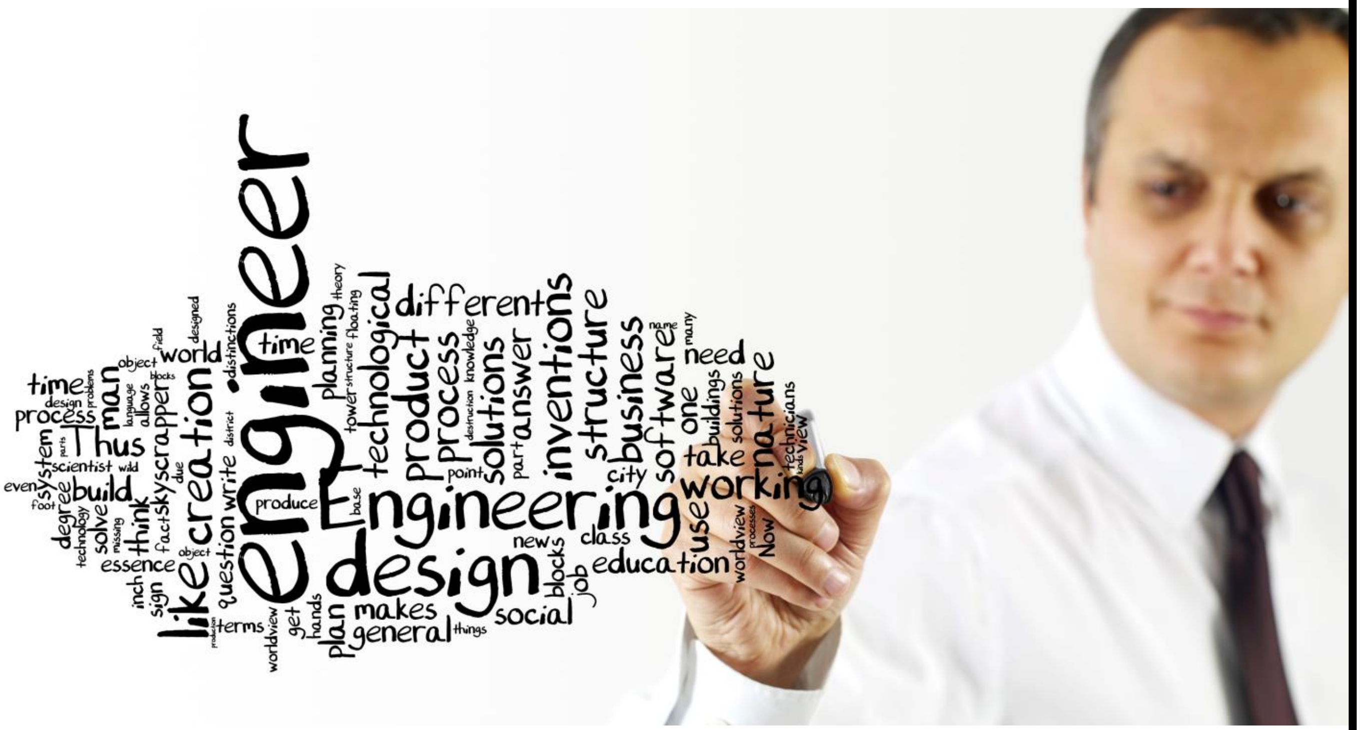
HIGHER ENGINEERING SCIENCE

Engineering Systems



Name ______________________

Class ______________________

Teacher ______________________

FAMAM EXTENDITE FACTIS

Ellon Academy
Technical Faculty

Learning Intentions

- To learn about complex engineering systems
- To learn about the effects (positive and negative) that engineering has
- To learn about emerging technologies and the impacts it will have on future projects
- To learn about systems diagrams and know what closed loop, 2 state and proportional feedback mean
- To learn about energy and efficiency within a system

Success Criteria

I can present a critical analysis of an engineered solution to a contemporary problem by:

- Describing clearly the nature of the problem
- Describing some social and economic impacts of the solution
- Describing clearly some environmental impacts of the solution
- Identifying and describing emerging technologies which may impact future developments

I can Research and describe a complex engineering system by:

- Analysing the needs being met by the system
- Identifying sub-systems, and describing the function of each and how they interact
- Producing system and sub-system diagrams
- Explaining the role of feedback in the system
- Carrying out an energy audit of the system

To access video clips that will help on this course go to **www.youtube.com/MacBeathsTech**

What exactly is an Engineer?

Engineering is one of the most important and vast jobs in the world today. It is behind everything – from the food you eat, the shoes you wear on your feet and the makeup on your face.

Engineers shape the word we live in, by designing, creating, testing, and improving almost every product or process you can think of!

Did you use deodorant this morning? (I HOPE SO!!!) Chemical engineers will have created and tested out the product in a laboratory. What about your new Playstation or X-Box? Electronics engineers played a major role in making it. The bus you travelled to school in? Automotive engineers have worked in a team to make it happen.

Engineering plays a big part in a vast array of businesses throughout Scotland, The UK and the world. Aberdeen is seen as the "Engineering Capital of Europe" because of the oil and renewable energy industry, but becoming an Engineer can lead you into many industries you may not have thought about such as space exploration, transport, medicine, technology, food, fashion, construction and much more.

With engineering, you can follow your interests – if sport is your thing, you can work as an engineer improving the performance of new tennis rackets or sports clothing. If you want to make a difference to people's lives, you can help develop artificial limbs or work in a team to rebuild a community following a natural disaster.

Engineers work in lots of different settings – in offices, laboratories, recording studios, hospitals, underground and at sea. The variety of the job is one of the most exciting things

http://www.tomorrowsengineers.org.uk/Post_16/

Although there is a huge array of paths that an engineering career could lead you, there are four main branches within engineering: civil, mechanical, electrical and chemical. These can then be broken down further into more complex specialisms.

Civil Engineering

Structural Engineering
Concerned with structural integrity and how it affects an item's function or safety

Transport Engineering
Concerned with the planning, design, operation and management of transportation within a project

Geotechnical Engineering
Concerned with the behaviour of earth and similar materials

Environmental Engineering
Concerned with protecting the environment within an Engineering project

Mechanical Engineering

Automotive Engineering
Concerned with the engineering of devices that control and propel vehicles

Aerospace Engineering
Concerned with the development of aircraft and spacecraft

Acoustic Engineering
Concerned with sound and vibrations

Thermal Engineering
Concerned with the heating and cooling of equipment and enclosed spaces

Electrical Engineering

Electronic Engineering
Concerned with the design of Analogue and Digital circuits

Computer Engineering
Concerned with the design of computer systems and the programming of microcontrollers

Power System Engineering
Concerned with the generation, transmission, distribution and utilization of power and the electrical devices connected to electronic systems

Chemical Engineering

Material Engineering
Concerned with the materials used within an engineering solution

Process Engineering
Concerned with the design, function and control of chemical processes

Molecular Engineering
Concerned with manufacturing molecules or creating new manufacturing materials using them

You will discover that although there are distinctly different branches of engineering, these disciplines can overlap and encompass several different specialisms. These engineers also frequently come together to work in teams for different engineering projects.

Consider the Falkirk Wheel. This is a rotating boat lift that was designed to connect the Forth and Clyde Canal and the Union Canal which is almost 80m above. Within the designing and creating of this many engineers were involved, such as Mechanical Engineers who would have to create the mechanisms inside to allow this to move safely and efficiently, Structural Engineers who would have make sure the actual structure is strong enough to safely lift the boats, with people and cargo inside. Chemical Engineers would be involved to ensure the material is strong enough to do the job, and that it won't be eroded or damaged by being in frequent contact with water. Electrical Engineers would also be involved in this engineering challenge to make sure there is enough power to actually do this lifting, as well as designing the lighting systems and other electrical projects within the project.

Impacts of Engineering

Within any Engineering Challenges or solutions we also have to consider the impacts that these will have on the population and the surrounding areas, which can be positive as well as negative.

We have to consider **social impacts**:

- Is there increased employment or training opportunities created through this engineering project?
- Will there be improved infrastructure because of it?
- Will there be traffic disruption because of its creation?
- Will there be disturbances because of noise?

We also have to consider **Environmental impacts**:

- Could this provide habitats for wildlife?
- Will there be a risk of damaging animal habitats or ecosystems?
- Will there be a loss of green belt? Will nature be destroyed/damaged because of it?
- Will there be a risk of danger to animals because of this engineering solution?
- Will there be more demand on water or power services?

We also have to consider **Economic impacts**:

- Will this Engineering solution bring money into the local area through tourism or other means?
- Will this attract other companies to invest in the area?
- Will this employ more people, meaning more money spent in the local area?

Task 1

A reflow oven is used to melt solder into printed circuit boards, and is a good example of the fact that the complexity of designing and producing many products have changed the traditional roles of engineers.

The area of Electrical Engineering now has specialist categories in analogue, digital, power and programming.

For one of these areas describe three specialist skills the engineer would have.

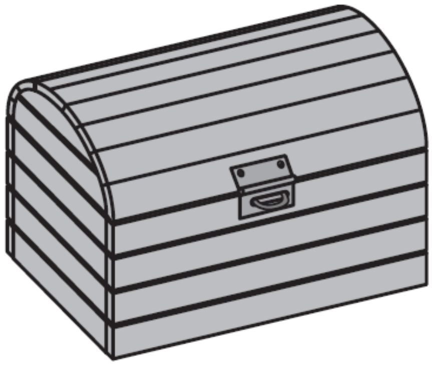
1.

2.

3.

Task 2

The research and development department of a toy company has appointed an engineering team to redesign the wooden treasure chest shown. The new version will have an electronically controlled locking system and may be constructed from a different material.



a) The development team includes a mechanical engineer and an electrical/electronic engineer. For each type of engineer, state **one specialist skill** and **one piece of specialist knowledge** which they could contribute to the redesign.

Mechanical engineer

Specialist skill

Specialist knowledge

Electrical/electronic engineer

Specialist skill

Specialist knowledge

b) Suggest an alternative material which could be used instead of wood to construct the treasure chest, and explain why it would be an improvement.

Task 3

Aldi has had so much success in Ellon it has decided to increase its floor area by one third. The current building is a modular framework assembly.

Describe the role of 2 different engineering disciplines in this expansion project.

Engineer 1

Engineer 2

Task 4

A large distribution warehouse for an online marketing company is being planned. The facility is to be largely automated as shown below. A civil engineer has been asked to outline some of the social and economic impacts this may have on the local community.

Describe **one positive** and **one negative social impact**, and **one beneficial** and **one harmful environmental impact** that the project might have locally.

Positive social impact

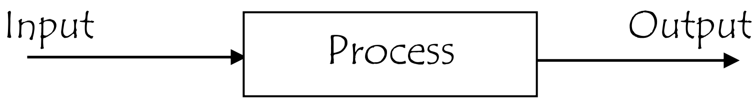
Negative social impact

Beneficial environmental impact

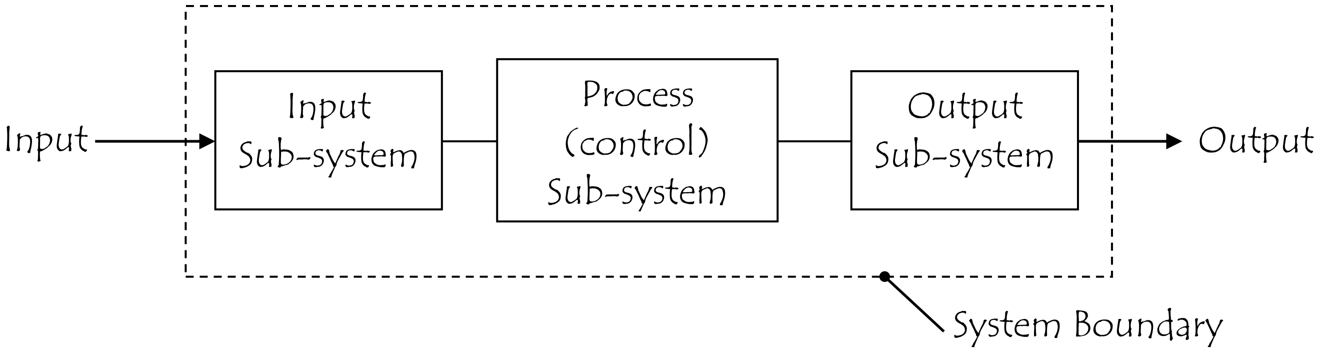
Harmful environmental impact

Sub-System Diagrams

The **Universal System Diagram** we all know is a very basic way for working out how technology works.

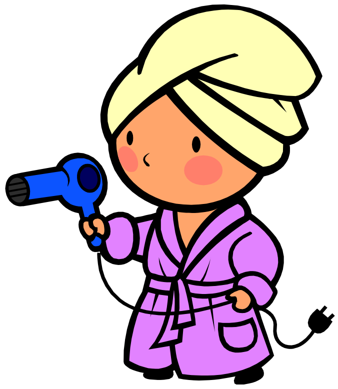


To get a greater understanding of the system we have to break it down into more detail. To do this we draw something called a **Sub-System Diagram**.

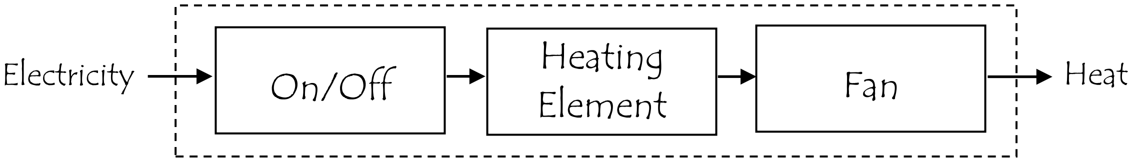


The sub-system diagram shows the *internal* detail of the system. Each box, called a **sub-system**, can be thought of as a system within a system and has its own input and output. The dashed line around the sub-system is called a **system boundary** and this marks the area of interest to us. The 'real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

By using a sub-system diagram it shows more detail of how a system works. For example, a hair dryer.



By doing a universal diagram not much information can be gathered on how the system actually works, but breaking it down into the sub-system diagram, it is clearer how the technology works.



Task 5

Draw the sub-system diagrams for:

a) A Toaster

b) A Treadmill

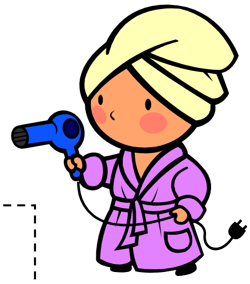
c) An Electric Window Blind

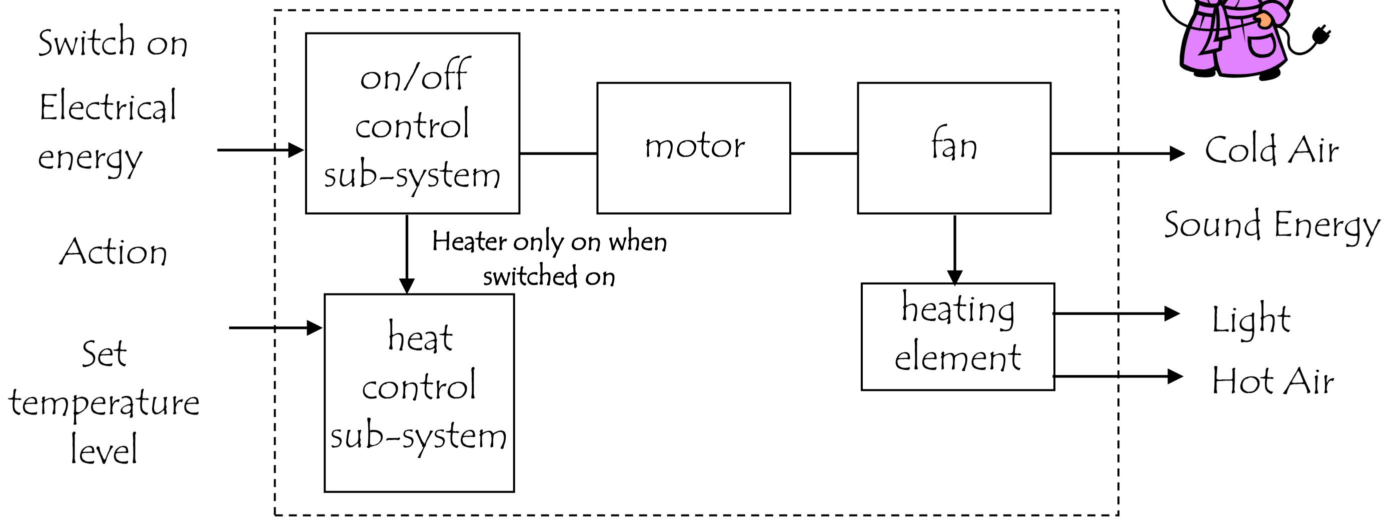
d) Hair Straighteners

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.

A more in depth sub-system diagram for the hair dryer is shown below.





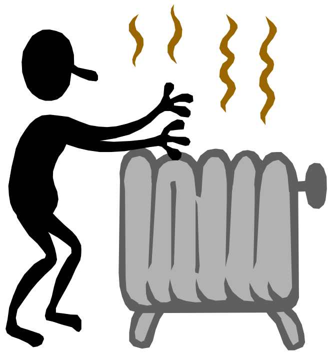
Here the input signal from the on/off and temperature switch is processed to produce the output. The output air is not monitored or adjusted in any way and it is just blown out at whatever temperature the heater warms it to.

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.

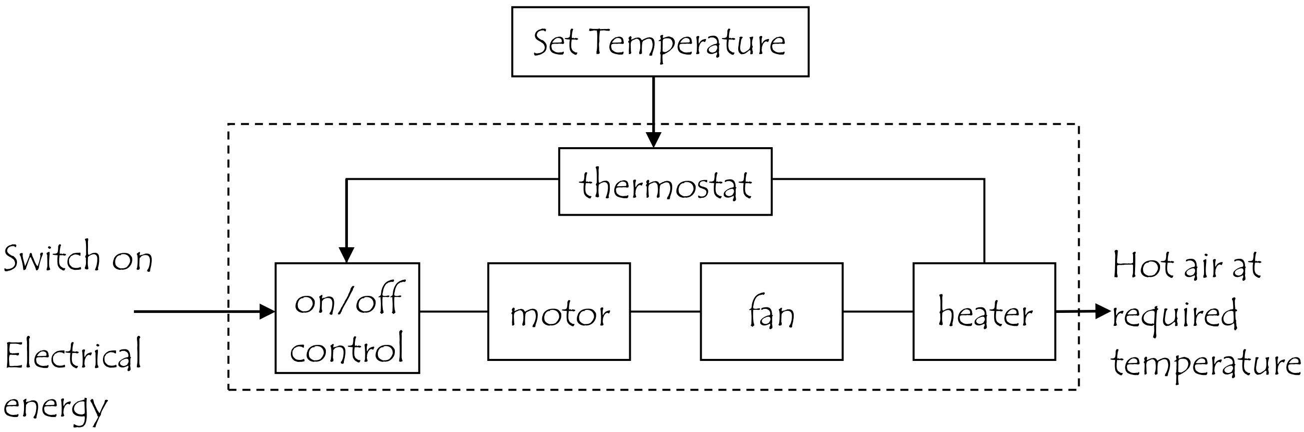
Closed Loop Control

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 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.



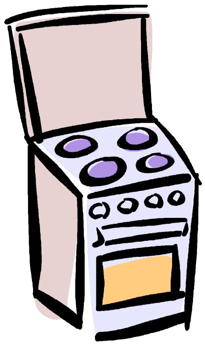
All closed-loop control systems include a sensing sub-system that feedbacks information to the control sub-system. The control sub-system will process this feedback signal and make a 'decision' on whether to alter the output

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.

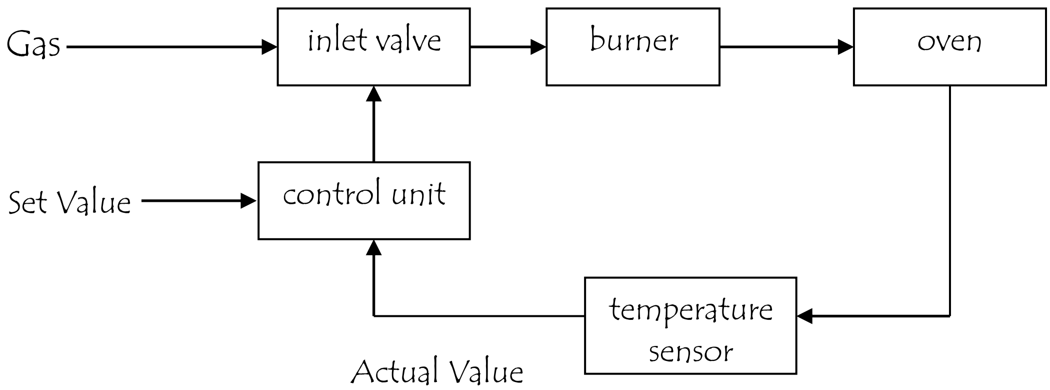
Control Diagrams

The purpose of closed-loop control is to ensure that the output is maintained at, or as closely as possible to, the desired level. For example, the temperature is set on a dial on the control panel of a cooker will be a closed loop control.

A temperature sensor constantly monitors the output (oven temperature) and produces a signal representing the *actual* temperature.



The *actual* signal is fed back to a control element, which compares it with the *set* signal. Any difference between *set* and *actual* signals produces an *error signal*. This causes the control element to either decrease or increase the input (gas flow) in order to reduce the temperature error to zero.

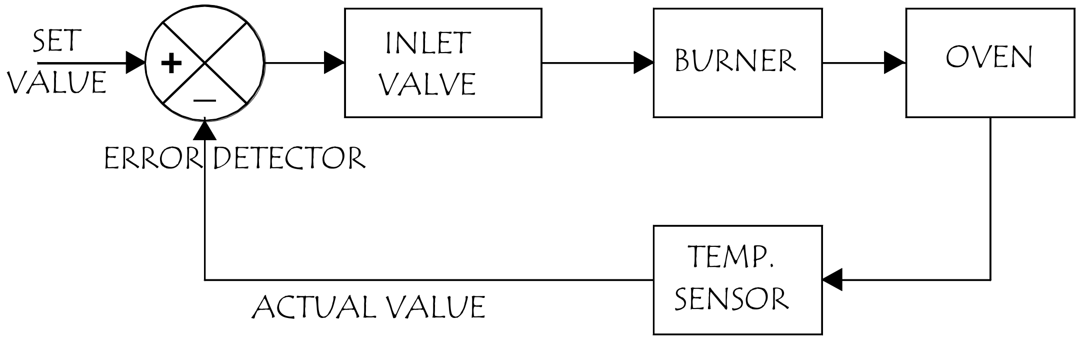


The control unit shown in the system diagram above performs two functions.

- The set and actual values are compared.
- Any resulting error is used to vary the input sub-system as required.

Error Detectors

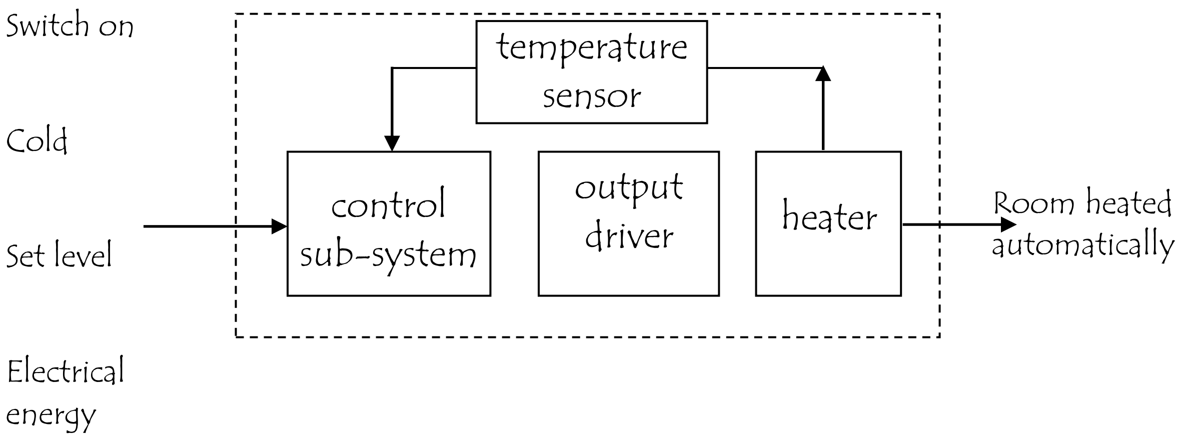
A more detailed diagram, sometimes called a control diagram, may be drawn. This shows the control unit in more detail.



The control diagram includes an *error detector*. It compares the actual value to the set value. If it differs, it changes the input to compensate.

Task 6

A sub-systems diagram for an automatic heater is shown below. Redraw the system to include an error detector.



Task 7

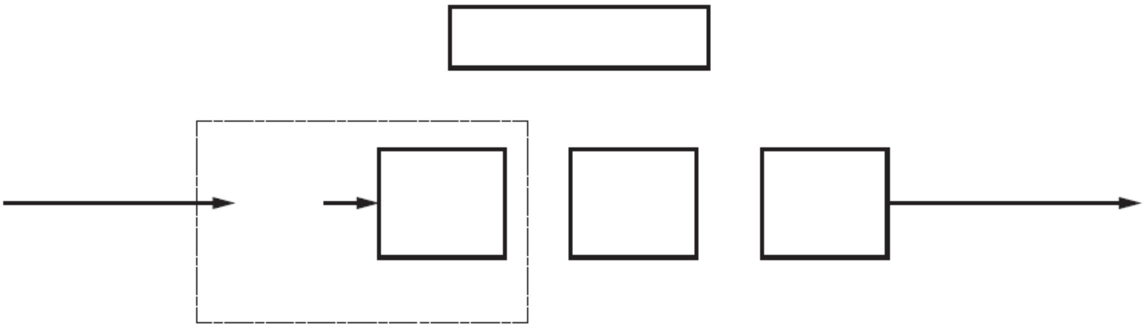
a) Describe the differences between an open loop and closed loop control system. Give examples of real products in your explanations, including systems diagrams for these examples.

b) Describe the purpose of a feedback sensing sub-system in a closed loop control system.

Task 8

The laser level device shown below has an automatic electronic control system. The system uses an accelerometer to sense whether the laser beam is horizontal. If it is not horizontal, a motor adjusts the laser levelling platform position.

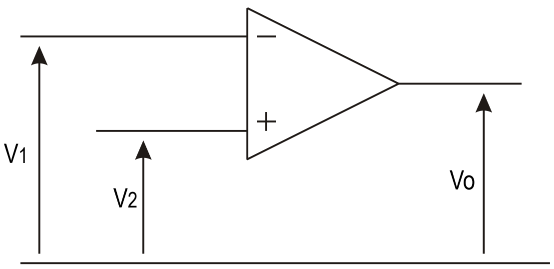
a) Complete a labelled control diagram for this device.



b) Describe how the system works.

Analogue Control Systems

Many control systems involve processing analogue signals such as heat, light and movement. Therefore analogue closed loop control systems require analogue processing devices such as the **operational amplifier (op-amp)**.



One of the most common control applications involves using the op-amp as a **comparator**. In it's simplest form a comparator just compares two voltage signals, V1 and V2, V1 being the feedback, and V2 being the **reference voltage** to compare against. If V1 is higher than V2 the output, Vo, is 'low', if V1 is lower than V2 the output is 'high'

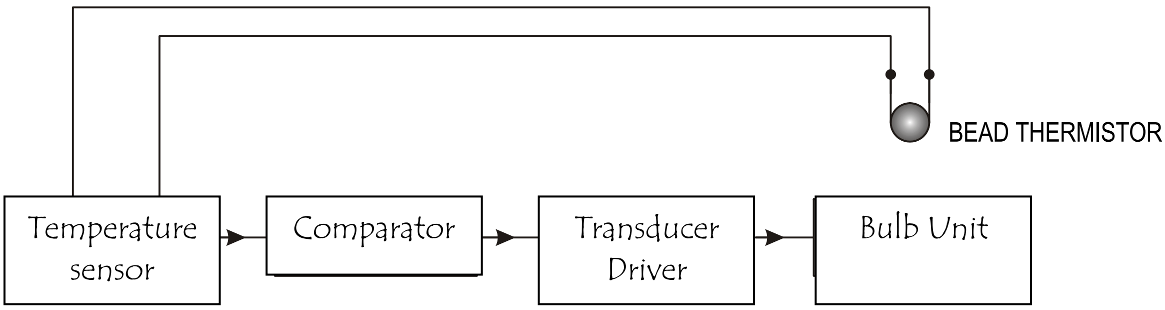
As the output is either 'high' or 'low', any system using a comparator op-amp is known as a **Closed Loop two state system.**

The comparator may be used as an error detector in closed loop systems, where it compares a feedback voltage to a reference voltage.

http://goo.gl/KC6bgk

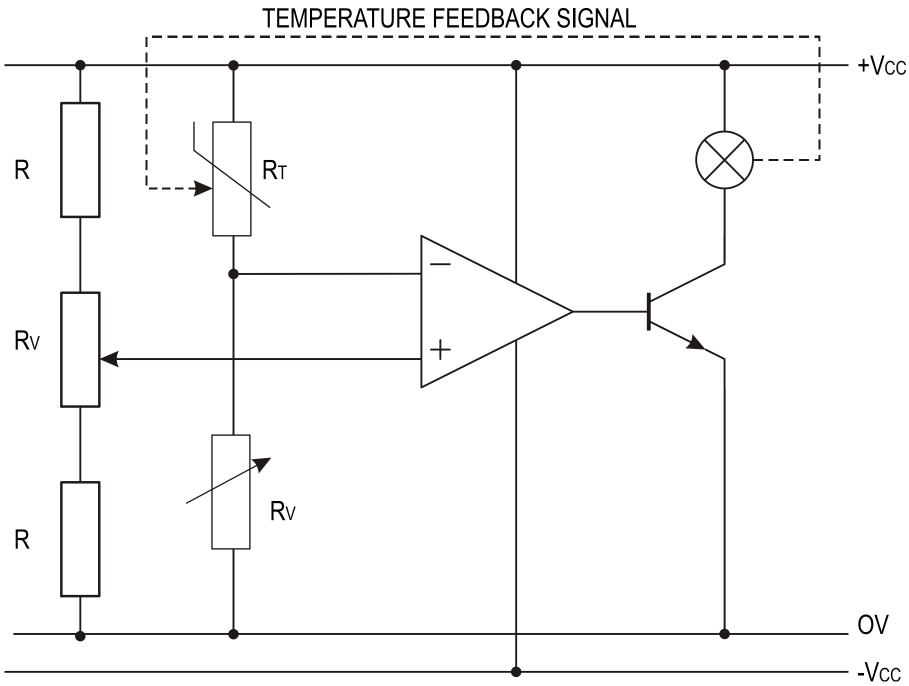
Task 9

The block diagram below simulates an automatic heating system. When the bulb heats up the temperature rise is detected by the bead thermistor, which sends a feedback signal back to the comparator.



a) Draw a sub-system diagram for the system

An electronic circuit diagram of the system is shown below.



Task 9 (continued)

The variable resistor, R_{V1} (connecting to the non-inverting input of the op-amp) is used to set the **reference level** (or threshold). This sets the desired temperature of the bulb.

Build the circuit using modular electronics boards. Calibrate the system to the following performance criteria:

- When the bulb heats above the reference level the thermistor should sense the temperature and send a signal to the comparator which will switch the bulb off.
- When the bulb cools below the reference level the bulb should switch on again.
- The system should operate continuously.

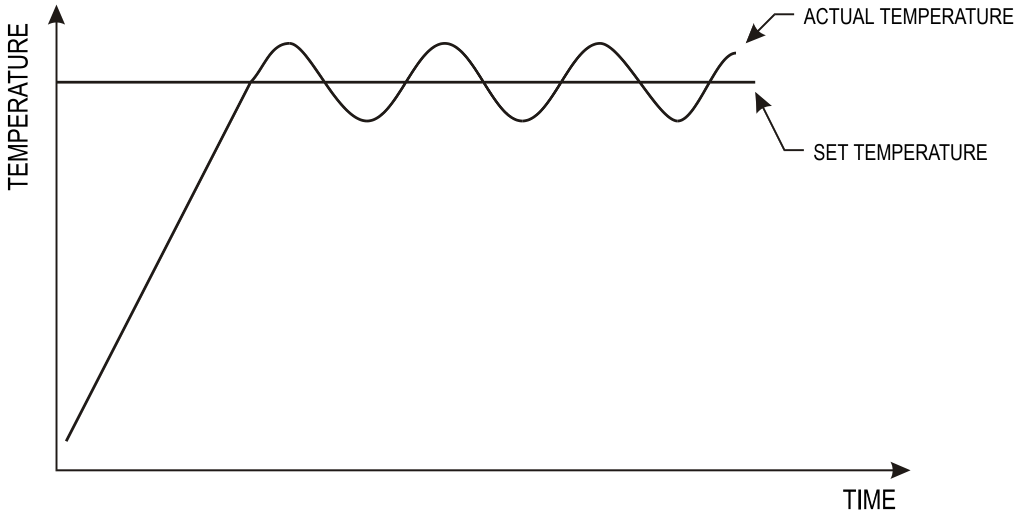
b) Describe how the circuit operates.

c) Explain clearly how you calibrated the system.

Negative and Positive Feedback

Negative Feedback

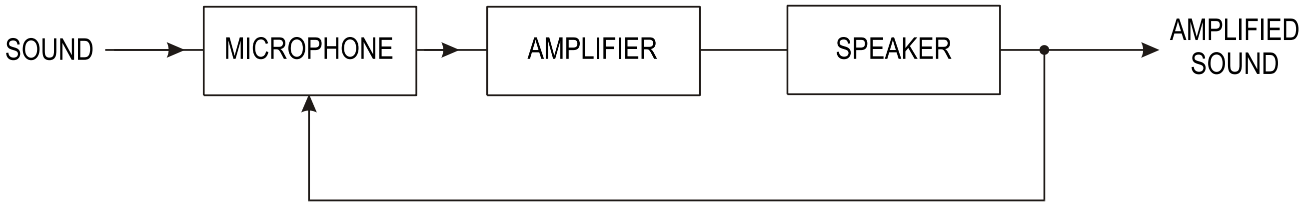
The purpose of closed loop control is to ensure that the output is maintained, as closely as possible, to the desired output level. In the case of a central heating system, a graph of the temperature in a room might appear as in the graph below.



As can be seen from the graph, the control system is constantly trying to pull the temperature of the room back towards the set temperature level by reducing the error. This type of control uses **negative feedback** to reduce the error.

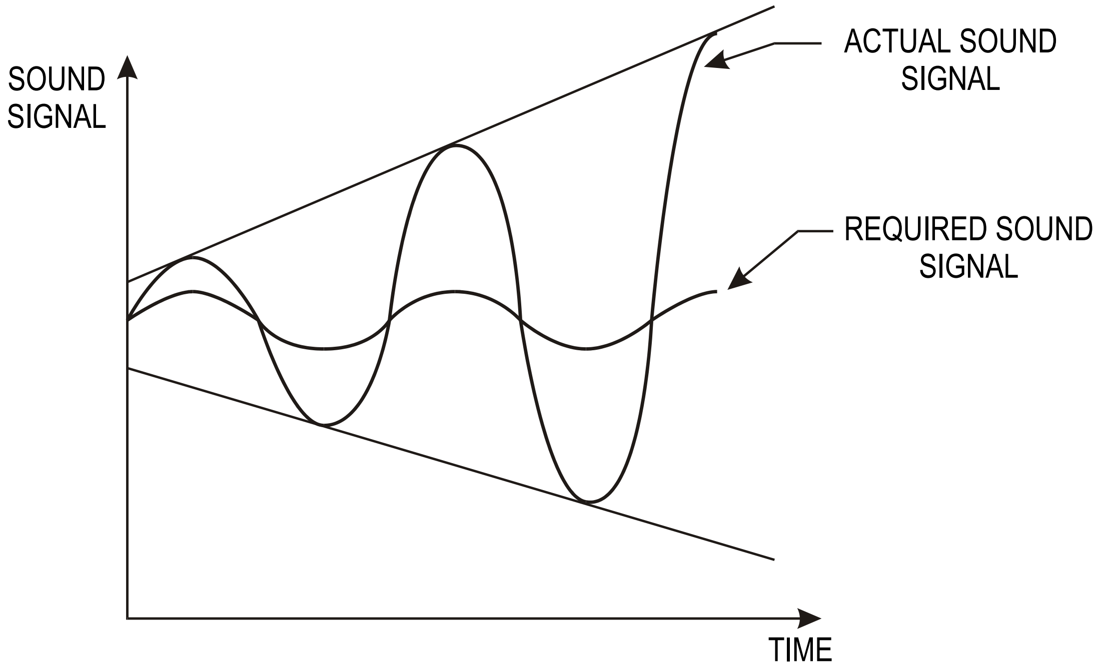
<u>Positive Feedback</u>

The opposite effect can be created by reinforcing the error, as can sometimes happen with public address systems when the microphone is held too close to the speakers.



AMPLIFIED SOUND FEEDBACK TO SPEAKER

A sound is picked up by the microphone, amplified, and then output through the speaker. The amplified sound is then picked up, re-amplified and so on. The net result is a high pitch sound, which can be represented by the graph below.



This is an example of **positive feedback**. Although positive feedback does have some useful applications, negative feedback is far more widely used in control systems.

Task 10

In your own words explain the following terms:

OPEN LOOP

CLOSED LOOP

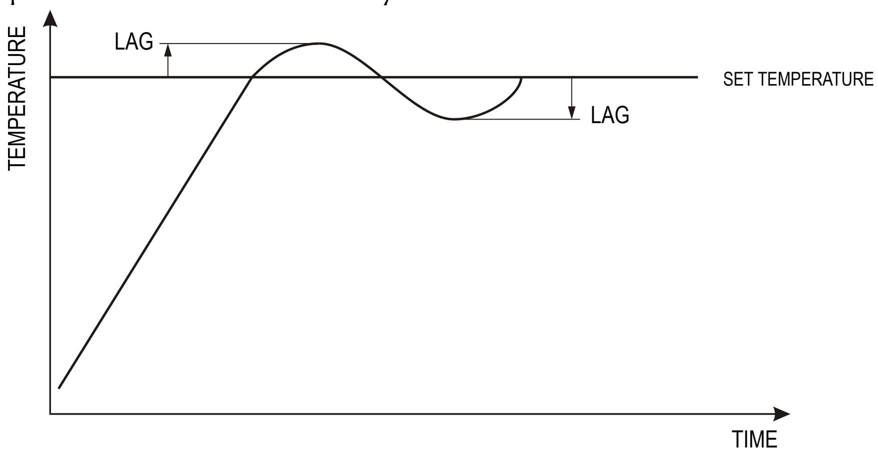
NEGATIVE FEEDBACK

POSITIVE FEEDBACK

ERROR DETECTOR

Proportional Closed Loop Control

The main problem with comparator based control systems is that there is a time 'lag' built into their operation. This means that the desired output state is never actually reached.



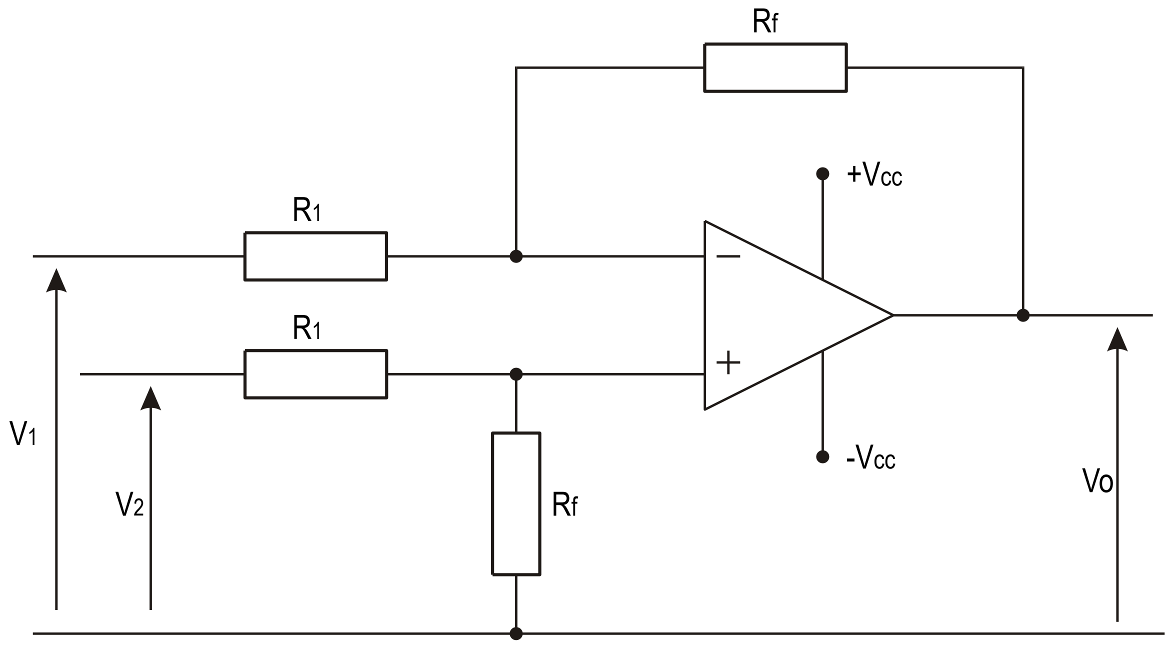
The graph of a temperature control system above shows the effect of lag.

When the reference level ("set temperature") is reached the heating system will continue to heat the room for a short period until the heating element cools down. This raises the temperature in the room above the set or desired temperature level. When the temperature in the room cools down to the reference level the heating system will be switched on. Whilst the heating element is reaching its operating temperature the room continues to cool below the reference level.

Whilst in heating systems the presence of lag does not present a problem, and in fact presents some advantages, in many other applications the inaccuracy of this form of control is not acceptable.

Difference Amplifiers

Proportional closed loop control systems are applied as a means of proving a more accurate form of analogue closed loop control. The operation of proportional control is based around the op-amp configured as a **difference amplifier**.



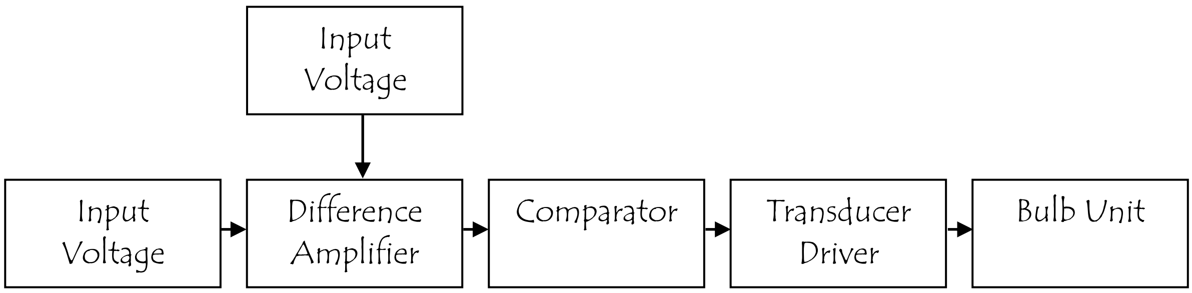
The **difference amplifier** amplifies the difference between the **reference level** and the **feedback signal**. Therefore if there is a large error there will be a larger output signal than when there is a small error. This help prevents the 'overshoot' and 'time lags' seen in the comparator based systems.

Task 11

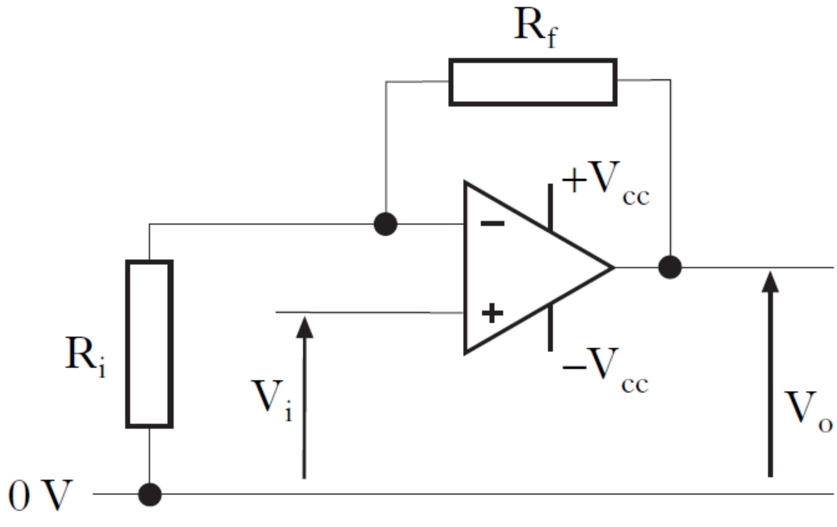
Using Modular Electronic Boards design a circuit that simulates a warning device that could be used in the driver's cab of a London Underground Train.

The train has 2 locomotives (one at the front and one at the back) in which are both operated by one driver sitting at the front of the train. Both Locomotives MUST go at the same speed.

When you have built a system, take a photo and stick below

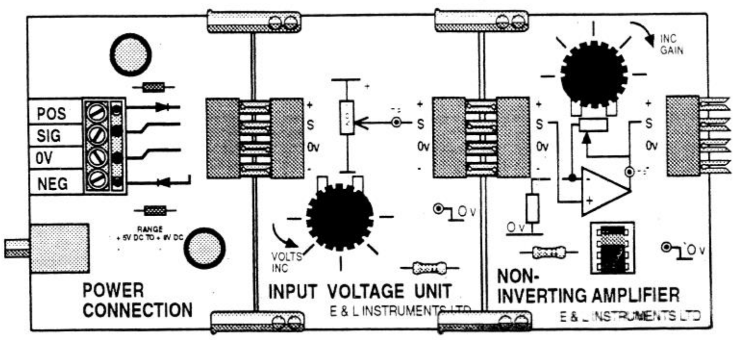


Non-Inverting Amplifiers



Task 12

Using Modular Electronic Boards you are going to investigate the Non-Inverting Amplifier. Build the circuit below and set the input voltage control to 1v and the gain control to 2v.



a) Keep the gain control at this setting and measure the output voltage when you increase the input voltage to 2v. What happens?

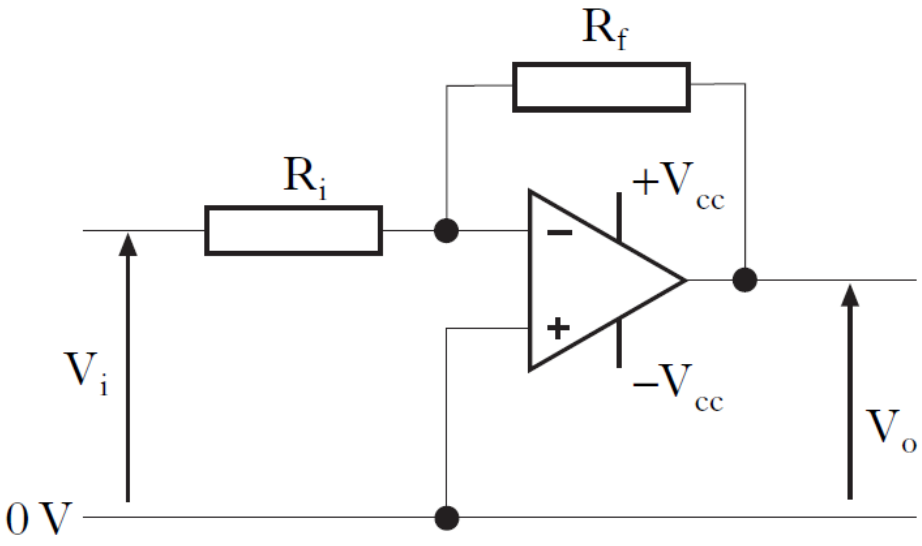
Task 12 (continued)

b) Continue to increase the voltage in steps of 0.5v and measure the output voltage each time. Complete the table for the results of your investigation.

Input Voltage	Gain Voltage	Output Voltage
1v	2v	
2v	2v	
2.5v	2v	
3v	2v	
3.5v	2v	
4v	2v	
Max.	Max.	

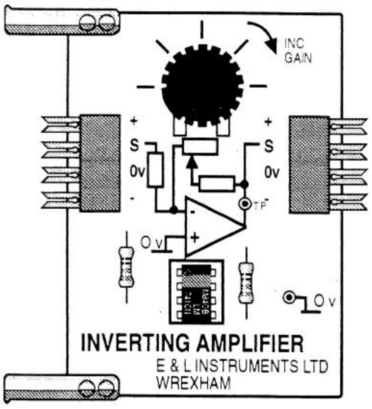
c) What does the non-inverting amplifier do? Use the circuit diagram to help you describe it.

Inverting Amplifiers



Task 13

Using Modular Electronic Boards you are going to investigate the Inverting Amplifier. Build the circuit below and set the input voltage control to 1v and the gain control to 2v.



a) Keep the gain control at this setting and measure the output voltage when you increase the input voltage to 2v. What happens?

Task 13 (continued)

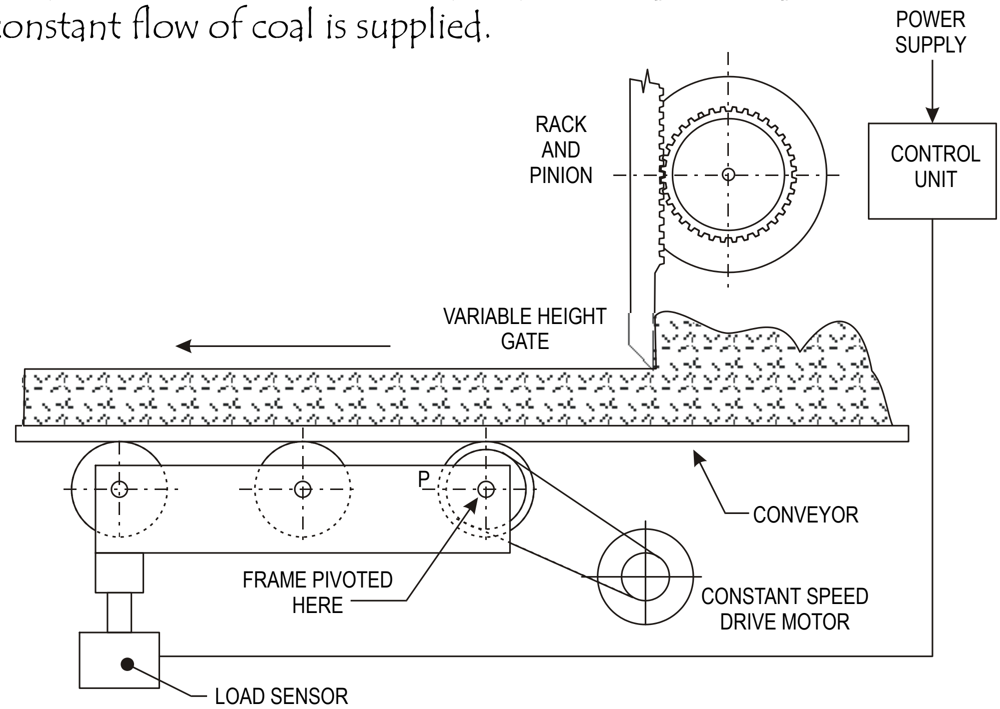
b) Continue to increase the voltage in steps of 0.5v and measure the output voltage each time. Complete the table for the results of your investigation.

Input Voltage	Gain Voltage	Output Voltage
1v	2v	
2v	2v	
2.5v	2v	
3v	2v	
3.5v	2v	
4v	2v	
Max.	Max.	

c) What does the inverting amplifier do? Use the circuit diagram to help you describe it.

Task 14

A proportional control system is used to regulate the flow rate of coal onto a conveyer belt. The system should sense the weight of coal on the conveyer belt and automatically adjust the gate height to ensure that a constant flow of coal is supplied.



a) Draw a systems diagram of the flow rate control system.

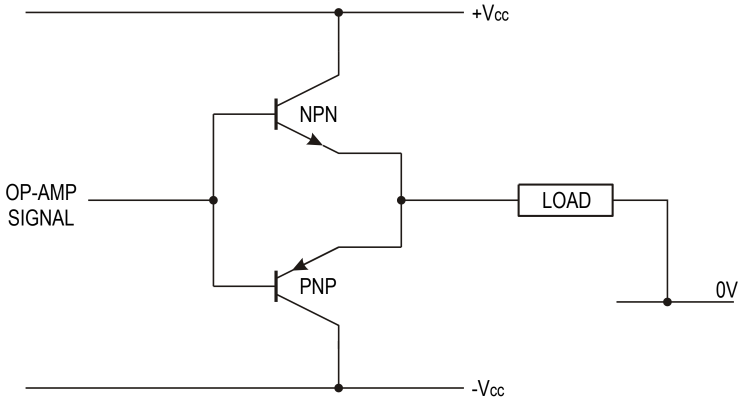
b) Explain the term 'proportional control'.

c) Name the configuration of op-amp used in proportional control systems.

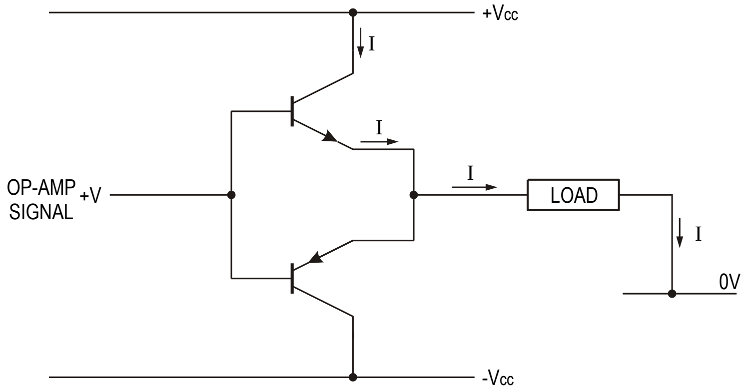
Drivers

In National 5 when we used a driver we would have used a transistor. This was useful as it acted as an 'electronic switch', saturating when 0.7v passed through. As we get into more complicated electronics this no longer becomes suitable. Instead we can use a combination of transistors known as a **push-pull follower** analogue driver circuit that allows the motor to spin in both directions. An op-amp cannot source sufficient current to drive most output components, so the dual rail push-pull follower is required to drive the output components.

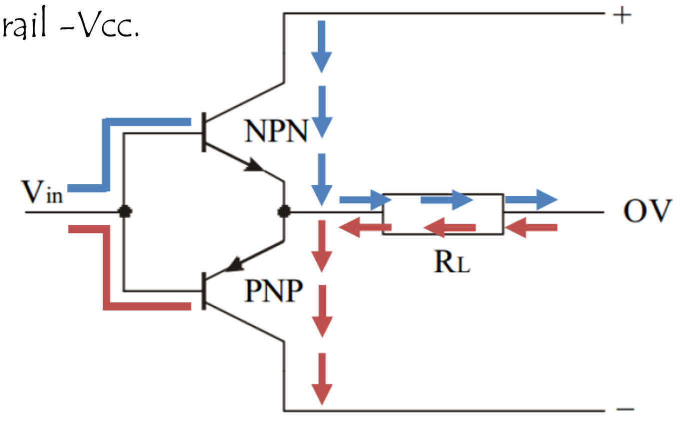
The dual rail push-pull follower is based around a two transistor circuit as shown.



When the signal from the op-amp is positive the NPN transistor will switch on, and current will flow through the load from the positive supply rail, +Vcc, to the ground rail, 0V.

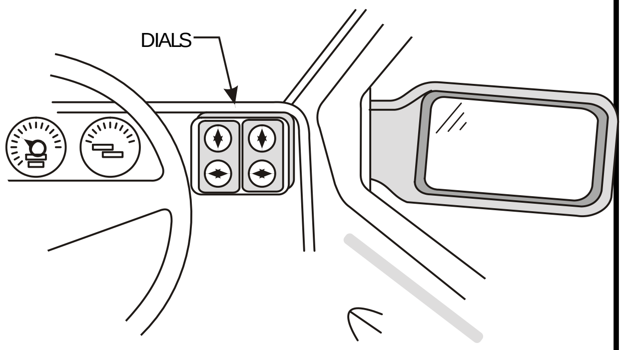


When the signal from the op-amp is negative the PNP transistor will switch on and current will flow through the load from the ground rail, 0V, to the negative supply rail -Vcc.

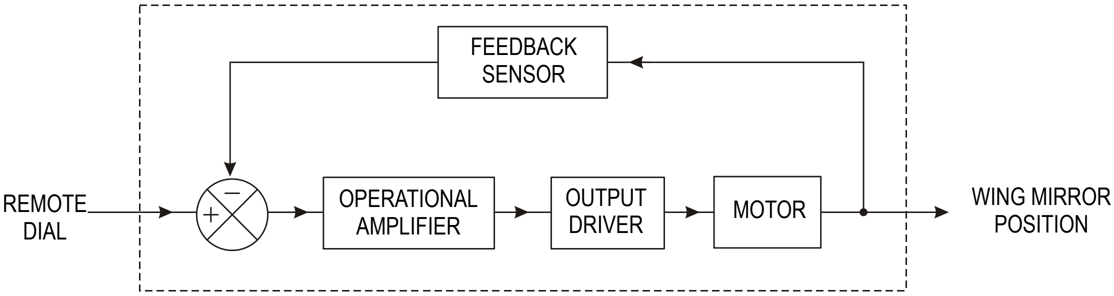


Task 15

The figure illustrates a system for controlling the wing mirrors on a car by adjusting remote dials on the dash.



A control diagram of the system for rotational movement in the X-axis (one mirror) is shown in the figure below. Similar systems are used for the Y-axis and for the other mirror.



a) With reference to the control diagram, explain clearly how the system operates.

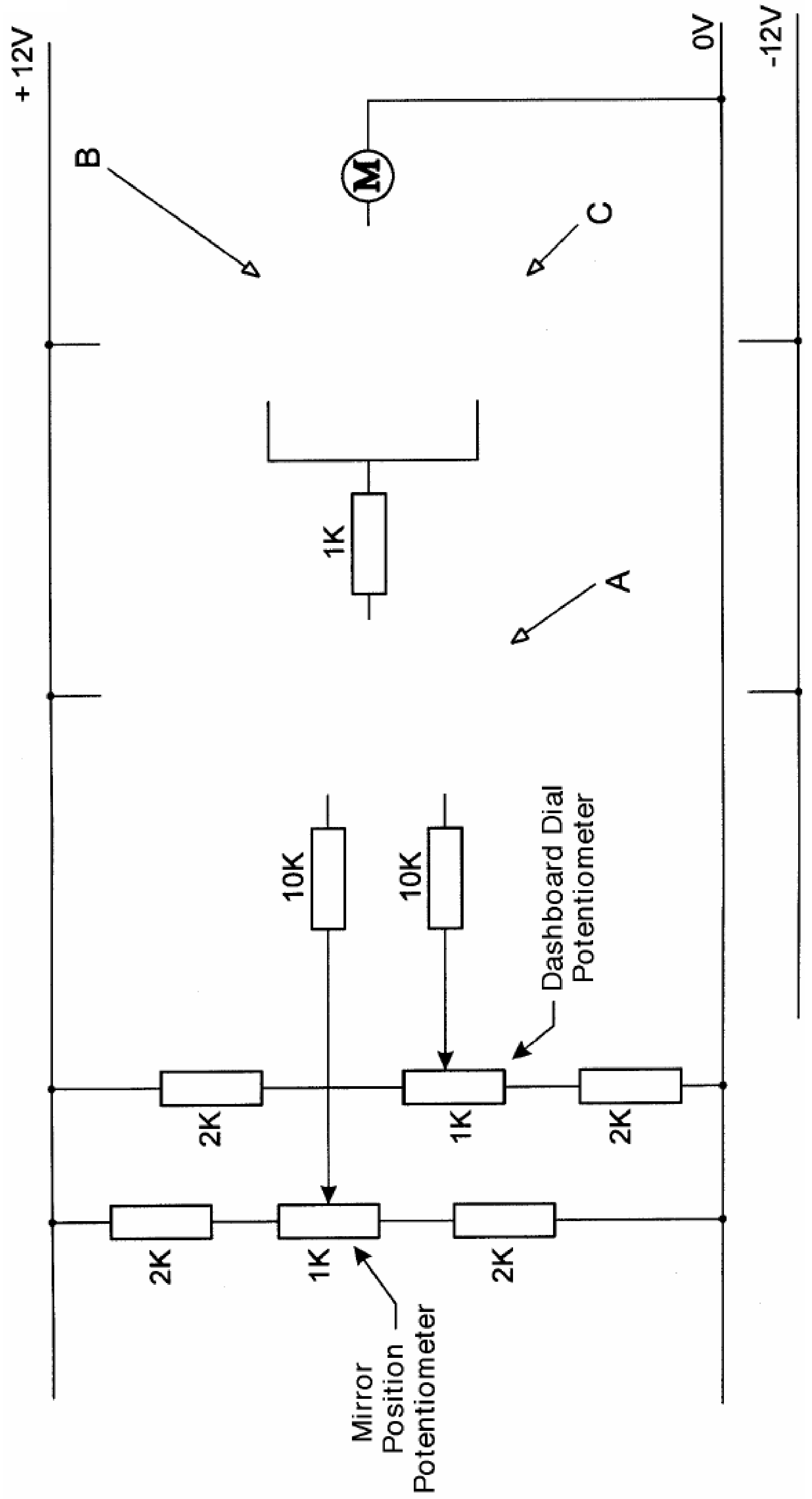
b) Name the type of control used in this system.

c) Name the configuration of op-amp required.

d) State two reasons why the op-amp cannot be used to drive the motor directly.

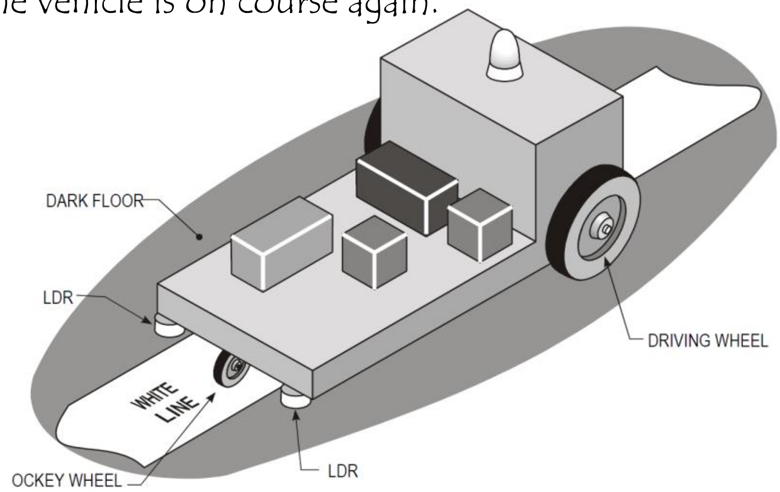
Task 15 (Continued)

e) Show the correct components required to complete the circuit at points A, B and C. Use the correct symbols and add appropriate connections for these components.



Task 16

An automatic guided vehicle (AGV) is to be used in a factory for moving parts from one production area to another. The AGV will follow a white line painted onto the floor. It has two drive motors, one at each of the two rear wheels. The vehicle has two LDR-based light sensors as shown in the diagram. Note that they are positioned just **outside** the line. If the vehicle moves off course, so that a light sensor moves **over** the line, it causes the drive motor on that side of the vehicle to stop, until the vehicle is on course again.



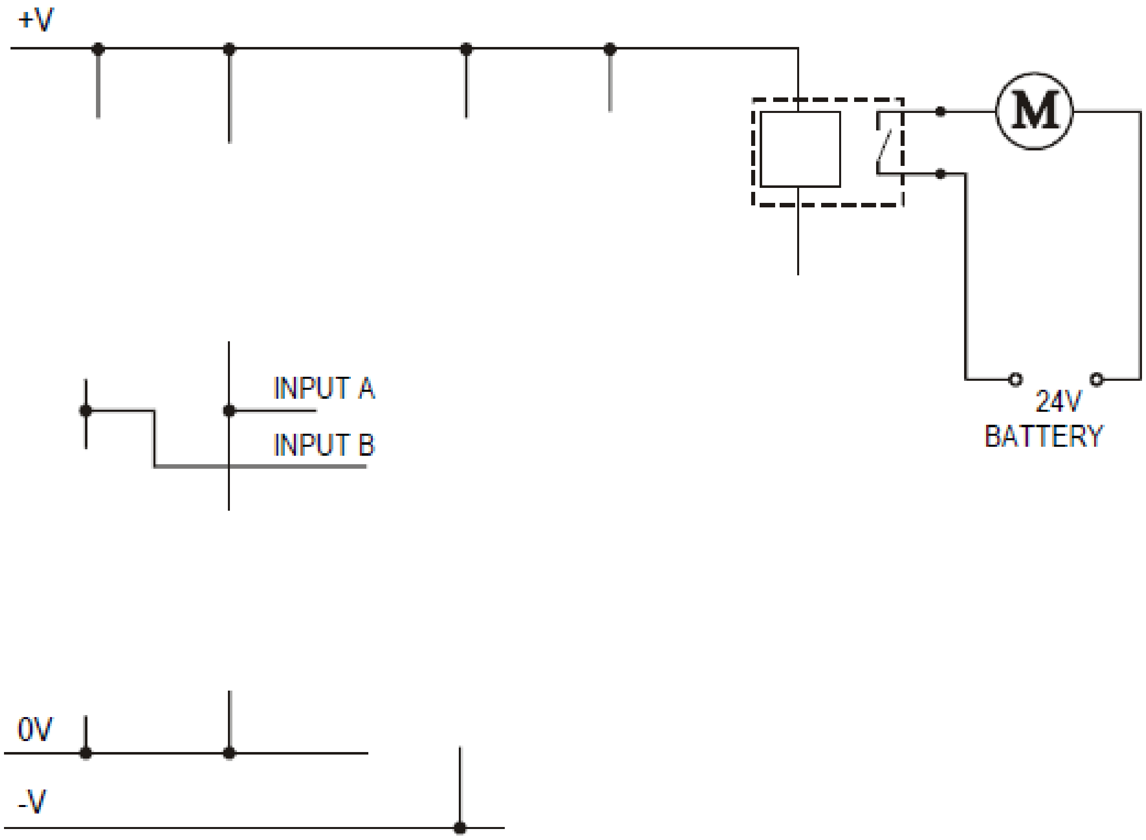
a) Name the type of closed loop control used in this system.

b) Draw a block diagram of the electronic control system required to control **one** of the drive motors.

c) Name the configuration of the operational amplifier suitable for this type of closed loop control.

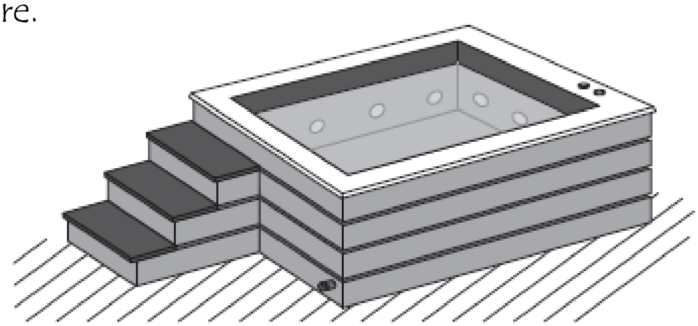
Task 16 (Continued)

d) Complete the circuit diagram shown below, including the op-amp in the required configuration. Show all appropriate components for the circuit and all connections.



Task 17

A hot tub uses a two-state closed-loop control system to regulate the water to a desired temperature.



a) For the hot-tub temperature control system:

(i) draw a control diagram;

(ii) State the name of the operational amplifier (op-amp) configuration used in this type of control.

b) Sketch a graph of temperature against time. Show a desired temperature and show how the temperature of the water changes as it is heated from a lower temperature.

Task 17 (continued)

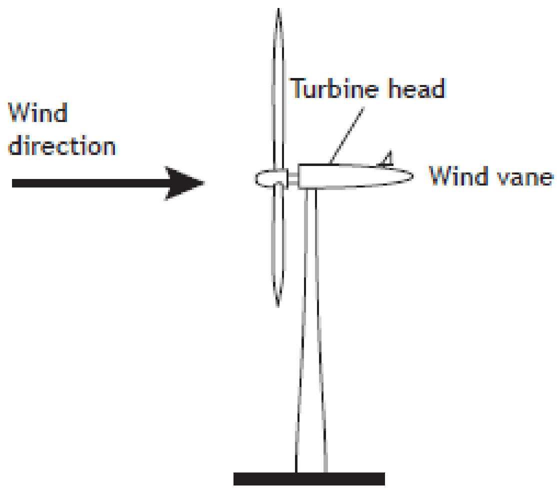
c) The control system is replaced by a closed-loop proportional control system.

(i) State the name of the op-amp configuration used in this type of control.

(ii) Sketch a graph of temperature against time showing the ideal response of a proportional control system, as the water is heated from a temperature below the required value.

Task 18

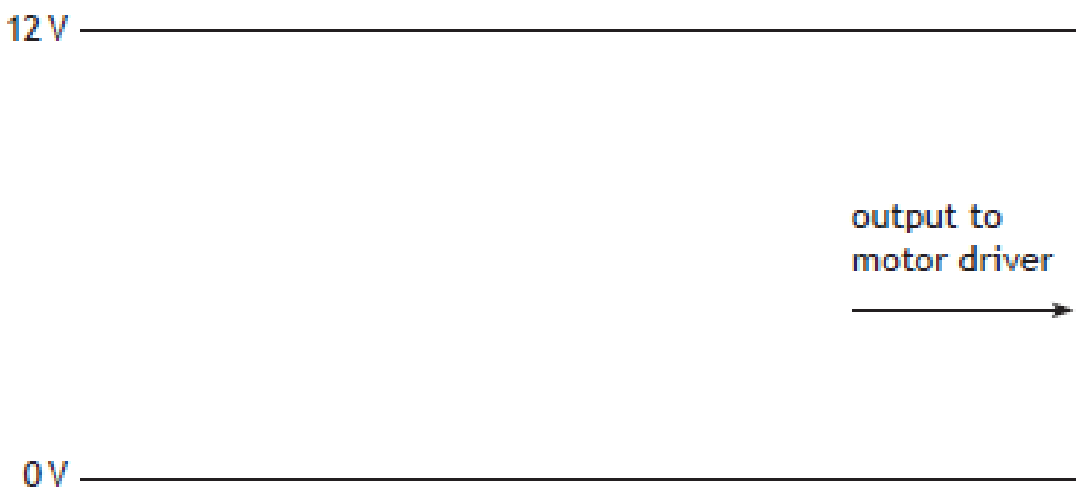
An electronic control system keeps the wind turbine (shown below) facing into the wind. The wind direction is sensed by a wind vane connected to a potentiometer. The signal from the potentiometer is compared with a reference voltage, and the turbine head is rotated by a motor to face the wind. As the turbine head moves closer to the wind direction, the motor slows and then comes to rest.



a) State the full name of the type of control used.

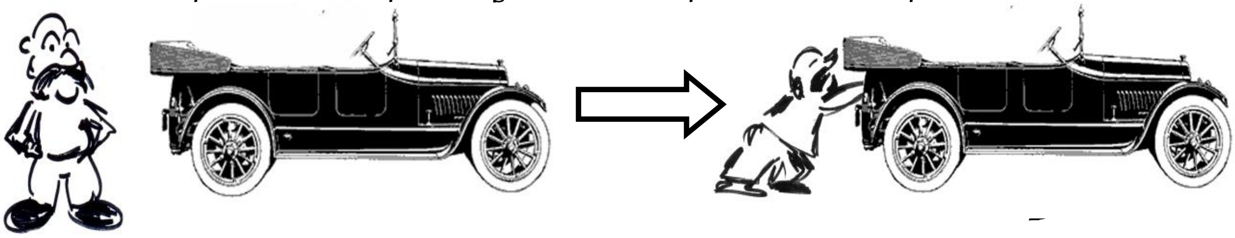
b) State which configuration of operational amplifier would be used in this electronic control system.

c) Complete a circuit diagram for this electronic control system. Show all components and connections.



Work Done within a system

When a force is used to move an Engineering system, 'work' is said to be done.
An example of this is pushing a car from position A to position B.



The amount of work you will do depends on how difficult the car is to push (the size of the force) and how far it has to be pushed (the distance). The amount of work that has to be done can be calculated using the formula:

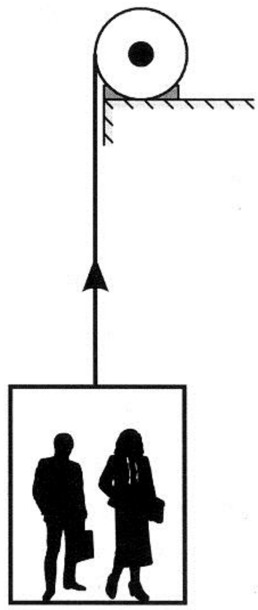
$$W = F \times s$$

(Work Done = force applied x distance moved)

Force is measured in **Newtons (N)**
Distance is measured in **metres (m)**
The unit for measuring **work** is therefore **Newton metres (Nm) or joules (J)**

Example

A lift raises a mass of 1000kg to the next floor in the Union Square shopping centre, which is 20m up. Calculate the minimum amount of work that must be done by the winch.



Remember – the gravitational pull is always 9.8

Weight of lift = mg (mass x gravitational pull)
= 1000 x 9.8
= 9800 N

Work = force x distance
= 9800 x 20
= <u>196,000 Nm</u>

Calculating Energy

Calculating Electrical Energy

The formula for calculation electrical energy is:

$$E_e = ItV$$

(Electrical Energy = Current x time x Voltage)

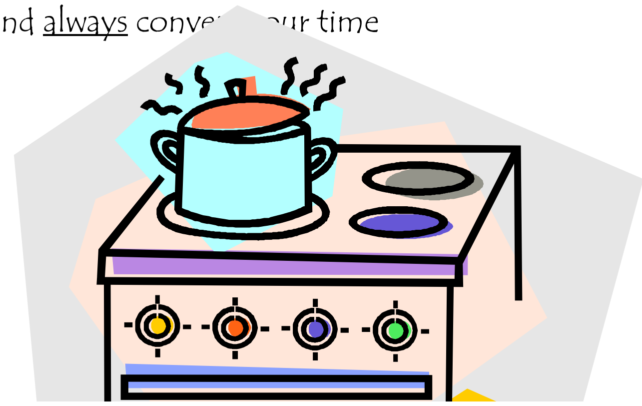
Current is measured in **amps**
Time is measured in **seconds**
Voltage is measured in **Volts**

Example

An electric hob in home economics has an operating voltage of 230 volts with a current of 5 amps. Calculate how much electrical energy has been used if the hob takes 5 minutes to heat up a pot of soup.

$E_e = ItV$
$= 5 \times 300 \times 230$
$= 345{,}000$ Joules
$= 345$ kJ

Remember and <u>always</u> convert your time into seconds



Calculating Kinetic Energy

Kinetic energy is calculated using the formula:

$$E_K = \frac{1}{2} mv^2$$

(Kinetic energy = ½ x mass x velocity²)

The object is measured in **Kg**

*Velocity is measured **in m/s***

Example

If a 90kg go-kart travels at 40m/s, how much kinetic energy does it possess?

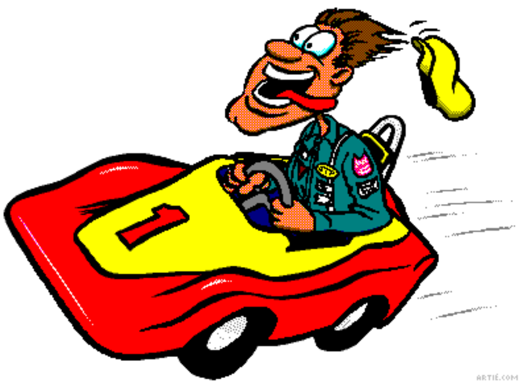
$E_K = \frac{1}{2} mv^2$

$= \frac{1}{2} \times 90 \times 40^2$

$= \frac{1}{2} \times 90 \times 1600$

= 72,000 joules

= 72 kJ



Calculating Potential Energy

The formula used for calculating potential energy is:

$$E_P = mgh$$

(Potential energy = Mass x gravity x height)

Mass is measured in **Kilograms (Kg)**
Height is measured in **metres (m)**

Example

Metal piles are driven into the ground using a Pile Driver. This consists of a 500 kg driver, which is raised by a winch to 3m high, then released.
Calculate the potential Energy stored when the driver is lifted.

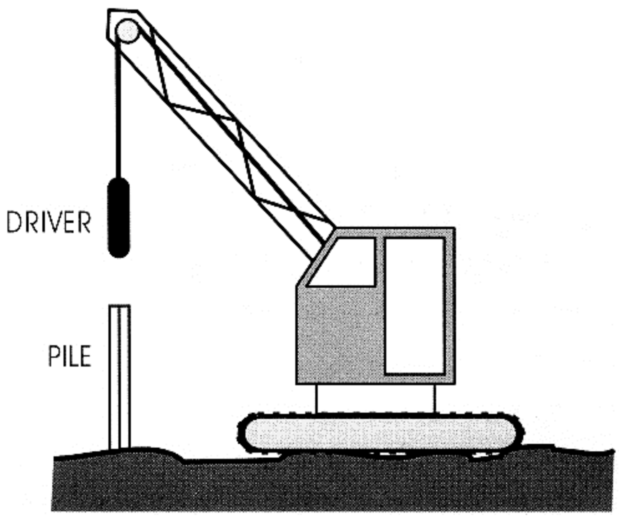
Remember – the gravitational pull is always 9.81

$E_p = mgh$

$= 500 \times 9.8 \times 3$

$= 14,700$ joules

$\underline{\underline{= 14.7 \text{ kJ}}}$



http://www.youtube.com/watch?v=ROeowItLVSc

Calculating Heat Energy

The formula for calculating heat energy is:

$$E_h = mc\Delta T$$

(Heat Energy = mass x heat capacity of material x change in temp.)

Mass (m)is measured in Kg

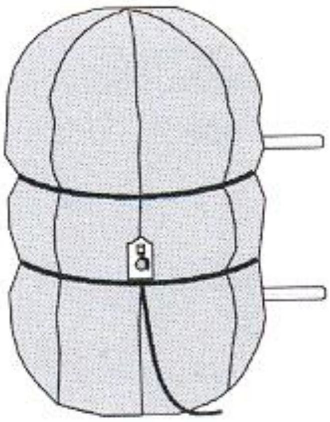
Change in temperature (ΔT) is measured in Celsius (°C) or Kelvin (K)

The specific heat capacity (c) of a substance, is the amount of energy required to raise the temperature of 1kg of the material by 1 K

Example

A hot water tank contains 200 litres of water at 18 °C.
Calculate how much energy is required to raise the temperature of the water to 50°C.

The specific heat capacity of water is 42000 Kj/kgK (Or otherwise Stated). If it does not state in the question it can be found in your data booklet



Change in temp. = 50-18
= 32

$E_H = mc\Delta T$
$= 200 \times 4200 \times 32$
$= 26880000J$
$= \underline{26.9MJ}$

http://www.youtube.com/watch?v=mUC-1iBt_lk

Calculating Strain Energy

Strain Energy is the energy which is stored in a body because it is stretched or compressed. For example the work which is done in compressing a spring is stored in the compressed spring as strain energy. When the spring is released it will expand back to its original shape and size.

The formula for calculating strain energy is:

$$E_s = \frac{1}{2} Fx$$

(Strain Energy = force x distance of compression/extension)

Force (F)is measured in Newtons (N)
Compression/Extension (x) is measured in metres (m)

Example
A toy catapult is being stretched to fire a missile. If it is pulled back 40cm at a force of 150 Newtons, what is the Strain?

$E_s = \frac{1}{2} Fx$
$= 0.5 \times 0.40 \times 150$
$= 26816000J$
$= \underline{\underline{26.8MJ}}$

Calculating Power

Power is a measure of the rate of energy transfer. It gives an indication of how quickly the energy is changed from one form to another.

Power is calculated using this equation.

$$P = E/t$$

Power = Energy transfer ÷ time

Power is measure in **watts (W)**
Energy transfer is measured in **joules (J)**
Time is measured in **seconds(s)**

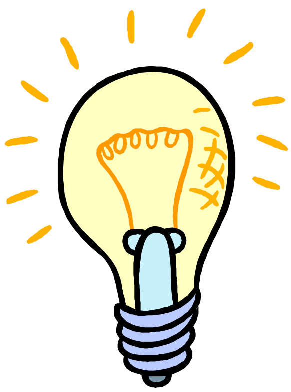
Example

If an electric light bulb uses 60kJ of energy in 10 minutes what is the power rating of the bulb?

P = E/t

= 60Kj / 10 minutes
= 60,000 / 600 (10 minutes x 60 seconds)

= <u>100 watts</u>



Efficiency of a System

Although we know energy cannot be destroyed, and that the energy output from a system is equal to its input, not all the energy is used efficiently.

When an energy conversion takes place there is always an energy change that we do not desire – usually in the form of heat sound or friction from the moving parts of the mechanism.

It is possible to look at how well an energy system is operating by calculating its efficiency. The efficiency of an energy transformation is a measure of how much the input energy appears as useful as the output energy.

To work out the energies going in and out the system we have to use the following calculations:

Electrical Energy

$E_e = ItV$

(Electrical Energy = Current x time x Voltage)

Kinetic Energy

$E_K = \frac{1}{2} mv^2$

(Kinetic energy = ½ x mass x velocity^2)

Potential Energy

$E_P = mgh$

(Potential energy = Mass x gravity x height)

Heat Energy

$E_h = mc\Delta T$

(Heat Energy = mass x heat capacity of material x change in temp.)

The efficiency can then be calculated using the following equation:

$$\eta = \frac{E_{out}}{E_{in}}$$

$$\left(\text{Eficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \right)$$

<u>Note</u> – η is the ratio of output to input energy.
<u>This can never be greater than 1.</u>

In order to convert η to a percentage, it has to be multiplied by 100

<u>Example</u>

An electric lift rated at 110V, 30A raises a 700kg load to a height of 20m in 2 minutes.
By considering the electrical energy input and the potential energy gained by the mass, determine the percentage efficiency of this energy transformation.

<u>Remember</u> – translate the time into seconds!

The **input Energy** is electrical, so…

E_E = ItV
= 30 x 120 x 110
= 396kJ

The **output Energy** is potential so…

E_P = mgh
= 700 x 9.8 x 20
= 137200

$$\eta = \frac{E\ out}{E\ in} = \frac{\text{potential energy}}{\text{electrical energy}} = \frac{137.2}{396} = 0.346$$

Percentage efficiency = 0.346 x 100% <u>= 34.6%</u>

Task 19

A typical tram has a mass of 38 tonnes when fully loaded. (1 tonne = 1000 kg). It can accelerate to its top speed of 15 ms^{-1} in 10 seconds. During this acceleration, its electric motors draw a current of 1500 A at 750 V.

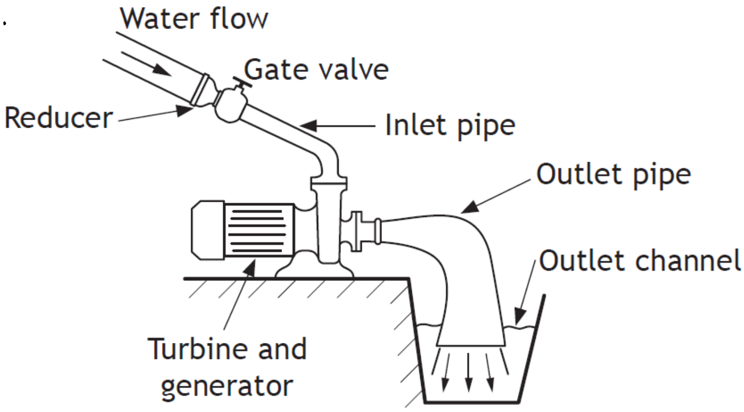
a) Calculate the efficiency of the tram during this acceleration.

b) Suggest where the energy losses will occur in the system, and so suggest some areas for research into improving the overall efficiency.

c) Draw an Energy Audit of the system showing all input and output energy

Task 20

An energy engineer is carrying out an audit on the micro-hydro system shown.



The engineer measured the electrical output from the generator to be 22 A at 230 V. The mass of water flowing through the inlet pipe into the generator was 2500 kg every second at an average flow rate of 3·2 ms−1.

a) Calculate the efficiency of the system.

b) Explain why it is impossible to achieve 100% efficiency in any system.

c) Describe **one** modification that could be made to this system to improve its efficiency.

Task 21

The water in a hot tub has a mass of 1200 kg.

a) Calculate:

(i) The heat energy required to raise the temperature from 22°C to 26°C.

(ii) The input electrical energy to the water heater if it is 82% efficient.

(iii) The current supplied to the water heater if it is rated at 230 V and the water is heated for 1 hour.

The hot tub was found to have an overall efficiency of 64%.

b) Describe **two** ways in which the efficiency of the hot tub could be increased.

Task 22

A vending machine, which dispenses hot drinks, heats one cupful of water (0.15kg) from 30°C to 90° C.

The heating element operates from a 240 volt supply and has a resistance of 12 ohms.

a) Calculate the current drawn by the heating element.

b) Calculate the heat energy transferred to the water.

c) Calculate the time taken to heat the water if the system is 100% efficient.

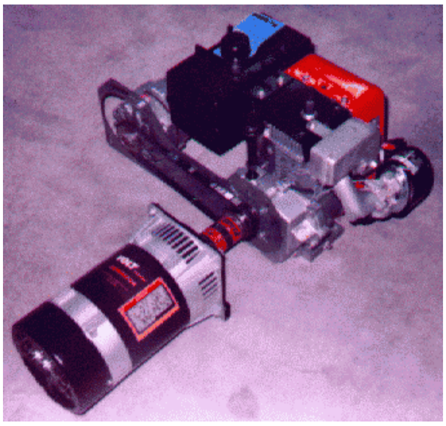
Task 22 (continued)

d) Calculate the percentage of energy lost if it actually takes 10 seconds to heat the water.

e) Draw a systems diagram showing the input and outputs to the system. Include the percentages.

Task 23

A small portable generator has an electrical load of 75A at 110V. The belt drive system has a 5% efficiency loss.



Calculate the power output from the diesel engine in KW.

Task 24

Renewable Energy mainly comes form 5 sources: wind, wave, tidal, hydro and solar.

State and justify which of these types is the most reliable.

Task 25

The motorised pump shown produces the following performance data, when tested by a maintenance engineer.

Energy output: 97 J in 5 seconds
Current drawn: 3·0 A
Voltage: 12 A

Draw an energy audit diagram for the pump, working out all inputs and outputs, showing its efficiency.