

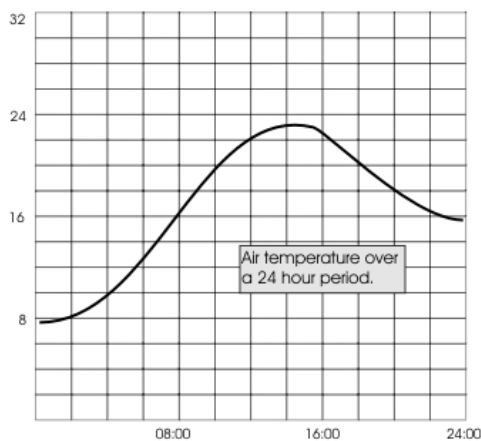
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## Analog and Digital Data

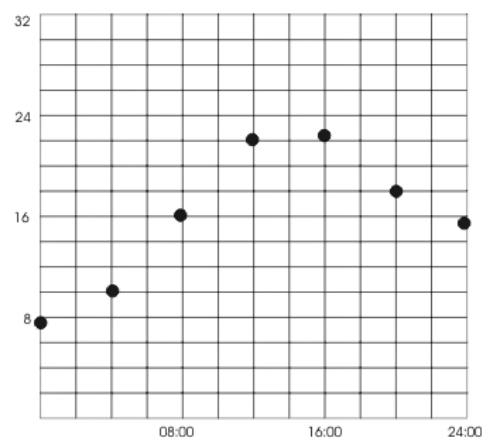
**Analog** (or analogue) data is **real world** stuff like sounds, electrical currents, paintings, temperatures, time. It has no precisely measurable or discrete value - we measure to the accuracy of our recording instruments.

**Digital** data, on the other hand is discrete, consider the bitmap as compared to an original image for example, a bitmap is made up of **discrete** pixels in one colour or another, the water-colour is not. When sounds are digitised they must be stored as discrete values representing the pitch, volume, duration and other qualities of the sound

Computers can **only** work with **digital data**.



Analog data



Digital data

To **convert** analog data to digital data, the analog data has to be **sampled** and then converted to an approximate value. Some information is lost in the process, for example the curve of the analog temperature can not be reproduced exactly from the digital data – the data between each sample has been lost.

Digitised data, although approximate, can be processed and transmitted by computer systems efficiently and reliably than analog data. More efficiently because the digital data is more compressed and more reliably since it is transmitted as digital states which are less subject to distortion by noise.

In addition **digital** data can be **manipulated** by computer - for example, pictures can be scaled and rotated quickly, digital effects can be added to sounds (eg echo) and temperature data can be used in a computer control system.

Suppose a computer converts the temperature graph above by storing a digital temperature as a 32-bit number every **four** hours. How many **bytes** of data are stored in a week?

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Suppose the temperature is recorded every 3 minutes instead?

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### Analog to Digital Conversion

To convert signals from analogue to digital require as an **analogue-to-digital converter** (ADC). The signals are gathered by **sensors** which are often also **transducers** (a device which converts one form of energy to another). Transducers used as sensors for input to ADC devices usually convert energy from (eg) heat, light, pressure to electrical impulses. These **analog** impulses are then **sampled** and **digitised**.

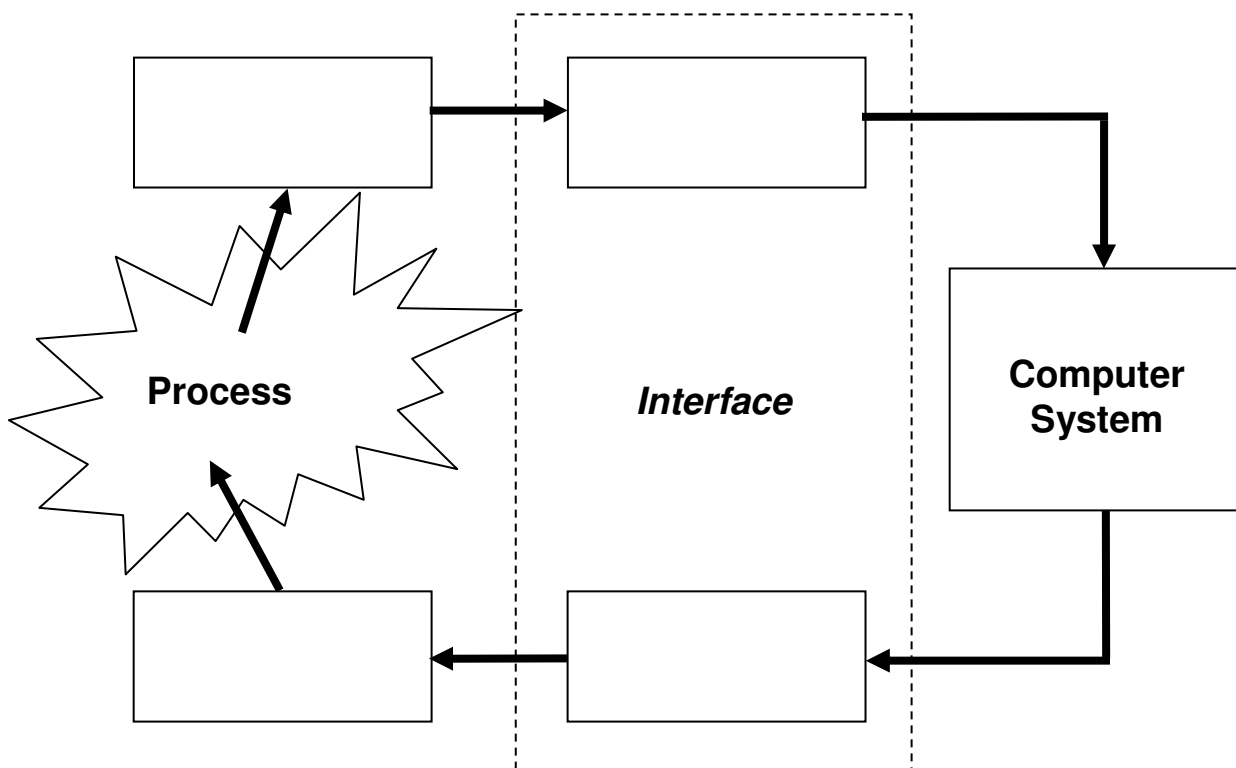
### Sensors

These are used in very many **control processes**, for example, microwaves, washing machines, video recorders, building heating systems, security systems etc etc. Often the actual computer program will be small enough to be located in ROM (or EPROM) and combined with a small memory chip (for storing sensor data) and a microprocessor. A washing machine will typically have water level sensors, drum rotation sensors and heat sensors.

### Actuators

To produce actions in the real world, computer instructions typically have to be converted to analogue form (**Digital-to-Analogue-Conversion**) and sent to an **actuator** a device that produces some effect in the real world (turning on a heater, activating a door lock, opening or closing a valve).

A typical control process thus consists of a computer (or microprocessor), an interface and sensors/actuators:

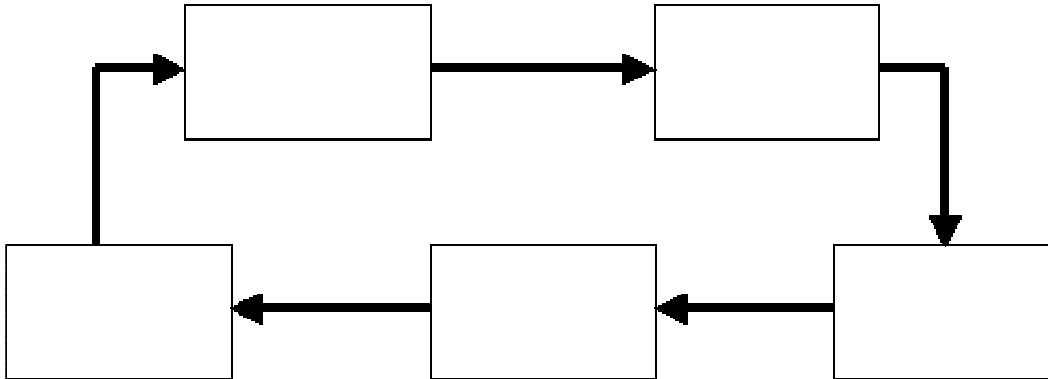


**Add labels:** *sensor, actuator, digital-to-analog and analog-to-digital convertor*

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### Feedback

Control systems rely on the principle of **feedback**:



Fill in the boxes with these phrases: *coffee cup emptied, temperature falls, heater off, sensor detects high temperature, toast buttered, heater on, sensor detects low temperature, cereal scooped.*

(**hint**: not all of the above phrases are needed in the diagram)

### Applications that require analog to digital conversion

**Temperature sensing** applications include room controls (for central heating or air-conditioning), control of commercial processes like growing vegetables in greenhouses, washing machines and conventional ovens.

The temperature is **sensed** and the measurement **converted** to **digital**. The temperature is then **compared** by the **computer** or microprocessor to the **desired** temperature. If the temperature is too high or too low, appropriate action is taken (heater, air pump, cooler, switched on or off). Other inputs are usually controls that change the desired set temperature level.

In the space below, sketch a diagram which illustrates this process:

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**Speech recognition** is a means of inputting data into a system. The speech may be simple commands for an application (eg a wheelchair – left, right, slow, fast, stop) or free text input, into a word processor for example. There are a number of commercial systems on the market with about 90-95% accuracy.

The input device, fairly obviously, will be a **microphone** which is an analog device. The sound waves have to be converted to digital form which is relatively complex. Because different people speak in vastly different ways, systems often have to be “**trained**”. People may also speak in different ways at different times (eg when they have a head cold). The computer stores the sound patterns as **digital information** which have to be compared to the **digitised input**. The stored pattern is then linked to a word or command.

**Light detection** is used in a range of devices such as **Optical Character Recognition (OCR)** devices and **Barcode Scanners**. The reflected light is usually measured, since darker areas reflect less light, some kind of pattern – like characters or bar codes – can be recognised. Again, the patterns are matched to data stored in the computer. Similarly in image processing, a scanner can be used to measure the reflected light from an image and to assign each pixel (picture element) a colour. This method is used in **fax machines** as well.

## Exercises

A scientist is conducting an experiment on the mixing of liquids at different temperatures. He uses a computer to measure the using sensors.

- a) **Outline** the need for the conversion of temperature data from analog to digital form.

[2 marks]

- b) **Outline** one advantage and one disadvantage of storing temperature data in digital format.

[4 marks]

- c) If 8 bits are used, **state** the binary representation of a temperature of 67 degrees.

[1 mark]

- d) If the scientist also uses a heating element, **draw** and label a sketch showing how feedback will work in the system.

[5 marks]

- e) With reference to the temperature measurements, **explain** how sampling works.

[2 marks]