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Information Technology

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Chapter 3

Monitoring and Control

Faisal Chughtai

info.sirfaisal@gmail.com

www.faisalchughtai.com

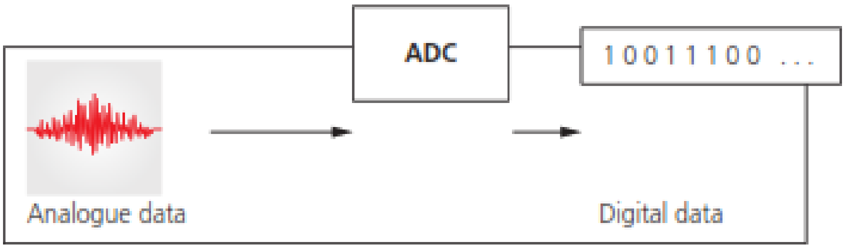
Monitoring Technologies

Monitoring, or measurement involves the use of a computer or microprocessor-based device to monitor or measure physical variables over a period of time.

It is important to know which sensors would be appropriate in a given situation to measure physical variables such as light, temperature, atmospheric pressure, humidity, moisture, sound, blood pressure and pH, among others.

A **sensor** is a device that is used to collect (input) data in monitoring systems. The data usually relates to physical changes in the environment that are being monitored. A sensor converts the physical characteristic, such as temperature, light or pressure, into a signal which can be measured electrically.

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).**



Control Technologies

A control system is one that uses microprocessors or computers to control certain physical variables. Computers can do this by maintaining certain physical conditions at the same level for a period of time or by controlling certain devices which cause the variables to change.

Physical variables that can be controlled by computers and microprocessors include temperature, pressure, humidity, light, and moisture.

Control systems use real-time processing. They make use of actuators to control devices, although some devices are actuators in their own right, such as a motor. Unlike in monitoring systems, in control systems the output affects the input.

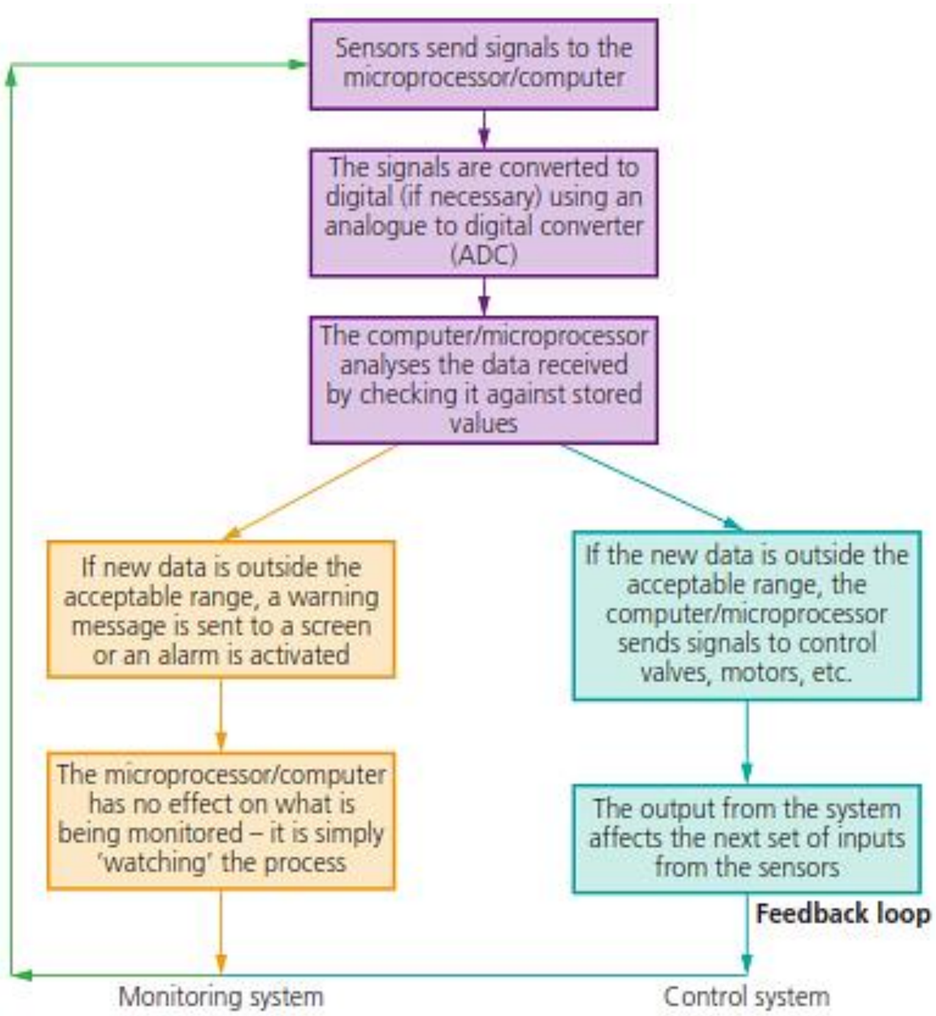
Actuators

Just as sensors provide the input to a control system, so actuators provide the output. An actuator controls a device, such as the valve which allows water to flow through heaters or sprinklers in a greenhouse.

It can actually be a motor which controls the opening or shutting of windows in a greenhouse or a switch which turns a heater on. It is essentially a device that turns an electrical signal from a microprocessor into movement.

When the computer is used to control devices, such as a motor or a valve, it is necessary to use a **digital to analogue converter (DAC)** since these devices need analogue data to operate in many cases.

There is a subtle difference in the way monitoring and control technologies work.



Sensors Used in Monitoring and Control Technologies

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
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)

Calibration

- Calibration in sensors refers to the process of adjusting or aligning a sensor's output to match a known reference or standard.
- Sensors, such as temperature sensors, pressure sensors may exhibit slight variations or inaccuracies in their measurements due to factors like manufacturing tolerances, environmental conditions, or wear and tear.
- The calibration process involves comparing the sensor's output with a reliable reference or standard measurement.
- This reference measurement is obtained through a trusted and accurate calibration equipment or technique.
- By analyzing the sensor's output and the reference measurement, adjustments can be made to the sensor's internal settings or signal processing algorithms to correct for any deviations or errors.

Methods used to calibrate devices

1. **Measurement:** The sensor is subjected to a known input or reference condition, and its output is recorded. For example, a temperature sensor may be placed in a controlled environment with a known temperature, and its output is measured.
2. **Adjustment:** Based on the comparison between the sensor's output and the reference measurement, adjustments are made to the sensor's calibration settings or signal processing algorithms. These adjustments aim to bring the sensor's output closer to the reference measurement, reducing any systematic errors or biases.

Calibration ensures that a sensor provides accurate and reliable measurements within a specified range. It is an essential process to maintain the quality and reliability of sensor data, especially in applications where precise measurements are critical, such as scientific research, industrial processes, medical devices, or environmental monitoring.

There are three different types of calibration that can be used for a sensor.

- One-point calibration
- Two-point calibration
- Multi-point calibration

One-point calibration

- One-point calibration is a calibration process used in various measurement systems and instruments.
- It involves adjusting a measurement device, such as a sensor, based on a single reference point or standard value.
- In this type of calibration, the instrument is calibrated using a known value or a reference material at a specific point, typically at the lower or higher end of the measurement range.
- During a one-point calibration, the instrument is adjusted so that it provides an accurate measurement at that specific reference point.

- The calibration factor or offset is determined based on the difference between the measured value and the known value at the reference point.
- Once the calibration is performed, the instrument assumes that the same calibration factor applies to the entire measurement range.
- One-point calibration is commonly used when the measurement system or instrument is expected to provide accurate readings within a limited range or when the measurement values are not expected to significantly deviate from the reference point.

Two-point calibration

- Two-point calibration is a calibration method commonly used in various measurement processes to ensure the accuracy and reliability of measuring instruments.
- It involves using two known reference points or standards to calibrate an instrument or sensor.
- The purpose of calibration is to establish a relationship or correlation between the instrument's measurement readings and the actual values being measured.
- In two-point calibration, two reference points with known values are chosen, typically at the minimum and maximum range of the instrument.
- The instrument is then tested at these reference points, and the measured values are compared to the known values.
- The calibration process involves adjusting the instrument's readings to match the known values, thereby establishing a linear or nonlinear calibration curve.

Multi-point calibration

Multipoint calibration is used in measuring an instrument's (such as a sensor) response and the corresponding known values of a quantity being measured. It involves determining the instrument's response at multiple reference points and then creating a calibration curve or equation to correlate the instrument's readings to the actual values.

Here's a step-by-step overview of how a multipoint calibration typically works:

1. **Selection of reference points:** A set of known values spanning the measurement range of interest is chosen. These values should be representative of the expected range of measurements and cover various points across the instrument's operating range.
2. **Measurement of reference points:** Each reference point is measured using the instrument being calibrated. The instrument's response or reading is recorded for each reference point.
3. **Calibration curve creation:** The recorded readings are plotted against the known reference values to create a calibration curve. The curve represents the relationship between the instrument's response and the true values being measured.
4. **Curve fitting:** Mathematical techniques may be employed to determine the equation or model that best fits the calibration curve. This equation relates the instrument's readings to the actual values.
5. **Calibration verification:** After the calibration curve or equation is established, additional reference points may be measured to validate the calibration. These

verification points should fall within the original reference point range and can be used to confirm the accuracy and reliability of the calibration.

6. **Application of calibration:** The calibration curve or equation is used to convert subsequent instrument readings into accurate measurements of the desired quantity.

Uses of Monitoring Technologies

Weather stations

Weather stations are set up to automatically gather data from the environment. They are used to monitor the weather in terms of temperature, rainfall, hours of sunlight, atmospheric pressure, humidity and UV radiation. For this purpose, it would need:

Temperature sensors to measure the ambient temperature. When referring to the weather, ambient temperature means the temperature of the surrounding air of the weather station.

Pressure sensors to measure atmospheric pressure, which is the pressure of the air above us. Weather forecasters use pressure readings to help them formulate weather forecasts.

Humidity sensors to measure absolute and relative humidity. Absolute humidity is the amount of moisture in the air, measured without taking temperature into account. Relative humidity is also a measure of moisture but does consider the temperature of the air and is actually a percentage value.

Light sensors to measure the number of hours of sunlight. Measuring sunlight requires an array of light sensors which collectively measure the intensity of the light radiation.

A tipping bucket and a reed switch to measure rainfall. Most nonautomated weather stations use a bucket into which the rain falls. When the bucket reaches a certain weight (usually after a very small amount of rain) the bucket mechanism causes it to tip over and empty the water. It then tips back to collect further rainfall.

In modern automated systems, the tipping of the bucket activates a reed switch which sends a signal back to the microprocessor. The microprocessor, counting the number of times the bucket tips, performs the same calculations that human operators used to do.

- When the weather station is operating, the readings from the sensors are fed back to an ADC and then sent to the computer.
- The ADC converts the data from analogue to digital so that the computer can understand and process it.
- On receiving the digital data, the computer stores the data in the form of a table, which could be done using a spreadsheet or database package, so that it can be processed.

Monitoring water pollution

Studies of water pollution usually happen with reference to bodies of water such as rivers, lakes and sometimes, seas.

There are basically two ways of carrying out the study. One is to compare the readings with those that would normally be expected. This requires the lowering of one set of sensors into the river or lake.

The other relates usually to industrial pollution. This involves:

- Inserting two sets of sensors, one upstream from the suspected site of pollution and the other downstream, immediately after the site.
- The readings from the two sets of sensors are compared to see if there are any differences so that a conclusion can be reached as to whether the site is causing pollution.
- The system operates the same as the weather station, with sensors feeding data to an ADC and then the computer processing the digital data.
- The sensors involved are temperature sensors, pH sensors, turbidity sensors, O2 and CO2 sensors.
- The processing carried out is a comparison of the readings from the two sets of sensors.

Monitoring of patients in a hospital

The following steps show what happens when a computer is used to measure the key vital signs of a patient 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.
- 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.

Uses of Control Technologies

Greenhouse (glasshouse) environment control

Five different sensors could be used to control the greenhouse environment. These include, temperature, humidity, moisture, PH and light.

- At the start of the process, the user inputs the required values (pre-set values) using a keypad, number pad or touchscreen.
- The computer receives the required data from the sensors.
- It needs an ADC to change the analogue data from sensors to a digital value the computer can understand.
- The computer compares the sensor data to the pre-set values input to the system earlier by the user.
- If the data from the sensors is above or below the pre-set values, a signal is sent to an actuator to take the necessary action.
- This whole process is continuous as long as the system is switched on.

Central heating systems

In this example, a gas supply is used to heat water using a heater. A valve on the gas supply is controlled by a microprocessor and is opened if the heating levels need to be increased. A water pump is used to pump hot water around the central heating system whenever the temperature drops below a pre-set value.

- The required temperature is keyed in and this is stored in the microprocessor memory (this is called the pre-set value).
- The temperature sensor is constantly sending data readings to the microprocessor.
- The sensor data is first sent to an ADC to convert the analogue data into digital data.
- The digital data is sent to the microprocessor.
- The microprocessor compares this data with the pre-set value.
- If the temperature reading >= pre-set value then no action is taken.
- If the temperature reading < pre-set value, then a signal is sent to an actuator (via a DAC) to open the gas valve to the heater, to an actuator (via a DAC) to turn on the water pump.
- The process continues until the central heating is switched off.

Burglar alarm systems

The burglar alarm system will carry out the following actions:

- 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 reset with a password.
- It probably also sends a signal to the police to alert them to the presence of a possible intruder.

Street lighting control system

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).
- Ff 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).

Car park barrier systems

One of the most common ways to detect vehicles in a microprocessor-controlled car-park barrier system is by using an induction (sometimes called inductive) loop buried just below the surface of the road in front of the barrier.

- As a vehicle passes over the loop, it causes a change in inductance which is detected by the loop.
- The metal in the vehicle causes a change in the magnetic field.
- This in turn causes a current to flow.
- The loop sends back data which is converted to digital and if the computer detects any change compared to a pre-set value, it sends a signal to the actuator.
- In this case, the actuator is the motor which, when activated, causes the barrier to rise.

- There is usually a second sensor, often a light sensor, which is used to detect when the vehicle has passed beyond the barrier.
- A light beam passes across the space occupied by the vehicle.
- If the vehicle prevents the light beam from reaching the sensor, then the microprocessor will keep the barrier raised.
- When the vehicle is clear of the barrier, the microprocessor detects that the light beam has resumed and so can send a signal to the motor to retract and allow the barrier to lower.
- This makes sure the barrier stays up until the vehicle has passed through the beam.

Traffic lights control system

The computer is programmed to react to different volumes of traffic during the day and often uses the same method as in car-park barriers (induction loops) to detect these.

- The computer receives data from the induction loops by way of the ADC and counts the number of vehicles travelling in each direction.
- These counts are then compared with pre-set values and the computer changes the traffic light timings/sequences as required by sending signals back to the control box in the traffic lights, which then operates the new sequence or timings.
- The whole process is continuous.
- For example, if a line of cars is coming from one direction and none from the other, the computer will decide to keep the light on red for the road which has no traffic.
- When a sufficient number of vehicles have stopped at the red light, the computer will cause the red light to turn green and the other one red.

Advantages and Disadvantages of Monitoring and Control Technologies

Advantages	Disadvantages
The computer won't forget to take readings	The computer is unable to respond to unusual circumstances
The computer's response time is much faster	Computer equipment and measuring software can be expensive to purchase and set up in the first place
Humans can get on with other tasks whilst the measurements are taken automatically	People become dependent upon computers and may not be able to learn the skills for measurement and analysis
Computers can work 24/7	If the computer or sensors malfunction, or if there is a power cut, the tasks my not be completed
The readings will tend to be more accurate	
Readings can be taken more frequently if done by computer and sensors	
It could be safer humans since computers can work in hazardous conditions	
Computers can produce graphs automatically for analysis of results	
There is a potential cost saving since fewer staff are needed	