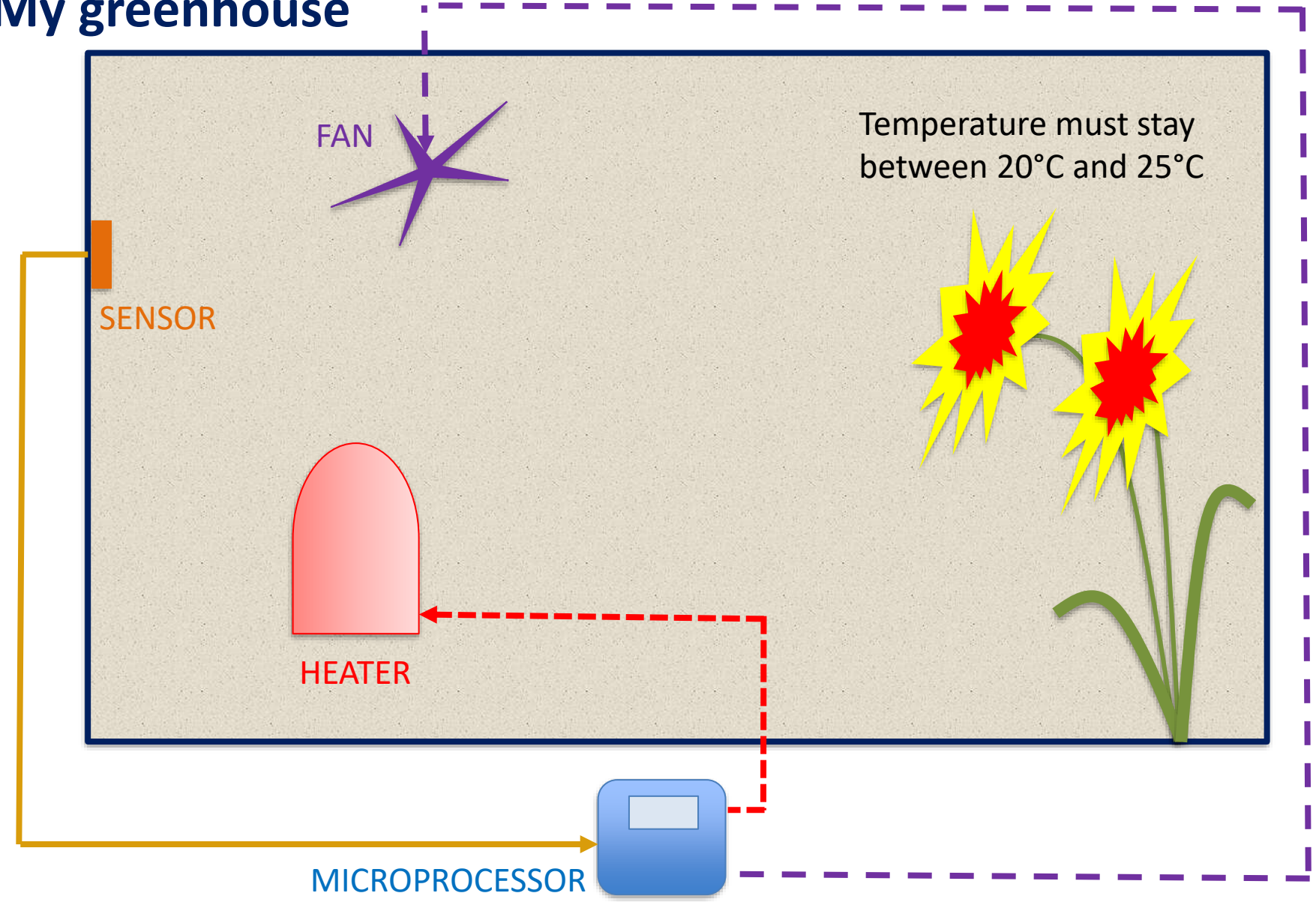
4 If new data is within acceptable range, nothing happens, data is stored.

5 If new data is outside acceptable range, a warning message is sent / alarm is started / output devices are used ...

6 System continues monitoring / controlling until it is switched off.

7 In a Monitoring System nothing changes.
In a Control System the output has an effect on the inputs into the system.

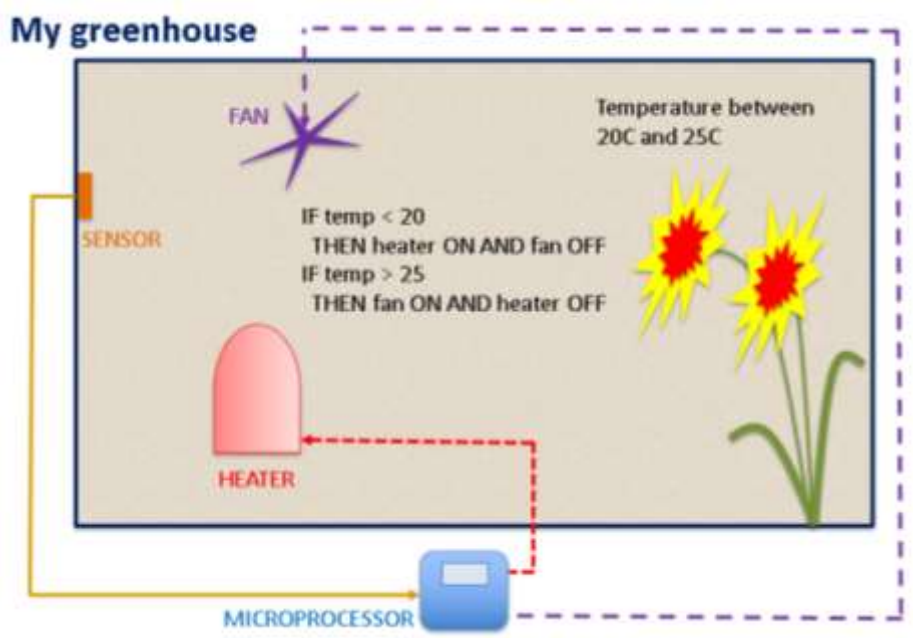
My greenhouse



Example of Computer Control

1. Temperature Sensor continuously sends data to the microprocessor.
2. Data is converted into digital by an ADC, before being analysed by the computer.
3. Computer checks data against pre-set levels.
4. If TEMP < 20 the microprocessor turns on the Heater and Fan off

   If TEMP > 25 the microprocessor turns on the Fan and Heater off
5. System continues until it is switched off.

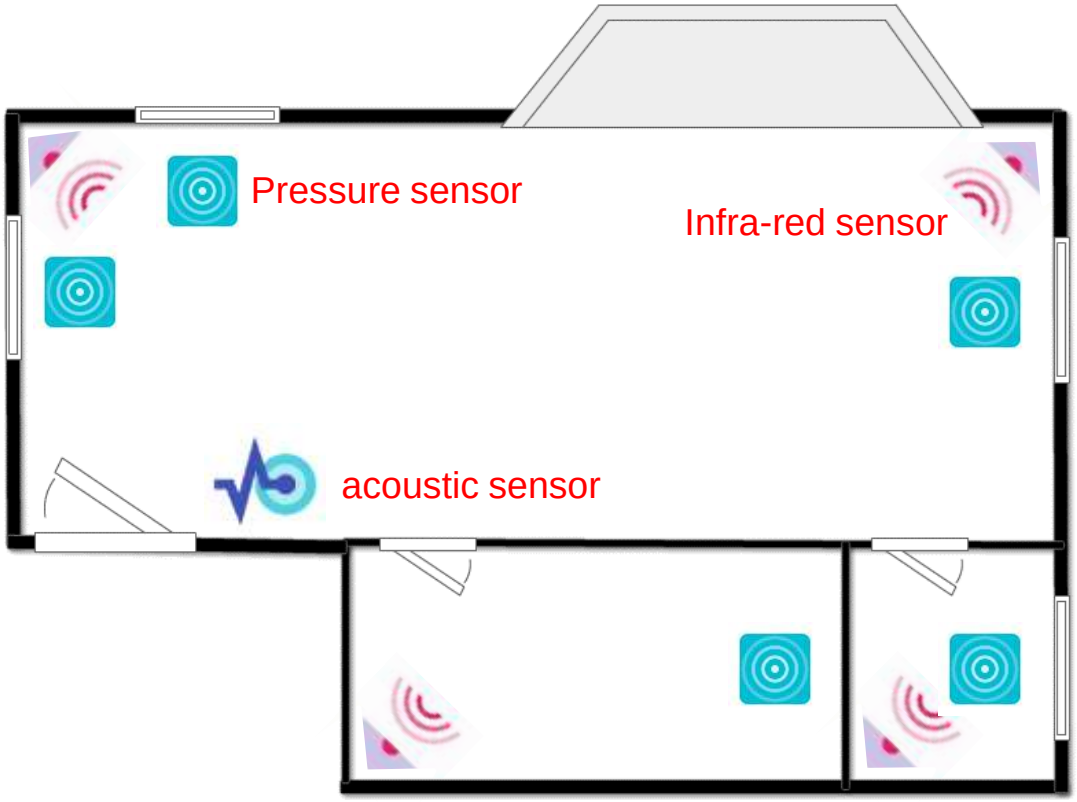


Activity

- Now complete **Task 2** on **Worksheet**

Monitoring systems

This example of monitoring involves an intruder detection and alarm system in a house:



Detection systems

- The **pressure sensors** monitor an intruder stepping on the floor next to the windows, doors or on the floor next to valuable paintings

- The **acoustic sensors** pick up the sound of breaking glass or footsteps on the floor

- The **infra-red sensors** pick up movement in the rooms but also any changes in heat (e.g. heat radiation from an intruder)

How does it work?

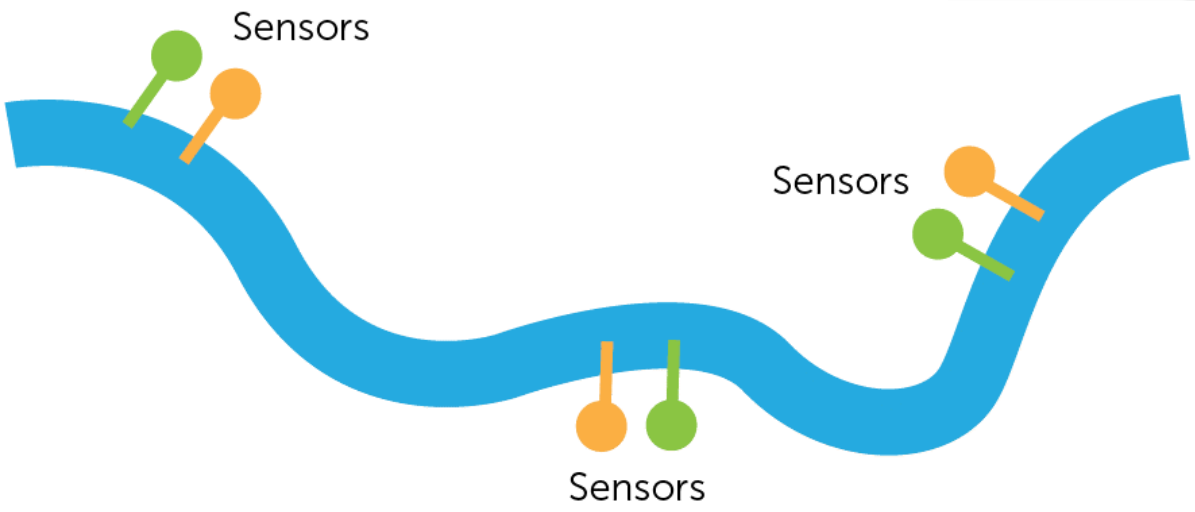
- The system is first activated by the user keying in a PIN code or by placing an alarm fob near a receiver
  - Sensors constantly monitor the rooms for intruders
  - Data is converted into digital form using an ADC and is sent to a microprocessor

Sensor feedback

- Sensors constantly take readings for monitoring
  - The microprocessor will have access to pre-set values for all sensors
  - The microprocessor will sample each sensor at a given frequency (e.g. every 2 seconds)
  - If any of the sensor readings exceed the pre-set values, then the microprocessor sends a signal to warn the user (this could be a screen output, a siren or flashing light …. or all three)
  - Each sensor will feed into an interface box so that the microprocessor can pin-point exactly which sensor sent the high value
  - Monitoring continues until the user keys in a PIN/passcode to deactivate the system

Monitoring systems

- Now complete **Task 3** on **Worksheet 3**
  - This task asks you to describe how sensors and a computer can be used to monitor the pollution levels in a river, at a number of points, over a period of time

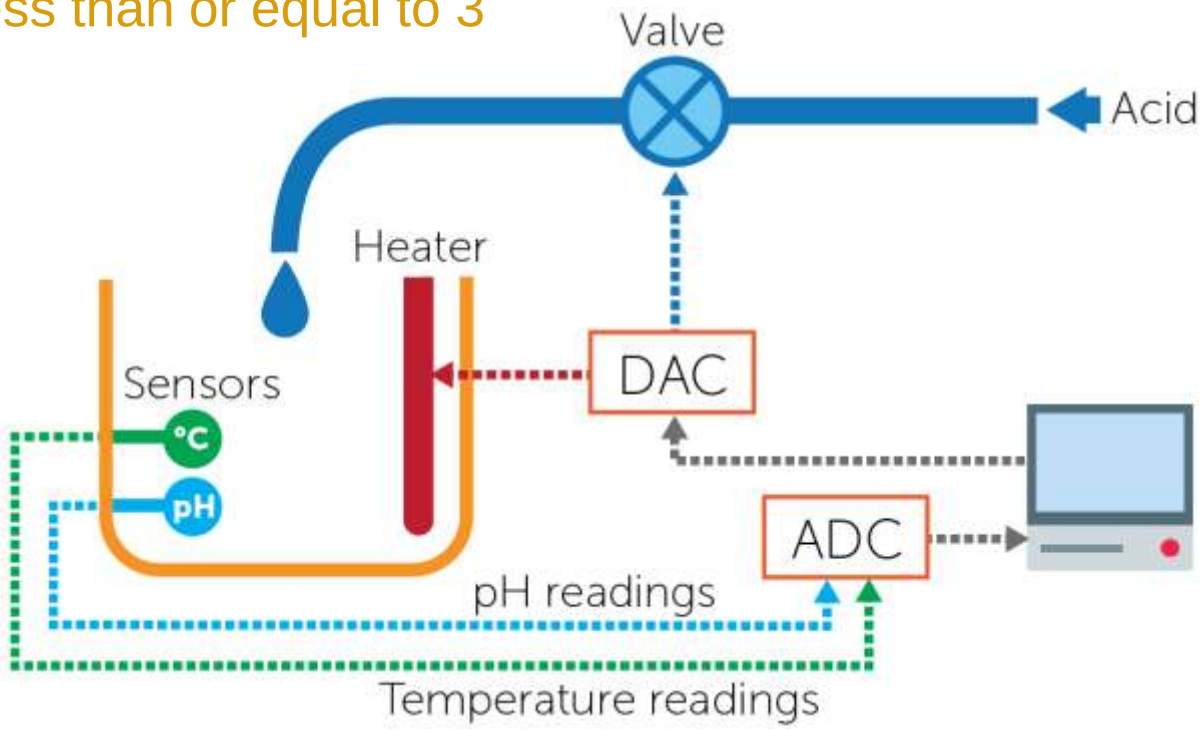


Pollution levels in a river

- **Monitoring processes**:
  - Gas and pH sensors send data to computer.
  - Data is converted into digital form using an ADC, before being analysed by computer
  - The computer checks oxygen levels against pre-set values
  - If oxygen levels <15% then the computer warns operators in control room
  - Computer checks pH levels against set values and if pH <6 or pH >8, then computer warns operators in control room
  - monitoring continues until system switched off

Control systems

- A computer can be used to control the temperature and acidity levels in a chemical process
  - The temperature must be 50°C or higher and the pH must be less than or equal to 3



Chemical process

- Temperature sensors and pH sensors are used to gather data so that the computer can control the process
- So what happens?
  - The temperature sensors and pH sensors constantly take readings from the chemical process
  - The data is converted into digital format using an ADC and is then sent to the computer
  - The computer has the pre-set values for temperature and pH stored in memory
  - Continued on next slide…

Chemical process continued…

- If the data received from the pH sensors shows the pH to be greater than 3, then the computer sends a signal to an actuator to open a valve to admit more acid
- If the data received from the temperature sensors shows the temperature to be less than 50°C, then the computer sends a signal to an actuator to switch on the heating elements in the reaction vessel
- Once the pH and temperature are within acceptable boundaries, the computer sends signals to close the valve and/or switch off the heater
- The control continues until the chemical process is complete

Worksheet 3

- Complete **Task 4** of **Worksheet 3**

Control of street lamps

- Sensor feedback is used to influence output
  - Light sensors constantly send data to a microprocessor and is converted into digital using an ADC
  - The microprocessor checks data from light sensors against pre-set values
  - If light levels < pre-set values then a signal is sent to switch on the street lamp. If light levels >= pre-set values then a signal is sent to switch off the street lamp
  - To prevent constant switching off and on as clouds pass over, the microprocessor doesn’t send any signals to change the condition of the street lamp for two hours
  - The microprocessor begins checking data again after two hours

Sensor	Description of sensor	Example applications

Magnetic field

Accelerometer

Proximity

Pressure

Infrared (active)

Humidity

Moisture

Infrared (passive)

Temperature

Light

Acoustic

Gas

pH

Flow (rate)

Level

Sensor	Description of sensor	Example applications
Temperature	measures temperature of the surroundings by sending signals; these signals will change as the temperature changes	• control of a central heating system • control/monitor a chemical process • control/monitor temperature in a greenhouse
Moisture	measures water levels in, for example, soil (it is based on the electrical resistance of the sample being monitored)	• control/monitor moisture levels in soil in a greenhouse • monitor the moisture levels in a food processing factory
Humidity	this is slightly different to moisture; this measures the amount of water vapour in, for example, a sample of air (based on the fact that the conductivity of air will change depending on the amount of water present)	• monitor humidity levels in a building • monitor humidity levels in a factory manufacturing microchips • monitor/control humidity levels in the air in a greenhouse
Light	these use photoelectric cells that produce an output (in the form of an electric current) depending on the brightness of the light	• switching street lights on or off depending on light levels • switch on car headlights automatically when it gets dark
Infrared (active)	these use an invisible beam of infrared radiation picked up by a detector; if the beam is broken, then there will be a change in the amount of infrared radiation reaching the detector (sensor)	• turn on car windscreen wipers automatically when it detects rain on the windscreen • security alarm system (intruder breaks the infra-red beam)
Infrared (passive)	these sensors measure the heat radiation given off by an object, for example, the temperature of an intruder or the temperature in a fridge	• security alarm system (detects body heat) • monitor the temperature inside an industrial freezer or chiller unit
Pressure	a pressure sensor is a transducer and generates different electric currents depending on the pressure applied	• weighing of lorries at a weighing station • measure the gas pressure in a nuclear reactor

Sensor	Description of sensor	Example applications
Acoustic/sound	these are basically microphones that convert detected sound into electric signals/pulses	• pick up the noise of footsteps in a security system • detect the sound of liquids dripping at a faulty pipe joint
Gas	most common ones are oxygen or carbon dioxide sensors; they use various methods to detect the gas being monitored and produce outputs that vary with the oxygen or carbon dioxide levels present	• monitor pollution levels in the air at an airport • monitor oxygen and carbon dioxide levels in a greenhouse • monitor oxygen levels in a car exhaust
pH	these measure acidity through changes in voltages in, for example, soil	• monitor/control acidity levels in the soil in a greenhouse • control acidity levels in a chemical process
Magnetic field	these sensors measure changes in magnetic fields – the signal output will depend on how the magnetic field changes	• detect magnetic field changes (for example, in mobile phones and CD players) • used in anti-lock braking systems in cars
Accelerometer	these are sensors that measure acceleration and motion of an application, i.e. the change in velocity (a piezoelectric cell is used whose output varies according to the change in velocity)	• used in cars to measure rapid deceleration and apply air bags in a crash • used by mobile phones to change between portrait and landscape mode
Proximity	these sensors detect the presence of a nearby object	• detect when a face is close to a mobile phone screen and switches off screen when held to the ear
Flow (rate)	these sensors measure the flow rate of a moving liquid or gas and produce an output based on the amount of liquid or gas passing over the sensor	• used in respiratory devices and inhalers in hospitals • measure gas flows in pipes (for example, natural gas)
Level	these sensors use ultrasonics (to detect changing liquid levels in, for example, a tank) or capacitance/conductivity (to measure static levels (for example, height of water in a river) – note, level sensors can also be optical or mechanical in nature	• monitor levels in a petrol tank in a car • in a pharmaceutical process where powder levels in tablet production need to be monitored • leak detection in refrigerant (air conditioning)

Computer control

- What are the advantages of using sensors with computer control?
- What are the disadvantages?

Computer control

Advantages:

- Can operate 24 hours a day without taking a break.
- Does not need any holidays or sick days
- Does not need any pay.
- Will accurately repeat actions over and over again
- Data from sensors is processed very quickly
- Can process many inputs at the same time
- Can make reliable and accurate decisions
- Can be used in places that are dangerous or difficult for people to go to

Computer control

Disadvantages:

- If the computer or sensor malfunctions, the system will not work
- If there is a power cut the system will not work
- The software for the control system is specialist and may cost a lot of money to develop
- The computer does not have the flexibility to react to unexpected events as perhaps a person could. It can only respond in the way it has been programmed.
- People sometimes want to know that an expert is in control even if a computer could do it as well. e.g. a driverless car, or pilotless aircraft, or robotic surgical procedure, is not comfortable or popular with many people, even though it may be technologically possible.

Automated systems

General advantages:

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