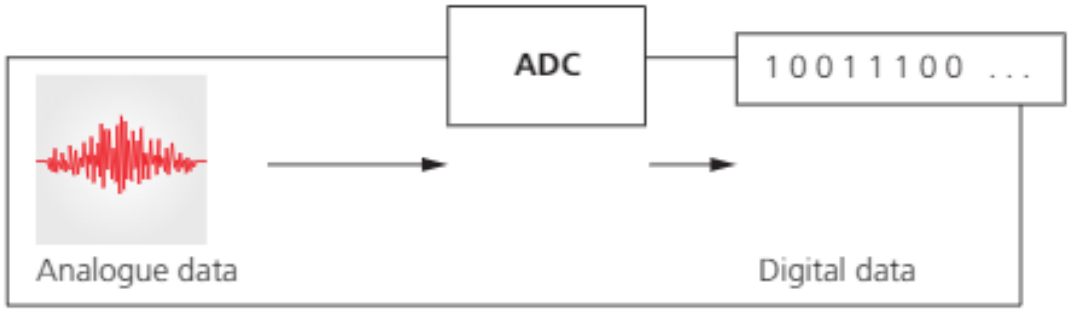
3.2.3 SENSORS

- Sensors are input devices which read or measure physical properties from their surroundings e.g., temperature, pressure, acidity level and length
- computers cannot make any sense of these physical quantities, so the data needs to be converted into a digital format. This is usually achieved by an analogue to digital converter (ADC)



▲ **Figure 3.49** ADC

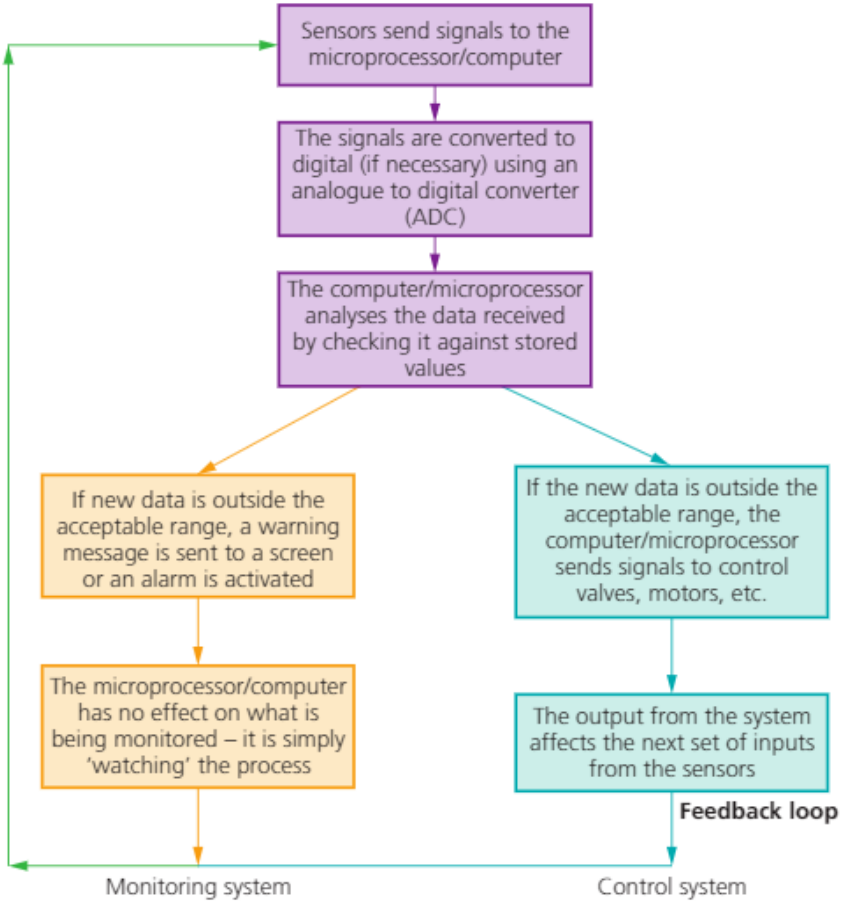
3.2.3 SENSORS

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

3.2.3 SENSORS

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
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)

3.2.3 MONITORING VS CONTROL APPLICATIONS



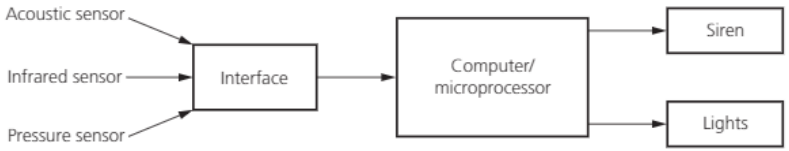
Examples of monitoring

- Monitoring of a patient in a hospital for vital signs such as heart rate, temperature, etc.
- Monitoring of intruders in a burglar alarm system
- Checking the temperature levels in a car engine
- Monitoring pollution levels in a river.

Examples of control

- Turning street lights on at night and turning them off again during daylight
- Controlling the temperature in a central heating/air conditioning system
- Chemical process control (for example, maintaining temperature and pH of process)

3.2.3 MONITORING APPLICATIONS



▲ **Figure 3.51** Security system

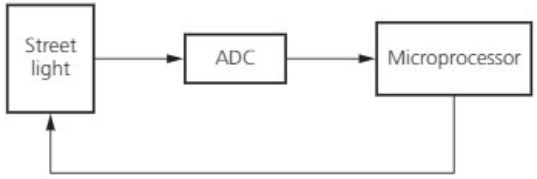
- the system is activated by keying in a password on a keypad
- the **infrared sensor** will pick up the movement of an intruder in the building
- the **acoustic sensor** will pick up sounds such as footsteps or breaking glass
- the **pressure sensor** will pick up the weight of an intruder coming through a door or through a window
- the sensor data is passed through an ADC if it is in an analogue form ...
- ... to produce digital data
- the computer/microprocessor will sample the digital data coming from these sensors at a given frequency (e.g. every 5 seconds) ...
- ... the data is compared with the stored values by the computer/microprocessor
- if any of the incoming data values are outside the acceptable range, then the computer sends a signal ...
- ... to a siren to sound the alarm, or
- ... to a light to start flashing
- a DAC is used if the devices need analogue values to operate them
- the alarm continues to sound/lights continue to flash until the system is re-set with a password.

3.2.3 MONITORING APPLICATIONS

Monitoring of patients in a hospital

- A number of sensors are attached to the patient ...
- ... these measure vital signs such as: temperature, heart rate, breathing rate, etc.
- these sensors are all attached to a computer system
- the sensors constantly send data back to the computer system
- the computer samples the data at frequent intervals
- the range of acceptable values for each parameter is keyed into the computer
- the computer compares the values from the sensors with those values keyed in
- if anything is out of the acceptable range, a signal is sent by the computer ...
- ... to sound an alarm
- if data from the sensors is within range, the values are shown in either graphical form on a screen and/or a digital read out
- monitoring continues until the sensors are disconnected from the patient.

3.2.3 CONTROL APPLICATIONS



▲ **Figure 3.52** Street lighting

Control applications

Control of street lighting

This next sequence shows how a microprocessor is used to control the operation of a street lamp. The lamp is fitted with a light sensor which constantly sends data to the microprocessor. The data value from the sensor changes according to whether it is sunny, cloudy, raining or it is night time (etc.):

- the light sensor sends data to the ADC interface
- this changes the data into digital form and sends it to the microprocessor
- the microprocessor samples the data every minute (or at some other frequency rate)
- if the data from the sensor < value stored in memory …
- … a signal is sent from the microprocessor to the street lamp …
- … and the lamp is switched on
- the lamp stays switched on for 30 minutes before the sensor readings are sampled again (this prevents the lamp flickering off and on during brief heavy cloud cover, for example)
- if the data from the sensor >= value stored in memory …
- … a signal is sent from the microprocessor to the street lamp …
- … and the lamp is switched off
- the lamp stays switched off for 30 minutes before sensor readings are sampled again (this prevents the lamp flickering off and on during heavy cloud cover for example).

3.2.3 CONTROL APPLICATIONS

Chemical process control

A certain chemical process only works if the temperature is above 70°C and the pH (acidity) level is less than 3.5. Sensors are used as part of the control system. A heater is used to heat the reactor and valves are used to add acid when necessary to maintain the acidity. The following description shows how the sensors and computer are used to control this process:

- **temperature** and **pH sensors** read data from the chemical process
- this data is converted to digital using an ADC and is then sent to the computer
- the computer compares the incoming data with pre-set values stored in memory
- … if the temperature < 70°C, a signal is sent to switch on the heater
- … if the temperature >= 70°C, a signal is sent to switch off the heaters
- … if the pH > 3.5, then a signal is sent to open a valve and acid is added
- … if the pH <= 3.5, then a signal is sent to close this valve
- the computer signals will be changed into analogue signals using a DAC so that it can control the heaters and valves
- this continues as long as the computer system is activated.

3.2.3 CONTROL APPLICATIONS

Greenhouse environment control

Five different sensors could be used here to control the greenhouse environment, namely: **humidity**, **moisture**, **temperature**, **pH** and **light**. To simplify this problem the control mechanisms are shown in Figure 3.54.