Engineering Systems

CONTENTS

INTRODUCTION

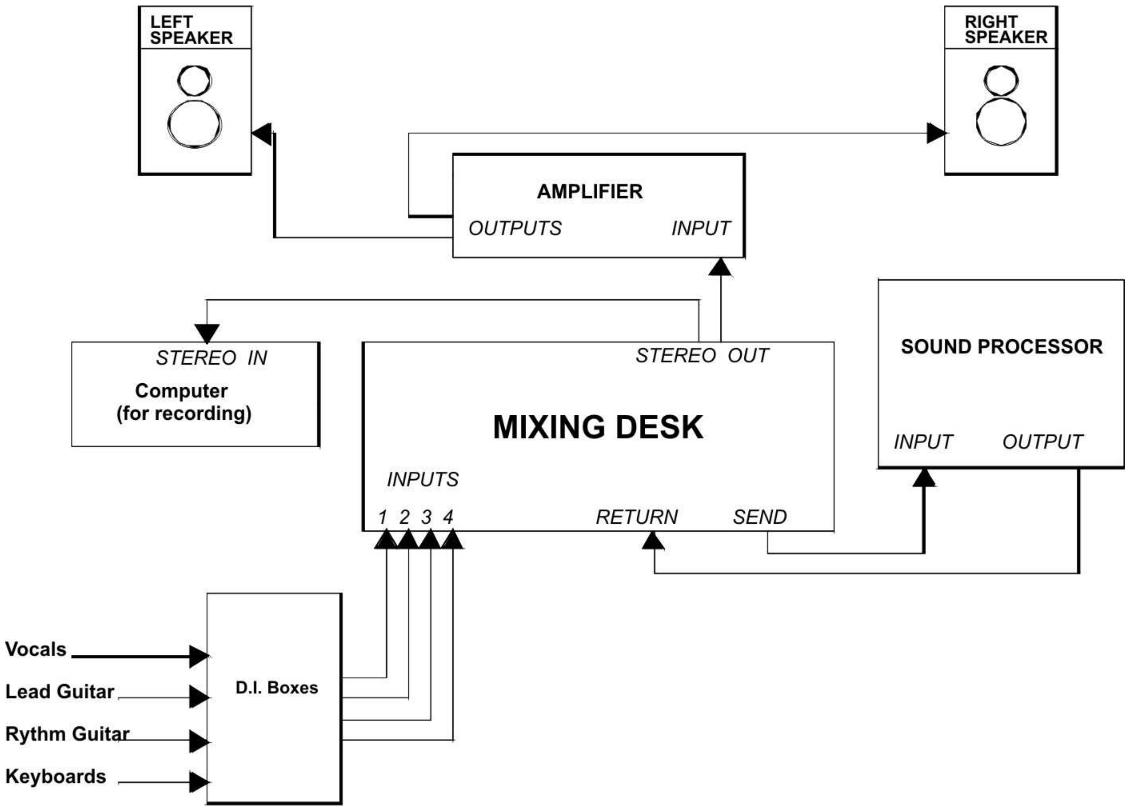
Technology influences all our lives so much that there is hardly a thing that is not affected by it. We take the term 'technology' to mean the things or products made by our society.

In our modern world there are so many new products being created that it is impossible for us to keep up and know everything about these developments. As technologists we need some help to use and understand all this technology. The strategy we use is called the *top-down* approach.

Here we limit the study of technology to what we need to know. For example, to use a toaster all we need to know is that if we plug it in, set the temperature, switch it on and insert a slice of bread then, after a few minutes, we will get toast. However, an engineer designing a new toaster will need to know a lot more and will have an understanding of all the parts that go to make up the toaster and how they relate to one another.

In order to simplify the difficulties of dealing with complex devices and machines, a method of analysis called the *systems approach* has been developed. It is based on the concept that any technological design or device can be described as a *system* and that this system can be split into smaller parts or *sub-systems*. Each sub-system deals with the *function* of a particular part of the design or device.

For example, the system diagram below describes a sound-mixing system used in the music department of a secondary school.

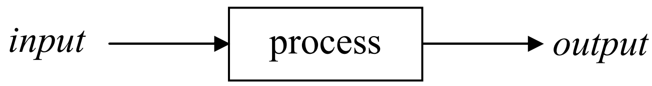


Even people with no training in the systems approach can look at a system diagram and gain an understanding of the function of the various elements of a system.

SYSTEMS APPROACH

We use system diagrams to show the top-down approach as we break down or analyse technology. All systems can be analysed in terms of *input*, *process* and *output*. A diagram called the *universal system diagram* consists of these three basic elements.

Universal system diagram



The *output* is the *specified function* performed by the system, (for example, the output of a kettle is 'hot water').

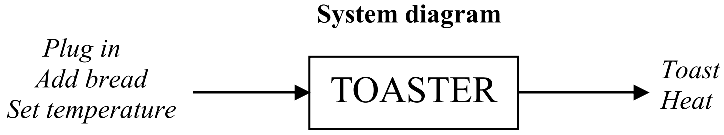
The system itself produces the output as a result of an *input* being supplied to it. (The input to a kettle is 'cold water'.)

The system changes the input in some way to produce a different output. This change is called the *process* (heating the water).

All systems can be analysed in terms of *input*, *process* and *output*.

So when analysing or breaking a product down to help understand it, we first try to find the *inputs* and the *outputs* and show these on a system diagram. Take, for example, the toaster.

System diagram



To help find the inputs to and outputs from a system we usually ask:

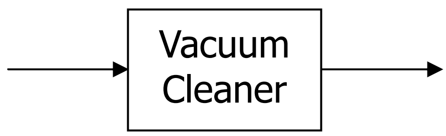
- (input) *what have I to do in order to make it work?*
- (output) *what does it do?*

Assignment 1

Draw a system diagram showing the inputs to and the outputs from each of the following.

(a)

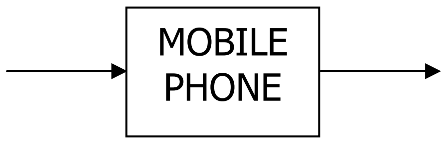
(b)



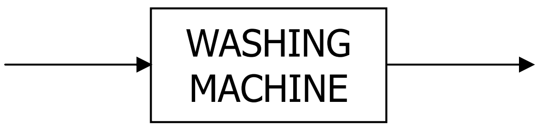
(c)

(d)

(e)

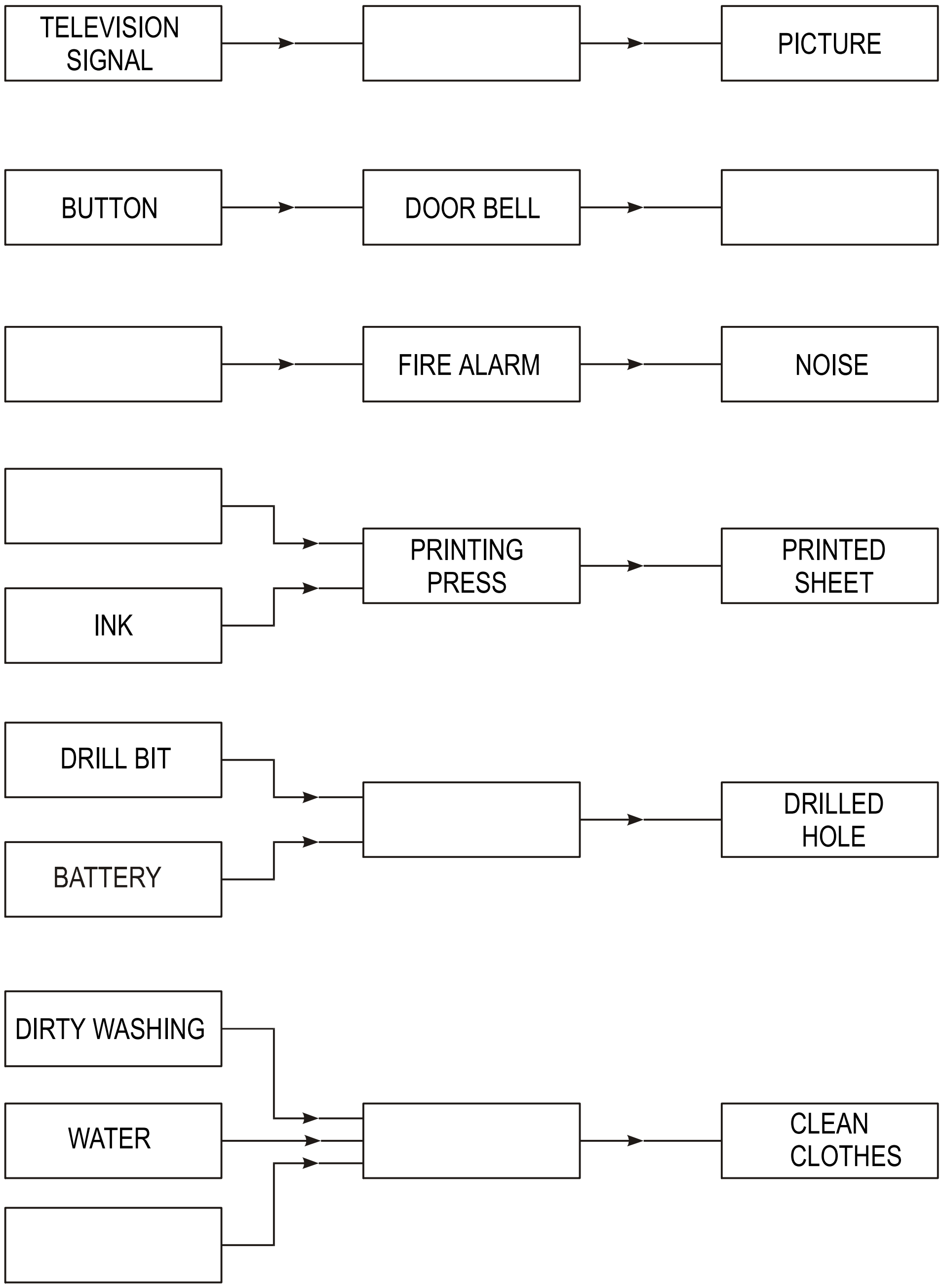


(f)



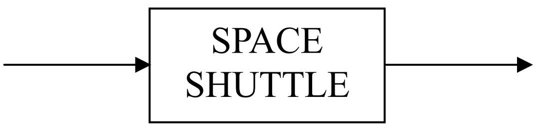
Assignment 2

Complete the following system diagrams.



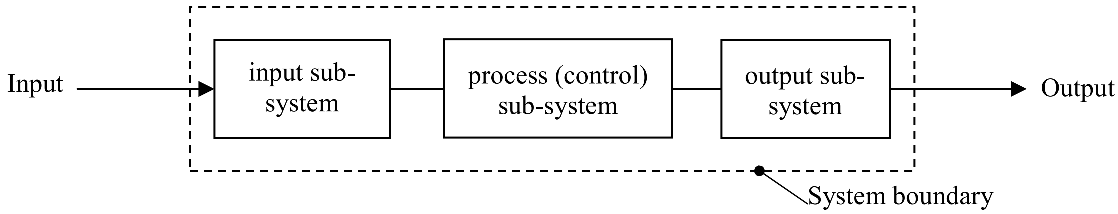
Assignment 3

Draw a system diagram based on the universal system, for each of the following. Show as many input and outputs as possible.



SUB-SYSTEMS

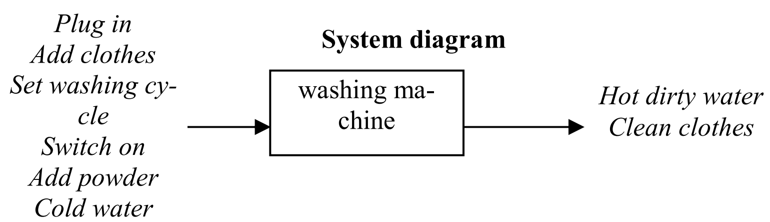
We have seen that the top-down approach is used when studying technology. This deals with technology on a need-to-know basis. For most people, knowing what they have to do to make the technology work (input) and what it does (output) is enough. However, we will be using technology to solve problems and so we need to break it down or analyse it in greater depth. To do this, we use a *sub-system* diagram as shown below.

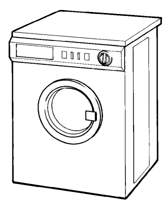


The sub-system diagram shows the *internal* detail of the system. Each box, called a *sub-system*, can be thought of as a system within a system and has its own input and output. The dashed line around the sub-system is called a *system boundary* and this marks the area of interest to us. The 'real world' input and output are shown as arrows entering and leaving the sub-system diagram.

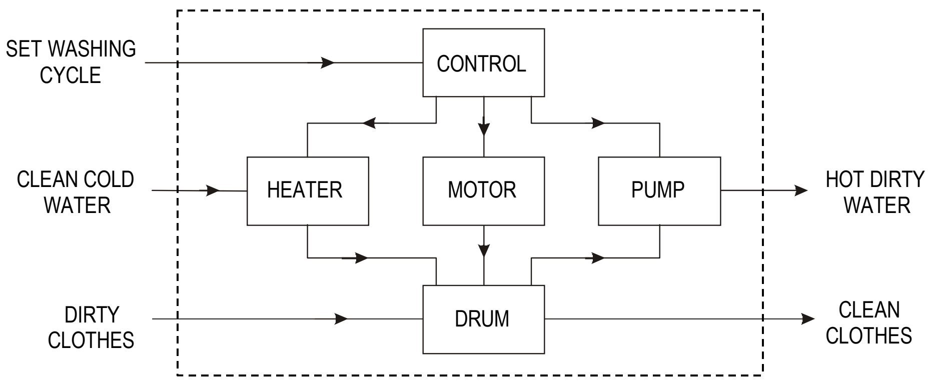
Consider a fairly complicated system, a washing machine. Most systems cannot operate entirely independently of other systems around them. A washing machine has a control system, which is electronic. It also has a water system using valves and pumps, which is a different system to the control system. However, for the washing machine to work, the control system and the water system must overlap each other. This can lead to confusion when drawing system diagrams. In order to isolate the system being considered, a *system boundary* is sometimes drawn. The system boundary is drawn as a dashed line right around the part of the system being considered, thus defining the limits of the system, as shown in the example below.

We would first complete a system diagram showing the inputs and outputs:





As we require more detail about the system, it must now be broken down into its sub-systems. This is shown on the simplified sub-system diagram below.



Assignment 4

1. Draw a sub-system diagram for the each of the following.

   (a) Computer (b) Phone

   (c) Burglar alarm system (d) Cash machine

CONTROL SYSTEMS

For any system to be effective, it must be adequately controlled.

Imagine the problems that might arise in your school if there was no-one:

- in charge
- taking responsibility for day-to-day activities
- ensuring that teachers were present and teaching their classes
- checking that pupils actually went to classes.

Such a scenario could hardly be called a *system,* much less an education system.

All types of system require some form of control to make the system work properly. A system may be based mainly around people (as in an education system) and is then known as a *soft system*. Systems based on manufactured components (as in a central heating system) are called *hard systems*. The emphasis of the Technological Studies course is on hard systems.

In many cases people do the controlling, especially in soft systems. However, hard systems are usually controlled automatically. Automatic control has become more and more common over recent years as technology has progressed. This type of control releases people from many of the boring and mundane jobs of watching machines operate, with only occasional adjustments to settings being necessary.

Control is absolutely central to the effective functioning of our society, from the streetlight that switches on automatically at night, through the air-conditioning in shops and offices and the autopilot in aeroplanes, to international electronic banking and the world wide web.

For this reason, control is also at the heart of the Standard Grade Technological Studies course and permeates every aspect of it.

Most hard systems have within them an element that is dedicated to the control of the main part of the system. This control element may be small in relation to the whole system or it may be the main part of the system.

In many cases, the control element of a system is important enough to be regarded as a system in its own right and it is then called a *control system*. Control systems can be split into two distinct types, either of which may be controlled *manually* or *automatically*.

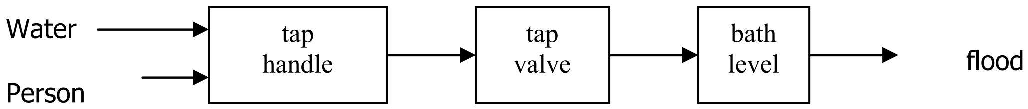
- *Manual control* is performed by the actions of humans.
- *Automatic control* is performed by technological devices (often electronic).

As part of the systems analysis we also normally consider the type of control the system provides. There are two types of control:

- ***open-loop control***
- ***closed-loop control***.

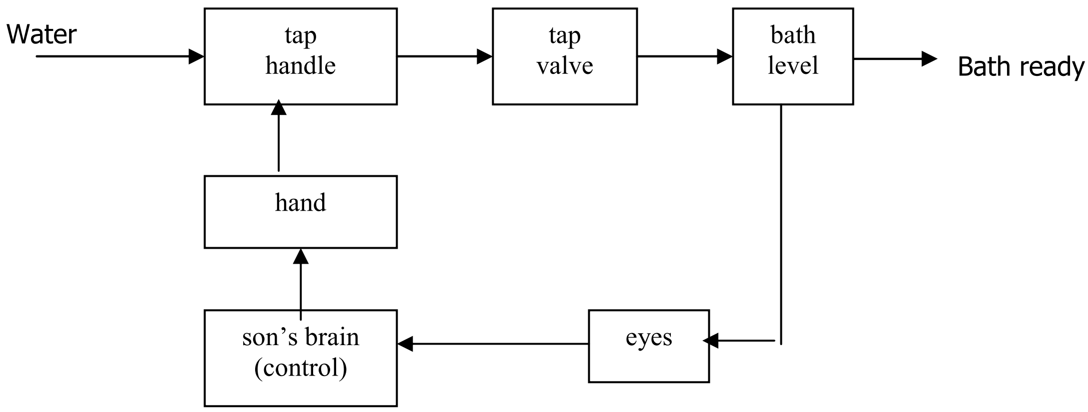
Illustration of control – filling bath water for an elderly person
An elderly person can be forgetful. Take the example of an elderly man who each morning, when filling a bath, goes through the same routine. He turns on the tap, and then watches television whilst the bath is filling, frequently forgetting that the tap is still on.

This is an example of *manual open-loop control*. The bath continues to fill, and will eventually overflow, because nobody is there to turn off the tap.



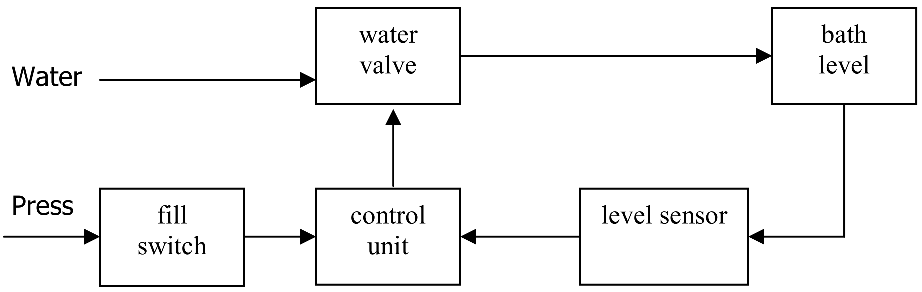
Because the bath has flooded several times recently, the elderly man's son decides to visit each morning and fill the bath. He turns on the tap, stands and watches until the bath is full enough and then turns off the tap.

This is an example of *manual closed-loop control*.



However, the son is a very busy man and cannot afford the time taken to fill the bath.

The elderly man's granddaughter studies Standard Grade Technological Studies and designs an *automatic closed-loop control* system for filling the bath. She replaces the hand-operated tap with an electrically operated valve, makes a control unit and fits a level sensor at the depth Grandad likes.



Grandad just has to press the 'fill' switch, and everything is done automatically. When the level sensor is activated by the water reaching the correct level, it feeds back a signal to the control unit, which switches off the water supply.

Clearly this illustration is extreme but it does show open- and closed-loop control in operation.

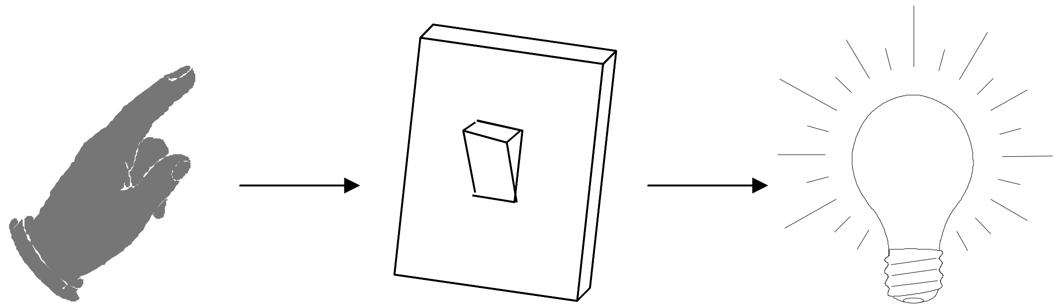
OPEN-LOOP CONTROL

At the simplest level a control system can process an input condition to produce a specified output.

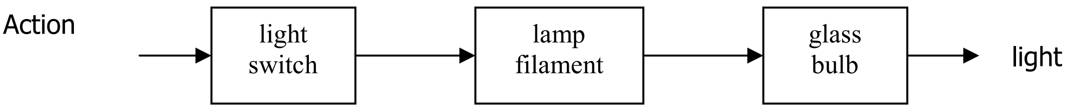
This is the simplest acceptable level of control. It is also the most common form of control system, used widely in domestic and industrial systems because it is cheap to install and simple to operate.

In open-loop control the *input* action causes a resulting *output*.

Domestic lighting systems usually have open-loop control. The input is the action of pressing the light switch and the output is light from the filament of the bulb.

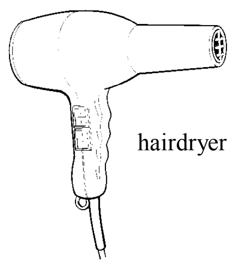


A system diagram for the light is shown below.

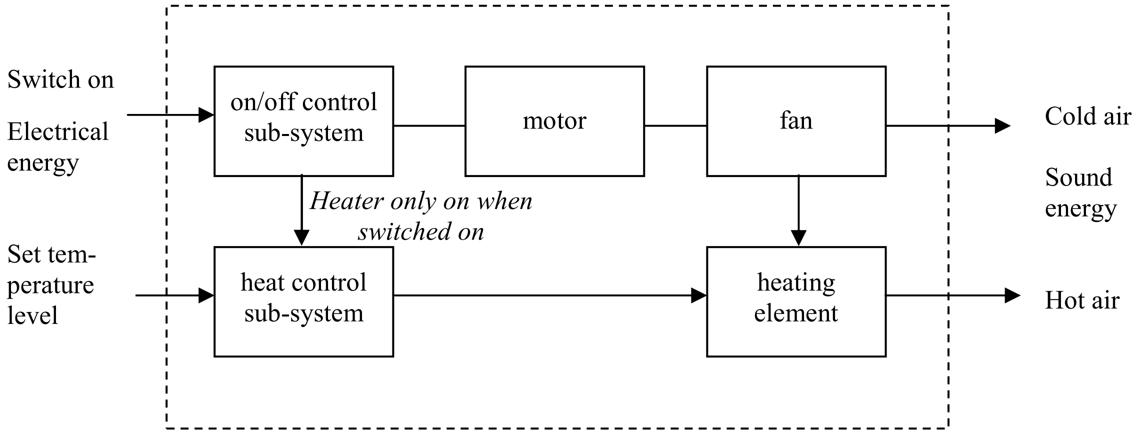


This is called an *open-loop control* system diagram. Here, it describes a *manual open-loop control system*.

Another good example of this type of control is a hairdryer.



In the hairdryer the heating element and fan motor are switched on when the appropriate switches are held down. This is shown on the sub-systems diagram on the next page.



Here the input signal from the on/off and temperature switch is processed to produce the output. The output air is not monitored or adjusted in any way and it is just blown out at whatever temperature the heater warms it to.

An *open-loop control system* is the simplest and cheapest form of control. However, although open-loop control has many uses, its basic weakness lies in its inability to adjust the output to suit the requirements.

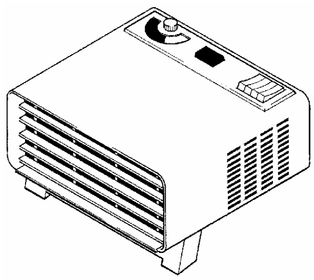
CLOSED-LOOP CONTROL

This is the most sophisticated form of control.

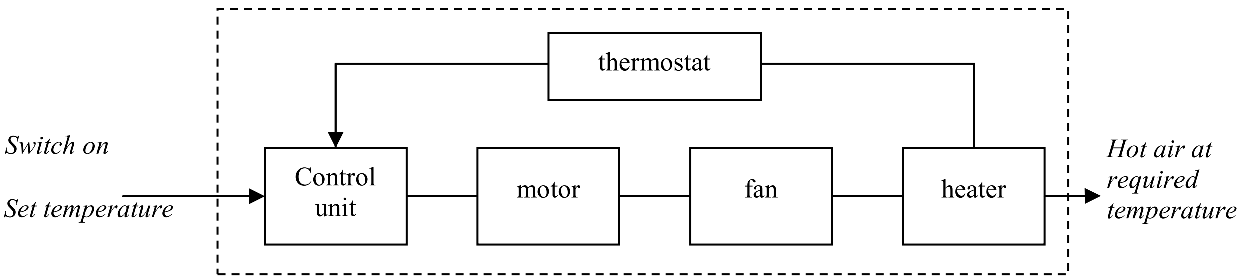
In closed-loop control *the value* of the *output* is constantly monitored as the system operates and this value is *compared* with the set (or reference) value. If there is any *difference* between the actual value and the set value (an *error*), then the *input* to the system is varied in order to *reduce* the *output error* to zero.

Closed-loop control is a more accurate system of control and at the same time more expensive. It employs *self-monitoring*, where a sensor is used to read the condition being controlled and adjust the output if necessary. This monitoring takes place through a *feedback loop*. Here an input sensor checks the output and adjusts it when it does not meet the requirements.

Closed-loop control systems are therefore capable of making decisions and adjusting their performance to suit changing output conditions. An example is a thermostatically controlled fan heater.



The sub-systems diagram for the heater is shown below.



In this example a thermostat monitors the output temperature and switches the heater on when it is too cold and off when the temperature is at the required or set level.

All closed-loop control systems include a sensing sub-system that feedbacks information to the control sub-system. The control sub-system will process this feedback signal and make a 'decision' on whether to alter the output.

Note that in closed loop systems the feedback loop is *not* necessarily a physical link between the sensor and the output. Instead the sensor monitors the *environment* that the output is controlling.

In the system diagram you should note that the *diagram* now forms a continuous loop that can be followed round repeatedly as the system operates.

This is why the system is called *closed-loop* and the comparison with *open-loop* becomes much clearer.

The line representing data flow from the output back to the input is called the *feedback loop* and the signal from the output back to the control sub-system is sometimes called the *feedback signal*.

A closed-loop system can always be identified by the presence of a feedback loop.

An open-loop system never has a feedback loop.

Assignment 5

Draw a sub-systems diagram for a fridge with a thermostat, control unit, coolant pump, door switch and light.

Assignment 6

1. State three examples of manual open-loop control. Draw a system diagram for each one and show the system boundary.

2. State three examples of manual closed-loop control. Draw a system diagram and show the system boundary.

3. State three examples of automatic closed-loop control. Draw a system diagram and show the system boundary.

Assignment 7

Explain the following terms when applied to control systems:

- open loop
- closed loop

Assignment 8

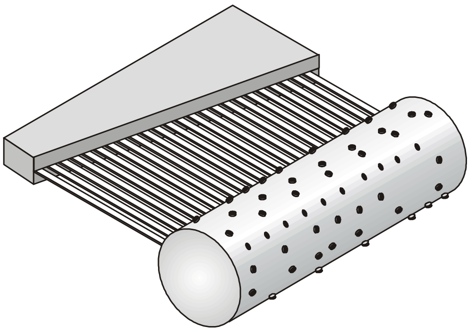
1. Draw a systems diagram showing the manual closed-loop control system for a cyclist steering a bicycle.
2. Draw a systems diagram showing the automatic closed-loop control system for the cruise-control in a car.

In each case show the system boundary and identify the feedback loop.

SEQUENTIAL CONTROL SYSTEMS

Sequential control is used where the outputs are required to follow a fixed cycle of events; that is to switch on or off in a particular sequence.

An interesting example of sequential control was that used in music boxes. Pins sticking out on the drum are arranged to produce notes; as the drum rotates the notes are played in the correct sequence to produce a tune.



A more modern example of sequential control is a robot arm used to weld cars together on a large production line.

Most modern sequential control systems use electronics or microcontrollers. For example, microcontroller chips are used to control traffic light sequences and for the timing of clocks and defrosting programmes.

SUMMARY

You should now understand, and be able to write a one sentence definition of, the following terms (or draw a suitable diagram).

Input
Process
Output
Boundary
Systems diagram
Universal System
Open loop systems
Closed Loop systems
Feedback
Sub-systems
Automatic/Manual systems