Nelson Thornes
Distance Learning

A2 Electronics

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First edition published in 2009. This edition published in 2010 by:
Nelson Thornes Distance Learning
Delta Place
27 Bath Road
CHELTENHAM
GL53 7TH
United Kingdom

10 11 12 13 14 15 16/ 10 9 8 7 6 5 4 3 2

Page make-up by OKS Prepress Services Pvt Ltd

Printed in Great Britain by Berforts

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A2 ELECTRONICS
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ELECTRONICS A2

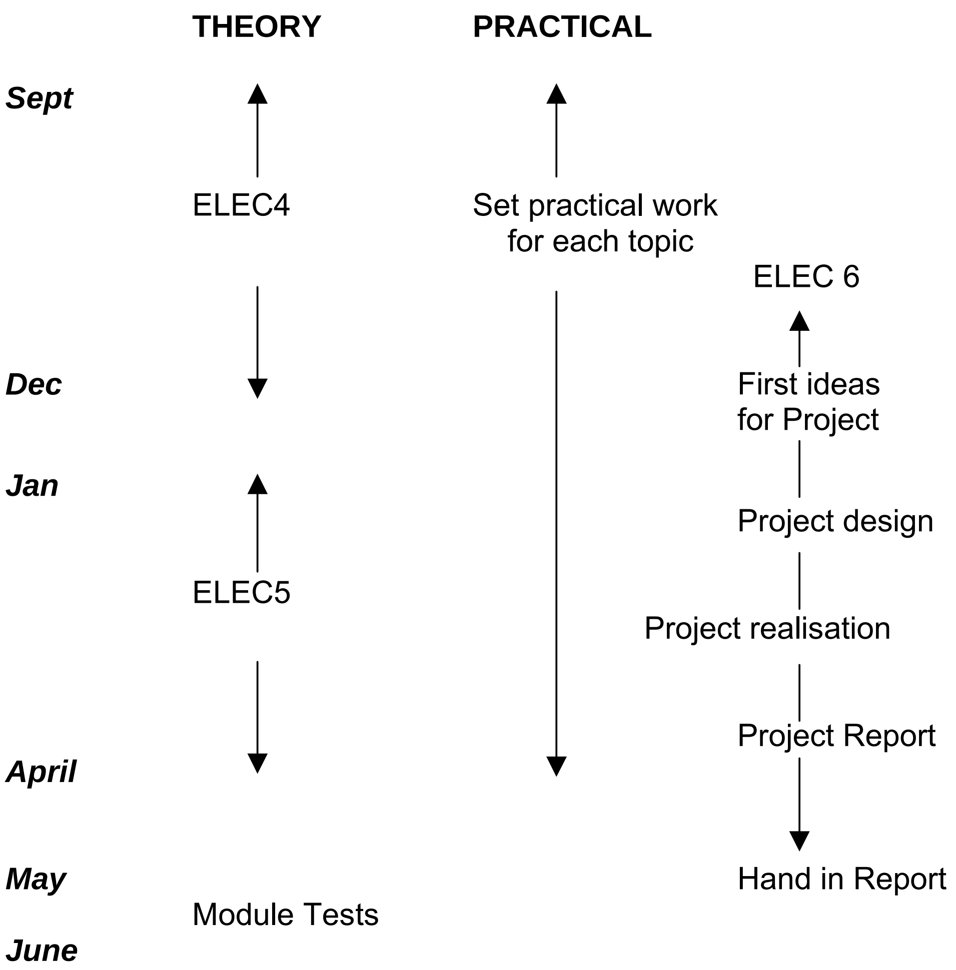
AWARDING BODY: AQA

SUBJECT CODE: 2431

ELECTRONICS A2

This year you will be studying two more separate theory modules and you will be undergoing one practical coursework assignment in the form of a project, just as you did last year.

The first theory module, ELEC4 is called “Programmable Control Systems”. That will take approximately the first term to complete, after which time you should be able to begin to think about a suitable title for your project. There will, of course, be a guidance package on this coursework given to you at the right time. In January, module ELEC5 entitled “Communications Systems” will be started, and this will continue until early April, when you will then concentrate on finishing your project and its report. After this you will begin preparation for the Module Tests in May/June.



ELEC4 Programmable Control Systems

This section is a **complete list** of all the topics covered in **ELEC4**.

The boxes are for you to use as a checklist to confirm you have completed **all the work**. When you have completed a topic, indicate this by writing in the box the **page number(s)** where you have found the relevant theory on that topic. In this way you will build your own index that will be useful when you come to revise for the Module Test.

ELEC4 is found in section 3.4 of the specification.

Section No.	Topic	Skills	Page
1	**Control Systems**	Open and closed loop control systems	
		Feedback in systems	
		Positive and negative feedback	
		Generalised control systems	
2	**Microprocessor Subsystems**	Hardwired and software controlled systems	
		Microprocessor architecture	
		Memory vs I/O mapping	
		Single chip processors	
		Social and economic implications of single chip processor systems	
3	**Programming**	Flow charts	
		Programming	

4	**Input subsystems**	8 bit ADC based on a digital ramp	
		Flash ADC	
		Optical shaft encoders	
		Opto-switches	
5	**Output subsystems**	8 bit DAC based on a summing amplifier	
		Seven segment displays	
		Dot matrix displays	
		Stepper motors	
6	**Interfacing subsystems**	Tri-state buffers	
		Data latches	
		Schmitt triggers	
		H-bridge drivers	
7	**Robotic systems**	System components	
		Power sources	
		Control algorithms	
		Artificial neural networks	
		Applications	
		Social and economic impact	
		Future developments	

PROGRAMMABLE CONTROL SYSTEMS

Section 1 : CONTROL SYSTEMS

AIMS: ***This section will help you to:***

Distinguish between open loop and closed loop systems	☐
Describe what is meant by feedback	☐
Distinguish between positive and negative feedback	☐
Describe the features of the generalised control system	☐

Tick the boxes when you have achieved each aim.

READING:

AQA support booklet for Electronic Control Systems

Read pages 6 – 10. ☐

‘Electronic Systems’ by M. W. Brimicombe

Read pages 7 – 9. ☐

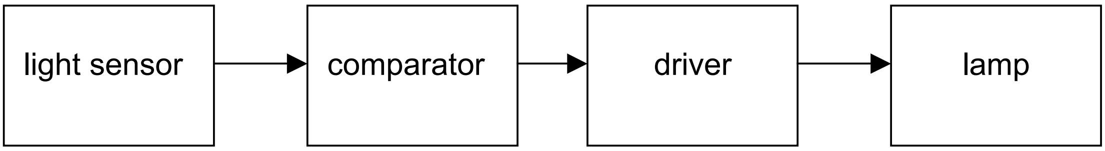
‘Electronics Explained’ by M. W. Brimicombe

Read pages 250- 256. ☐

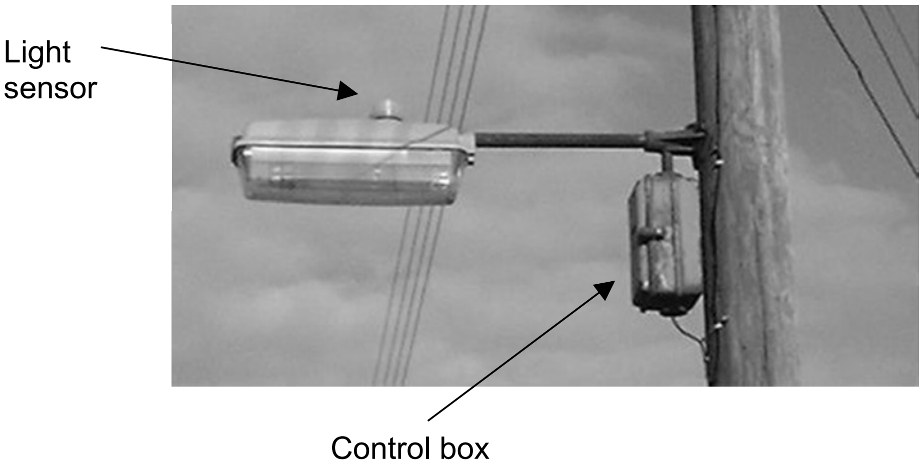
Tick the boxes when you have completed each task.

Open Loop Control Systems

These systems have inputs, processes and outputs, but not feedback. The information flow through the system is one-way, and no information can flow from the output back to the input closing the loop, hence the name ‘**open loop**’.
A simple example of an open-loop system is an automatic streetlight system:



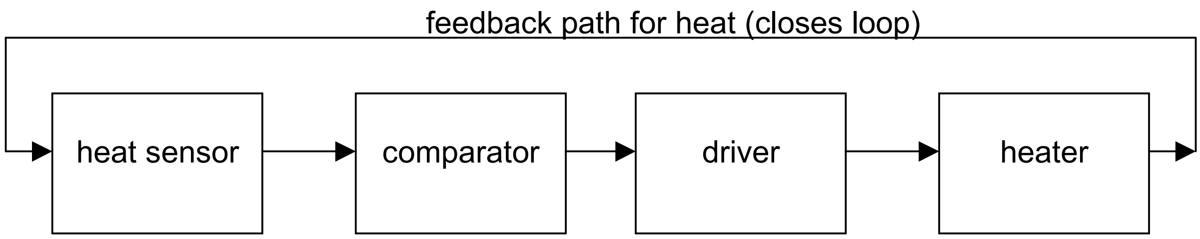
When the light level falls, the light sensor converting the light level to an electrical signal detects this. The comparator gives an output when its threshold level is crossed, and the driver then switches the lamp on. Good automatic streetlight systems will have the light sensor placed so that it cannot pick up the light from the lamp otherwise this would have affected the operation of the system. On the picture below you can see the sensor on top of the lampshade so that it can respond to the skylight and not to the lamp.



Closed Loop Control Systems

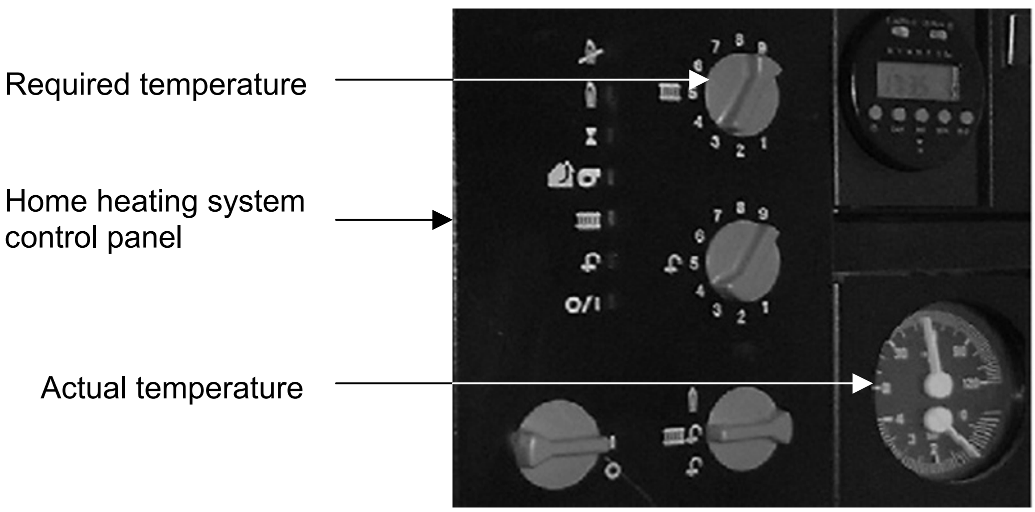
In a closed loop control system, a signal can travel from the output of the system, back to the input. This feedback signal may be electrical or some form of energy that carries information with it.

A simple example of a closed-loop system is a home heating system:



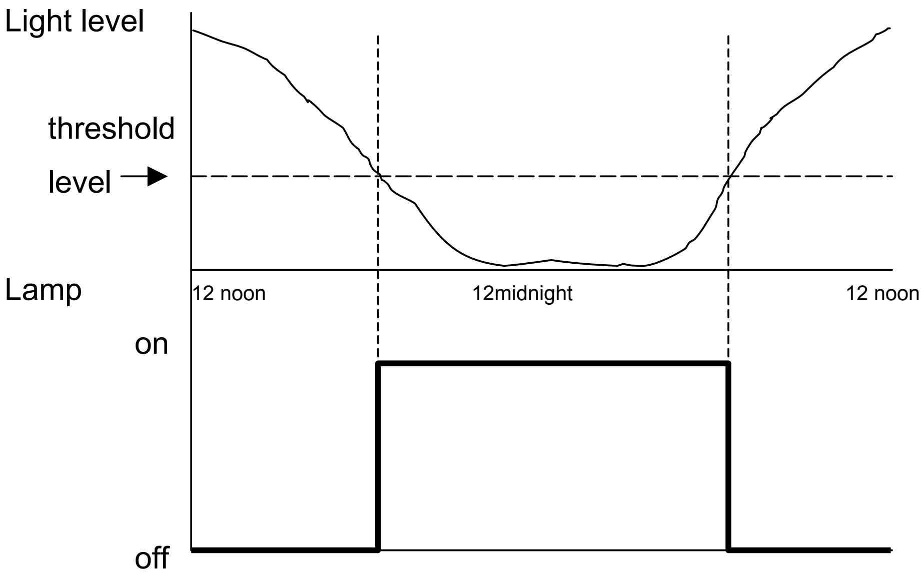
When the home is cold, the heat sensor detects this and turns on the heater via a comparator giving an output to the driver at the switch-on temperature. The heater then produces heat, which eventually warms up the home. This is the feedback signal, for the heat sensor detects this warmth and eventually will turn off the heater.

This system is also known as an on-off control system. The heater can still be switched fully on even if the home is only just below the required temperature.



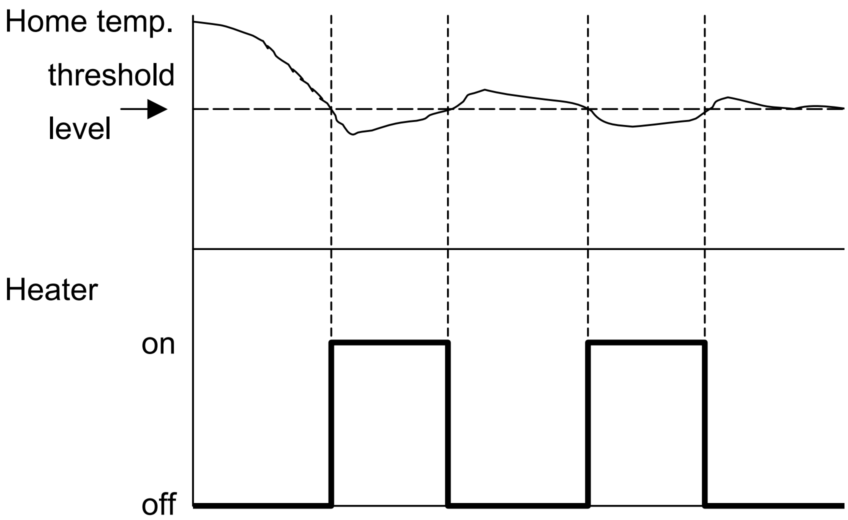
The Characteristics of Open- and Closed-Loop Control Systems

The automatic streetlight characteristics are illustrated by this graph of its input/output behaviour:



When the light level drops below the threshold level, the lamp switches on.

The home heater characteristics are illustrated by this graph:



The heater output affects the home temperature and this will result in the heater switching on and off repeatedly.

Positive and Negative Feedback

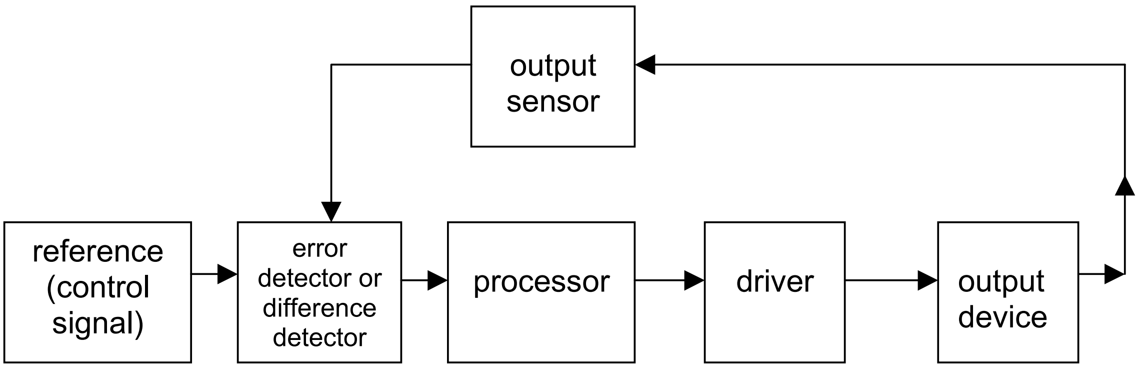
There are two types of feedback in systems - positive and negative. The home heater system described earlier is an example of negative feedback. When the room temperature is ***low***, the heater control is at logic 1, or ***high***. When the temperature is ***high***, the heater control is at logic 0, or ***low***. Negative feedback tends to be error-correcting feedback and results in a stable output. The home temperature tends to stabilise around the threshold temperature.

Positive feedback tends to drive a system to one extreme or the other. If the inputs to the comparator in the home heater system were wired incorrectly, then in the cold, the heater would remain off …forever. If the home temperature rose on a warm day, the heater would switch on and remain on, with the home temperature rising all the time until the maximum possible temperature was reached. This is clearly an unsuitable state of affairs.

Positive feedback can sometimes create a signal in a system that was not present initially, such as a public address microphone, amplifier, and loudspeaker system. If the microphone is too close to the loudspeaker, a loud howling sound results from positive feedback.

The Generalised Control System

A typical negative feedback control system having an electrical feedback signal is as follows:



The desired output level is the setting in the reference input box. This can be thought of as a control signal.

The error detector compares the desired output level with the signal from the output sensor and feeds information on the difference between the two inputs on to the processor.

The processor reacts when the difference signal exceeds the level at which it can provide a control signal to the driver, which controls the output device.

The level of output is detected by the output sensor and converted into an electrical signal to be fed back to the error detector.

READ THE FOLLOWING CAREFULLY:

Health and Safety Precautions:

Proper Use of the 'Hands On' A2 Electronics Kit

You are reminded that in the AS course notes you read and agreed to obey the rules which are repeated below. These rules apply equally to the A2 course and you should refresh your memory by reading through them:

- Circuits assembled from these components should only be powered up from the 9V battery when they are complete, and have been checked.
- Do not build or adjust any circuit with the battery connected.
- Use only the recommended 9V battery to power all circuits (do not use any other power source). The 9V battery has been chosen to avoid the possibility of large currents flowing, causing overheating.
- The tools provided should only be used in connection with the Practicals described in the booklet and with your coursework.
- Care should be exercised when cutting and stripping wires, particularly if wire fragments could fly off when wires are cut.
- Eye protection should be worn and the open face of the cutters should face away from yourself and others.
- The screwdrivers are necessarily sharp at their blade ends and undue force should not be used on them, as there is danger of puncture wounds being inflicted.
- Wire ends (including component leads and meter probes) are also sharp, and care should be exercised when handling them.
- The multimeters should not be used for any electrical measurements other than those indicated in the Practicals.

UNDER NO CIRCUMSTANCES ARE THE MULTIMETERS OR ANY OTHER COMPONENTS OR TOOLS TO BE CONNECTED DIRECTLY OR INDIRECTLY TO THE MAINS ELECTRICAL SUPPLY.

The Equipment Cases

Check the contents of the **A2 equipment case** against the list given later. This will help you familiarise yourself with the locations of the components and tools within this new resource. The A2 equipment case is designed to be used with the AS equipment case.

The double-sided **A2 parts organiser box** contains all the small components required for the A2 Practicals. Diagrams are included later to give the location of each of the components. To avoid spilling the contents, make sure the lids are closed on both sides before turning over the organiser box.

As stated earlier, the AS equipment case and its contents will continue to be used for the A2 course. If there has been any serious depletion of components or tools, this will need to be made good by your school using the contents list in the AS course notes.

The A2 Equipment Case

The Parts Organiser Box and Environment Meter

Contents of A2 'Hands On' Kit (subject to minor changes)

1 equipment case	1 wire stripper	1 screwdriver set
1 advanced multimeter	1 side cutter	1 radio kit
1 environmental meter	1 long-nose pliers	1 PIC chip board
1 AC adaptor	1 combination pliers	1 x microphone

1 Parts Organiser Box containing:

Semiconductors:

1 x IR LED
1 x IR PD
1 x VIS PD
2 x HUF75337
2 x LM386
4 x NE555
4 x TL081
4543 IC

Sensors:

1 x microswitch
1 x tilt switch
2 x thermistor
2 x LDR
1 x PIR module
1 x reed switch & magnet
2 x 4AA holder
2 x PP3 clip
8 x AA cells

Miscellaneous:

2 x 6.5V 0.3A lamps
2 x lampholders
1 x 22Ω 3W resistor
1 x 1m optical fibre

Plan of Side 1 of Parts Organiser Box:

Optical fibre & PP3 clips			
6 AA cells	6V bulbs and lamp holder	reed switch and magnet	
3W resistors	AA battery box and cell	AA battery box and cell	tilt switch
			microswitch

Plan of Side 2 of Parts Organiser Box:

thermistors	LDRs	4543	MOSFETs
IR LED	555		IR photodiode VIS photodiode
LM386		PIR module	Op-amps
40098			40373

Section 1 Practical: General Principles

In this section you are going to build and test an open loop system and a closed loop feedback system, and investigate the action of both positive and negative feedback in control systems as described in Section 1.

For these Practicals you will need:

- breadboard
- wire links
- resistors
- 10kΩ potentiometer
- LDR
- thermistor
- op-amp
- MOSFET
- 6.5V lamp and holder
- 22Ω 3W high power resistor
- 4AA batteries, battery box and PP3 clip

The top four items on this list are to be found in the AS ‘Hands On’ kit. The bottom three items are only in the A2 ‘Hands On’ kit. The other items are in both kits.

You will also require the use of a multimeter and the environmental meter included in the A2 kit, as you will be measuring light levels and temperature.

Practical 1

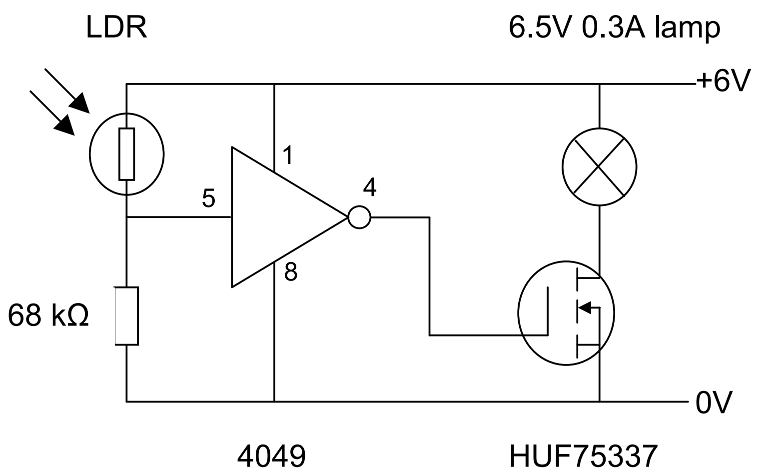
An automatic streetlight system

In this Practical you are going to make an open-loop control system for a streetlight. The light level is sensed with an LDR in a voltage dividing circuit to provide the input signal for a NOT gate used as a simple comparator. The NOT gate input will respond to voltages varying from 0V to half its supply voltage as if a logic 0 signal had been applied to its input, and give a logic 1 output. An input voltage above half its supply voltage will be read as a logic 1, and give a logic 0 output.

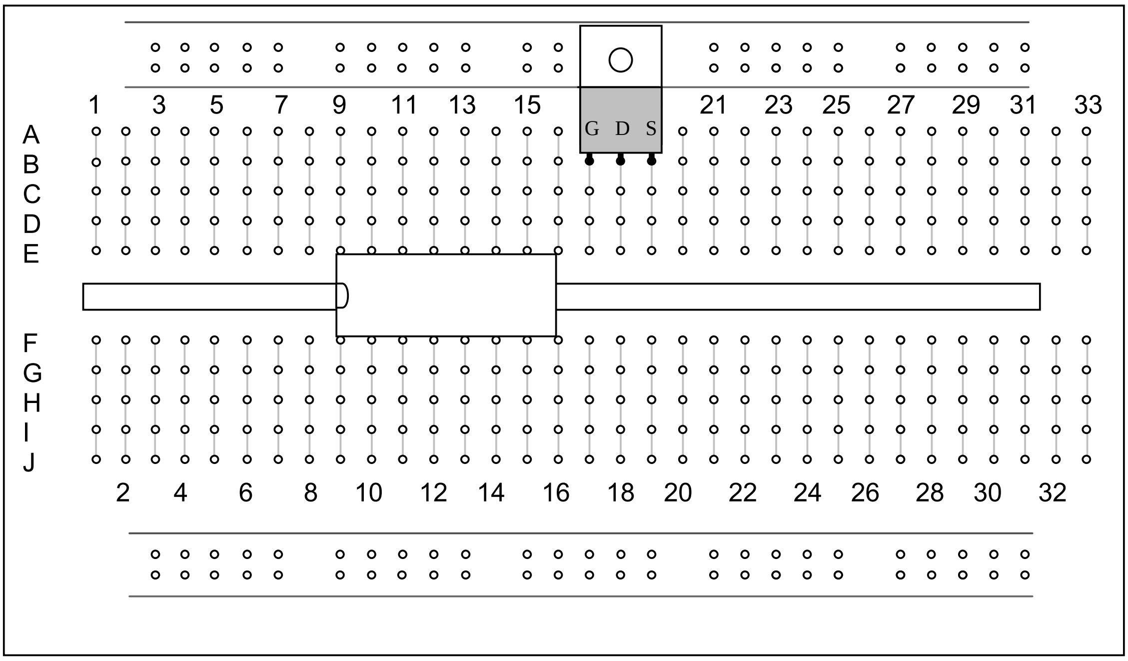
The output of the NOT gate is connected to the input gate terminal of a MOSFET which switches the lamp on when its gate voltage exceeds 3V. The voltage divider resistor value of 68kΩ is chosen so that in the dark the output voltage is below half the supply voltage. The NOT gate reads this as a logic 0 and gives a logic 1 from its output. This signal turns on the MOSFET, which switches on the lamp.

Design a breadboard layout for the circuit shown below.

Circuit diagram

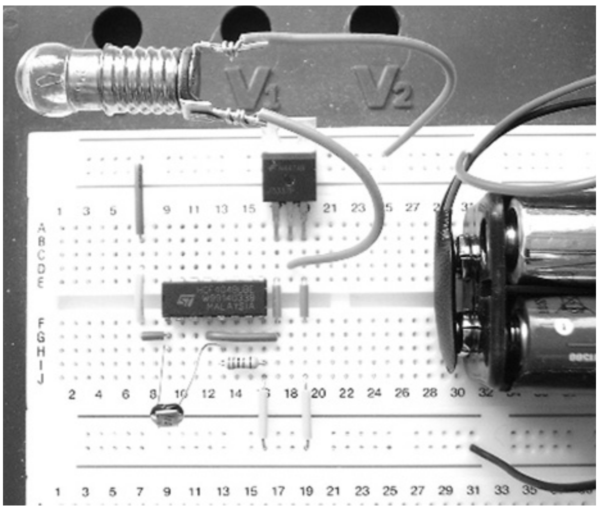


Breadboard Layout



Use the HUF75337 MOSFET and the 4049 NOT gate IC. The 6.5V 0.3A lamp is screwed into the holder, which has two metal contacts, which are too large to fit into the breadboard. Cut two 10cm lengths of single core wire, stripping both ends; one to about 2cm which can then be used to wrap tightly around the metal contacts (see the photograph).

The automatic streetlight system



The 6V (4 AA cell) battery pack must be used for this Practical. The 9V battery would probably burn out the 6V bulb, or over-run it, shortening its life and running the battery down unnecessarily.

Construct the circuit, making sure that the light from the lamp is shaded from the LDR, and test it by observing its behaviour in normal daylight, and then take it to a location where the light level is below 2 lux (measure the light level with the environmental meter).

Record the behaviour of your system in the table:

light level	**lamp state**
daylight	
below 2 lux	

Now find the exact light level at which the system switches on:

light level	…………. lux

If your lamp flickers or is dim when it switches on, this is because some light from the lamp is affecting the LDR and giving unwanted negative feedback. Try putting your hand between the lamp and the LDR to prevent this happening. You should see the lamp switches on to full brightness. You now have an open-loop control system with no negative feedback.

Further Work

Change your circuit by exchanging positions of the 68kΩ resistor and the LDR on the breadboard. This will give a system that will switch on the lamp in the light, and off in the dark. Move the lamp so that it shines directly on the LDR. You now have a system that has positive feedback since the light from the lamp will directly affect the LDR.

Investigate the system behaviour: If you operate the system in daylight, what happens if you then take the system to a dark place?

Remove the power to your system while still in the dark place, and then reconnect the power. What happens now?

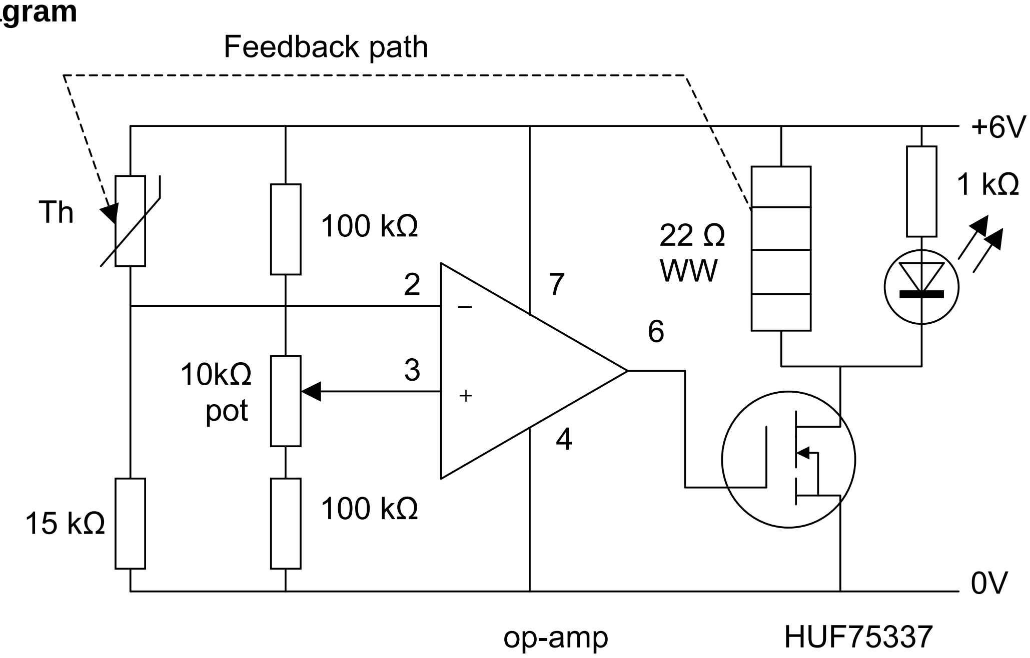
While still in the dark place, briefly switch on a torch or other light then immediately switch it off. What happens this time?

Practical 2

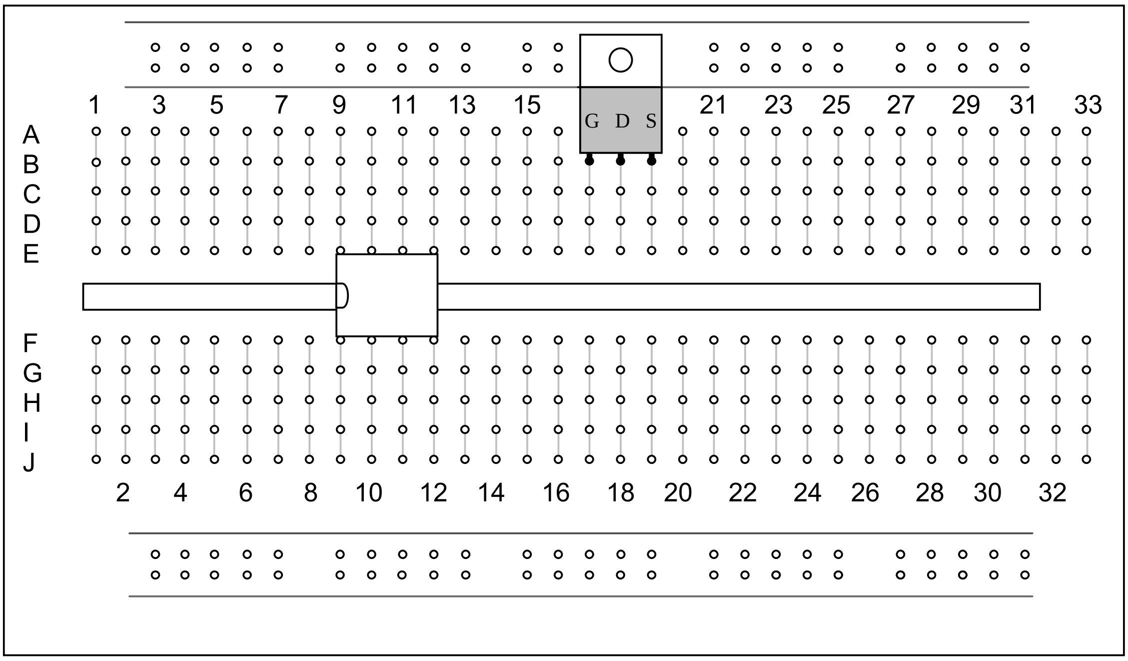
A closed loop temperature control system

This system uses a thermistor and comparator circuit to monitor the temperature of a high-power wire-wound resistor. When the voltage signal from the thermistor circuit at a low temperature falls below the comparator reference voltage, the comparator output goes high, switching on the MOSFET and so enabling current to flow through the resistor. This current then heats up the resistor and thermistor. When the thermistor heats up, the voltage signal from it increases and causes the comparator to give a low voltage output, switching the MOSFET off and allowing the resistor to cool. The cooling continues until the comparator again switches on and the cycle repeats. This is a closed loop system as the heat from the output device affects the input device. It is a negative feedback system because a cold resistor creates a signal to warm it up and vice versa.

Circuit diagram

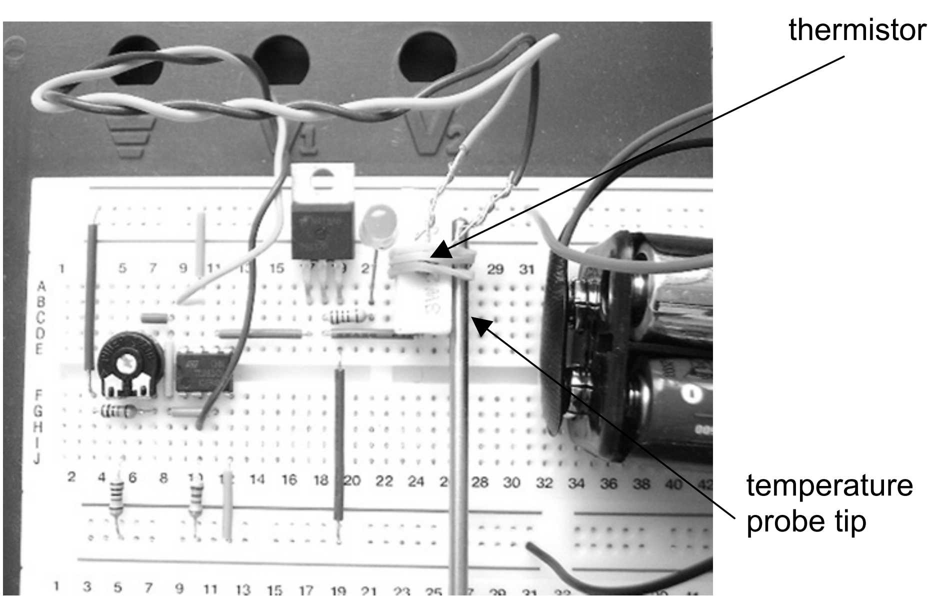


Breadboard layout



Use an elastic band to hold the thermistor in contact with the resistor (see photograph). To monitor the temperature of the resistor and thermistor, also place the temperature probe from the environmental meter under the elastic band.

Temperature control system



Turn the potentiometer arrow to the 12 o'clock position, connect the 6V battery and watch the temperature increase as the MOSFET is switched on (you can see when the MOSFET is switched on as the LED will light also). You should see the temperature fall when the MOSFET switches off (LED goes off) until the thermistor reacts to the falling temperature and causes the MOSFET to switch back on. The temperature should only vary by one degree in between switching on and off.

Try the positions of the potentiometer arrow in the table below and record the temperature of the resistor when the system has reached equilibrium.

potentiometer position	**temperature**
11 o'clock	
12 o'clock	
1 o'clock	
2 o'clock	
3 o'clock	
4 o'clock	

Further Work

Read the temperature at five-second intervals and plot a graph to show the operation of the system.

Section 1 Theory questions

In the following questions use these codes for your answers:

input = A	feedback = B	negative = C
output = D	positive = E	process = F

Which of the above:

1. Takes a signal from the environment? ☐
2. Is missing from an open-loop control system? ☐
3. Has some action on the input signal in a control system? ☐
4. Produces a signal detectable in the environment? ☐
5. Is used only in a closed-loop control system? ☐
6. When used in a system gives control over the desired output? (2 codes required, enter 2nd code in answer to question 7.) ☐
7. Enter here the 2nd part of answer to question 6 ☐
8. Drives the output of a system to an extreme when used as a feedback signal? ☐
9. Results in the output switching on and off continually, maintaining a desired output level? (2 codes required, enter 2nd code in answer to question 10.) ☐
10. Enter here the 2nd part of your answer to question 9. ☐

Section 1 Practical Questions

Based on Practical 1, what is the ….

1.	lamp state in daylight?	
2.	lamp state below 2 lux?	
3.	switching light level?	lux

With positive feedback, what is the …

4.	lamp state in daylight?	V
5.	lamp state in darkness?	V

Based on Practical 2, what is the …

6.	temperature at 11 o'clock potentiometer position?	°C
7.	temperature at 12 o'clock potentiometer position?	°C
8.	temperature at 1 o'clock potentiometer position?	°C
9.	temperature at 2 o'clock potentiometer position?	°C
10.	temperature at 3 o'clock potentiometer position?	°C