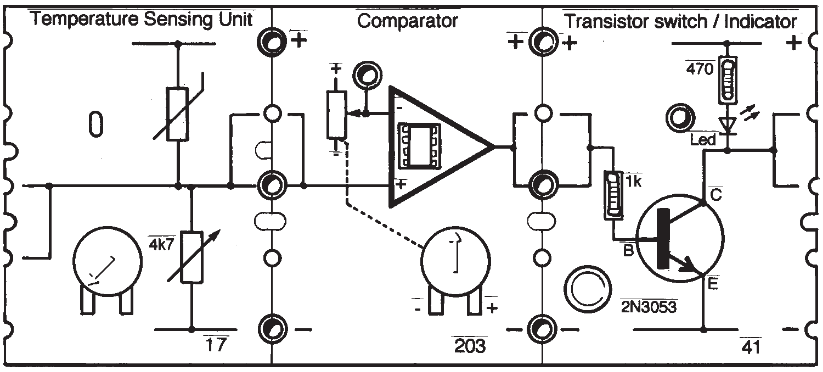
MODELLING AND THEN MAKING A CIRCUIT

PROTOTYPING A CIRCUIT

It's easy to build working models of electronic circuits using a kit of parts. The picture to the right shows three parts of a kit joined together to make a temperature controller.

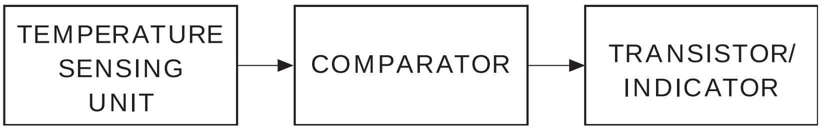


A complete circuit like this is called a **system** and the parts are called **sub-systems**. Each sub-system is really a mini-circuit.

This way of building electronic circuits is called modelling and allows you to try different ideas quickly. It's a method used by engineers to solve electronic design problems. The final circuit is built as one unit on a printed circuit board (PCB).

BLOCK DIAGRAMS

Block diagrams are a useful way of representing electronic systems. The block diagram below shows the temperature controller represented this way.



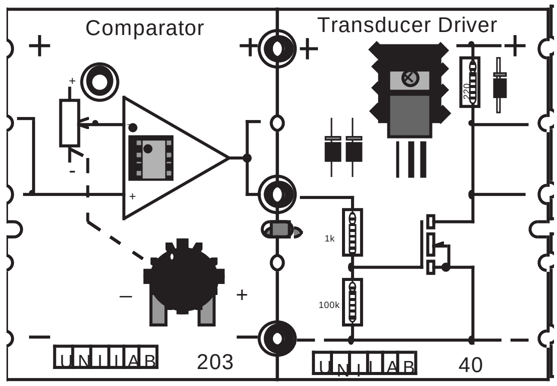
The direction of the arrows going left to right shows that, when the temperature sensing unit gets hot, it sends an electrical signal to the comparator which then switches on the transistor/ indicator. Block diagrams like this always follow a pattern which starts with an **input** on the left of the diagram followed by a **process block** and finally an **output.** In the block diagram of the temperature controller, the input is the temperature sensing unit.

Q. What parts of the temperature controller represent the processing and output stages?

USING ALPHA BOARDS

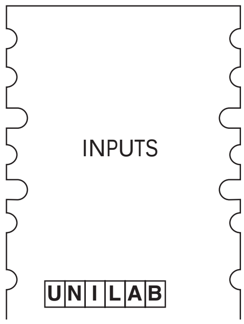
The Alpha board system is one of many kits used to make electronic systems. Each board is a sub-system.

Boards are connected together edge-to-edge using yellow Alpha links. Power from the power supply is carried to each board through the top and bottom connections. The middle connection carries the electrical signal.



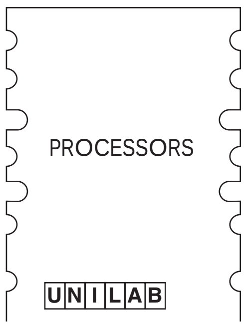
Example of an Alpha Board

A wide range of boards is available for the input stage. These are simply called INPUTS:



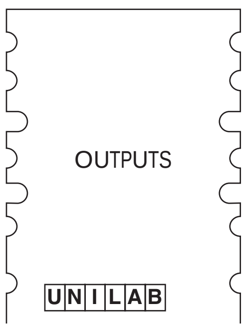
- light sensing unit
- sound sensing unit
- rain sensing unit
- magnetic switch unit
- temperature sensing unit

The same is true for the processing stage. These are called PROCESSORS:



- comparator
- AND gate
- bistable
- inverting amplifier
- OR gate

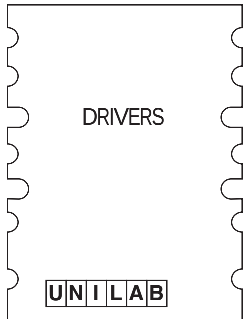
and also the output stage which are simply called OUTPUTS:



- bulb unit
- buzzer unit
- relay switch unit
- motor unit
- reed relay

DRIVERS

Another group of boards are called DRIVERS which fit between the processors and the outputs. They make sure that there is enough current to drive the outputs.



transducer driver (delivers up to 1 A)
transistor switch / indicator (up to 0.25 A)
darlington pair (up to 0.5 A)

MAKING A LIGHT SENSOR

Design brief

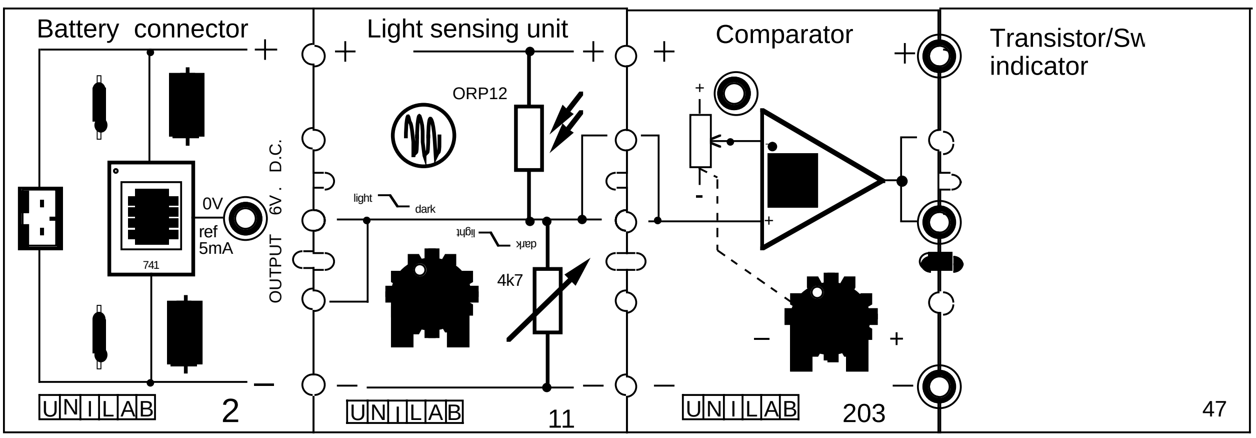
Using the Alpha boards, design a circuit which will indicate when the lighting level in a work area is too low. From your final design, make the complete circuit on a PCB.

Design your circuit by choosing an Alpha board for each stage:

- Input stage - choose a board that can detect changes in light level.
- Processing stage - you need a circuit which will make your circuit sensitive to small changes in light level. Try the comparator board.
- Output stage - you can use the transistor/switch indicator here. The indicator is a Light Emitting Diode (LED) and will come on if the circuit is working correctly.

ASSEMBLY

Connect your boards together as shown in the diagram below and connect a power supply. Use either the battery connector board or the power supply regulator to connect to the power supply:



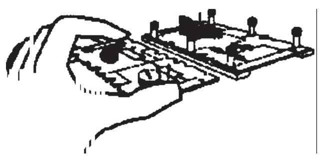
TESTING THE ALPHA LIGHT SENSOR

- Place your hand over the light sensing unit and check that the LED on the transistor/switch indicator comes on.
- If the LED does not come on, check connections to the power supply and make sure that the Alpha links are screwed tightly to the boards.
- Draw a block diagram of the system.
- Describe how the complete system works.

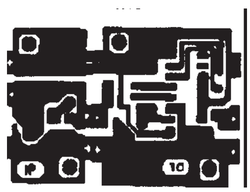
Its good practice to draw the block diagram before trying out your ideas. Always start with your input on the left and work through to the output on the right.

You have now completed the design using Alpha boards and tested the final system. Normally, the next stage in the process of producing a working circuit is to draw a circuit diagram. (If you want to do this, see the panel on the next page). However, with the Alpha system and using a computer programme called QuickTrack, you can go straight on to make the PCB.

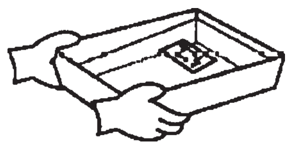
FROM CIRCUIT DESIGN TO PCB



Systems design



PCB mask



PCB's

There are two stages to complete between the Alpha board design and making a PCB of the complete system:

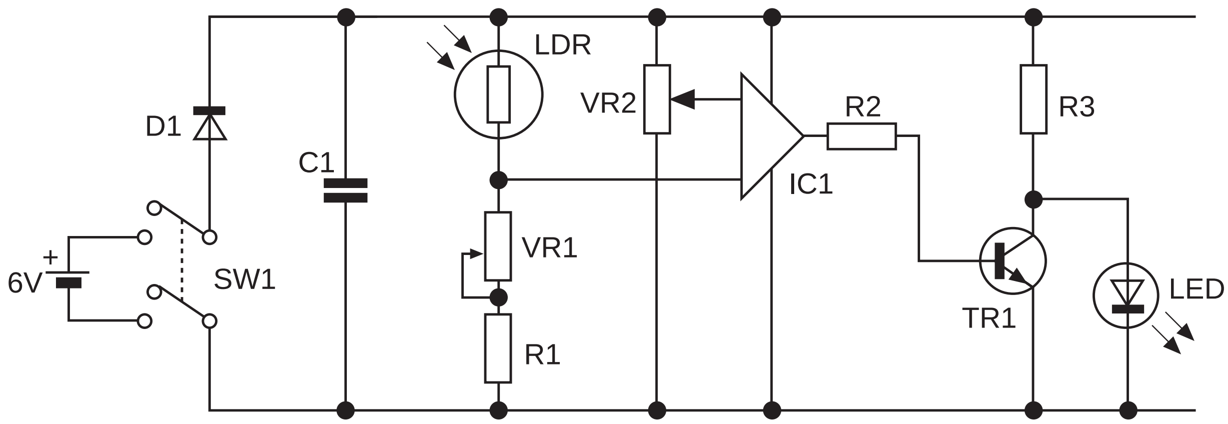
- Making a PCB mask using a computer program.
- Making the PCB on which the components will be mounted.

NOTE

See Technology Study File 2 (Making a PCB)

THE CIRCUIT DIAGRAM

It is possible to show in a single drawing how all the individual components connect to make the complete circuit for the light sensor. This is called a circuit diagram.



Circuit diagram of the light sensor

You can see that this diagram is made from the diagrams printed on the surface of each of the Alpha boards that make up the light sensor. Each component has its own symbol. Lines represent the connections between the components.

NOTE

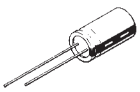
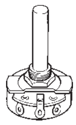
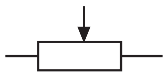
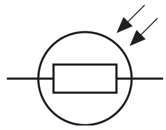
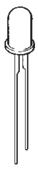
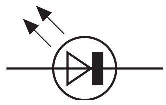
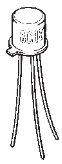
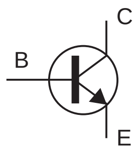
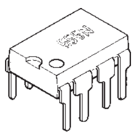
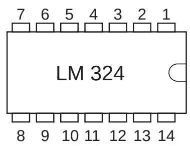
See Technology Study File 1a (Crocodile Clips)

Next to each symbol is a circuit reference consisting of a letter(s) and a number. The letter is a shorthand way of describing the component, e.g., C for capacitor and the number gives its position in the circuit.

C1 This is the first capacitor in the circuit

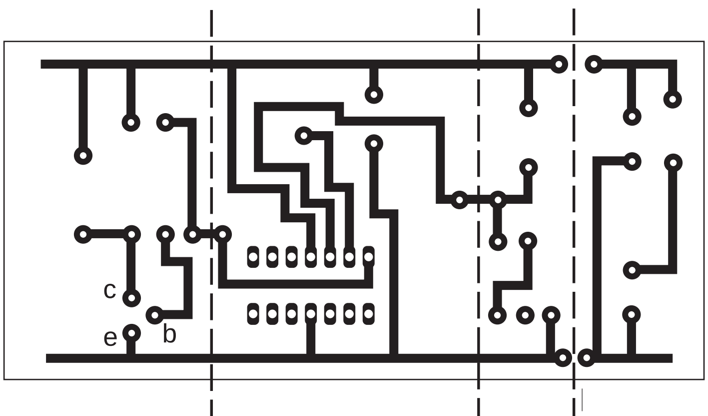
For more information on drawing circuit diagrams, see BS 5070.

The table below gives pictures of some of the components, their symbols and their circuit reference:

Component	Symbol	Circuit Reference
 Capacitor		C1
 Variable resistor		VR2
 Light dependent resistor		LDR
 Light emitting diode		LED
 Transistor		TR1
 Integrated circuit (shown with 8 pins only)		IC1

THE PRINTED CIRCUIT BOARD (PCB)

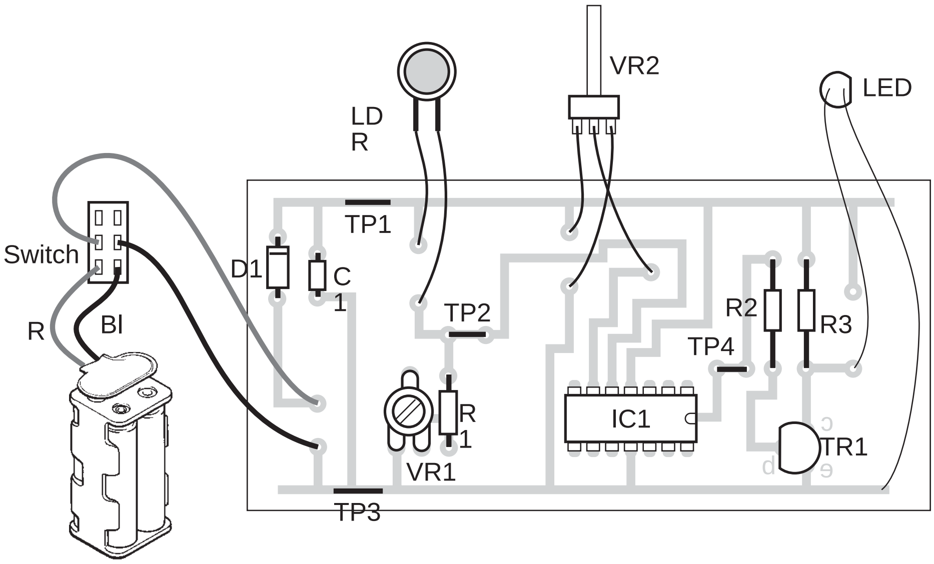
After you have completed the previous two processes you will have made a PCB which looks like this from the copper track side:



PCB Copper track side

The following four sections show you how to mount the components on the PCB, stage by stage. Each stage is tested as you progress so that you will have a high quality product on completion.

When all the components have been mounted, your completed circuit will look like this:



PCB Component side

MOUNTING THE COMPONENTS

You are going to assemble your circuit one sub-system at a time, starting with the power connector. After you have made each sub-system, you will test it before you go on to the next sub-system.

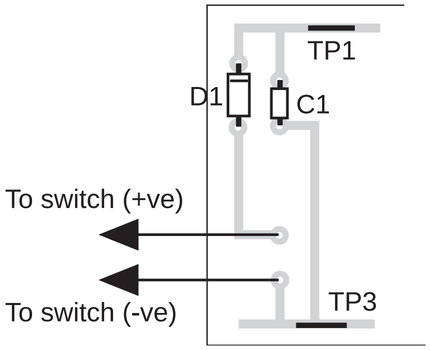
THE POWER CONNECTOR

You need the following components:

Component	**Circuit Reference**
A 4AA battery box connector	
A diode (1N4001)	D1
A 0.1 μF capacitor	C1
An on-off slider switch	
Two x 10 mm lengths of tinned copper wire 22 swg	TP1, TP3
4 x 100 mm length stranded wires, 2 red, 2 black	

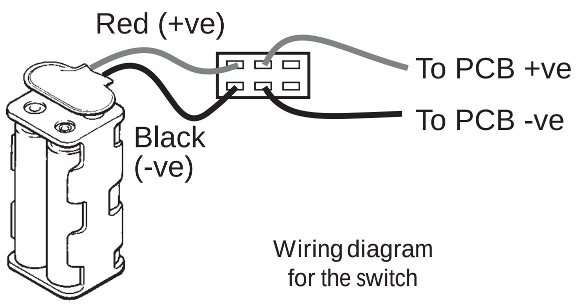
ASSEMBLY

- Solder the capacitor C1 onto the PCB as shown in the diagram. It can go either way round.
- Next solder the diode D1 into place making sure the band is towards the top of the board.



For the next section, make all wires approximately 100 mm long.

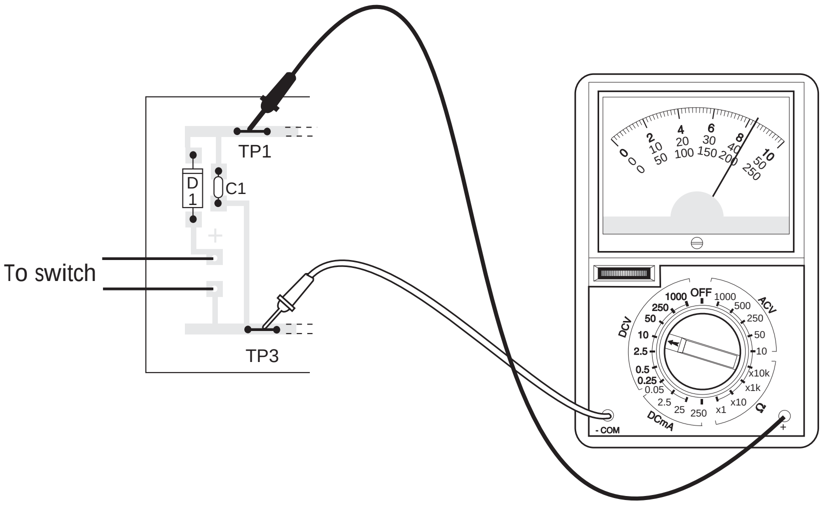
- Solder two wires from the battery connector to one of the pairs of end contacts on the slider switch as shown in the diagram. This end of the slider switch is the ON position for the slider.
- From the centre pair of contacts of the switch, solder two wires to the PCB. The red wire must go to the pad marked +ve on the PCB and the black wire to the pad marked - ve.
- Finally, solder two short loops of tinned copper wire in position for test points 1 (TP1) and 3 (TP3).



Wiring diagram
for the switch

TESTING

- Select the DC 0-10 V range on the multimeter. Attach a 6V battery to the battery connector.
- To measure the voltage between the top track and the bottom track, attach the + ve lead from the multimeter to TP1 and the -ve lead to TP3 as shown below.
- Slide the switch to the ON position. The reading on the meter should be about 5 V.
- Slide the switch to the OFF position and check that the meter reading drops to 0 V.

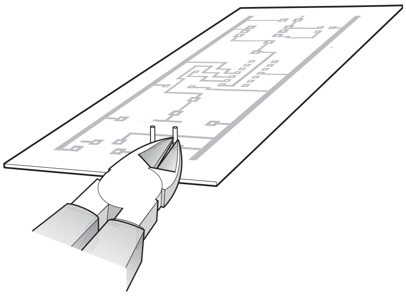


FAULT FINDING

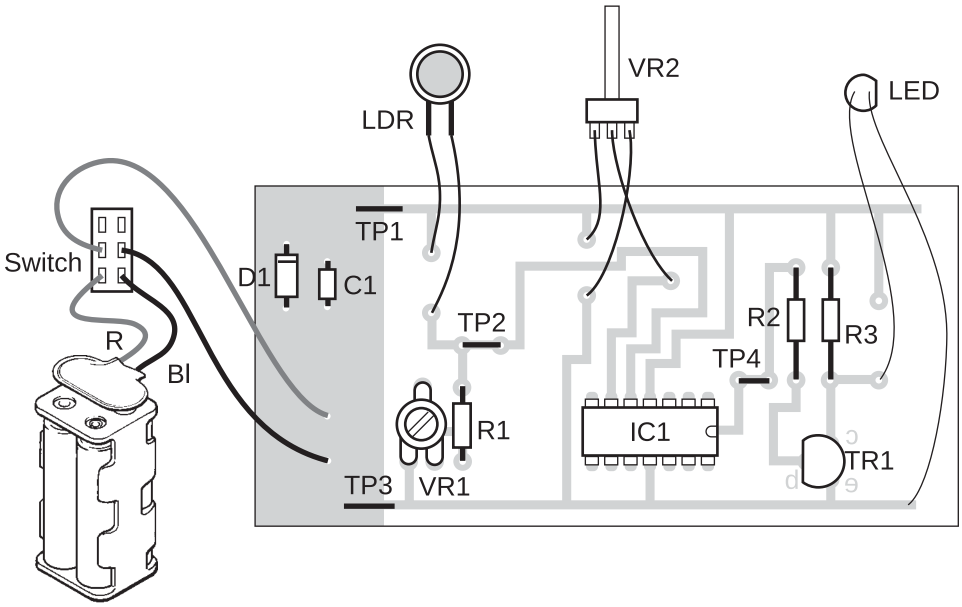
FAULT	ACTION
0 V is measured:	Check all the joints are soldered correctly. Check the diode and battery connector are soldered the right way round.
The measurement is between 0 V and 6 V	Measure the voltage of the battery. The reading should be close to 6 V - if it is lower than 4 V, replace the battery.
–5 V is measured	Check the diode and battery connector are soldered the right way round. Also check that the meter leads are the right way around.

FINISHING OFF

When you are sure the power connector section is working correctly, you need to finish it off by removing the ends of the leads sticking out of the board. Use a small pair of cutters to do this.



Your circuit is made up of four sub-systems.
You have now completed the first.



Before you go onto the next section:

- Describe the tests you have done on this section.
- Report any faults you have found. Describe the cause of each fault and how you repaired it.
- Describe what this part of the circuit does.

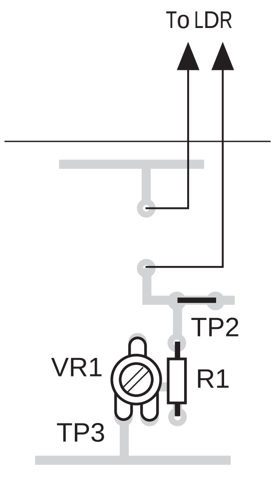
THE LIGHT SENSOR

COMPONENT	CIRCUIT REFERENCE
A light dependent resistor	LDR
A 2.2 kΩ resistor	R1
A 4K7 kΩ preset resistor	VR1
Window plug and O-ring for LDR	
2 x 20 mm lengths of sleeving	
2 x 100 mm lengths of wire	
1 x 10 mm length of tinned copper wire (22 swg)	TP2

ASSEMBLY

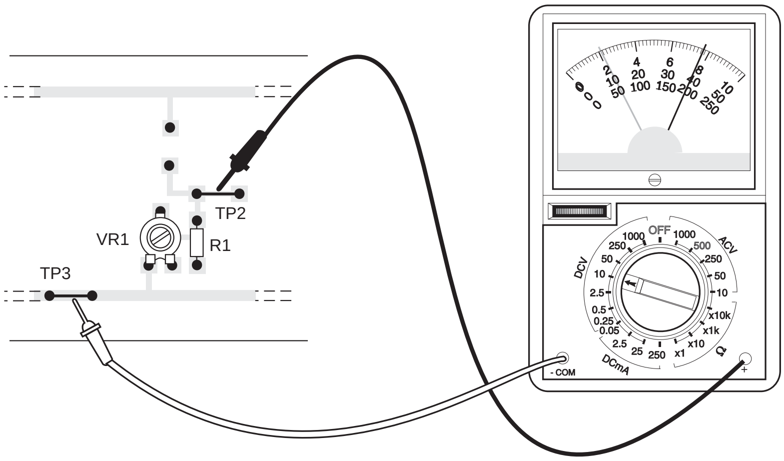
Make sure the battery is disconnected before you start.

- Solder the preset resistor VR1 in place on the PCB.
- The resistor R1 should be soldered into place next. It can go either way round.
- Cut two lengths of wire 100 mm long for the LDR. Strip the ends and put 20 mm of sleeving on each wire.
- Solder wires from the legs of the LDR to the PCB as shown in the diagram below. They can go either way round.
- Finally solder a 10 mm length of tinned copper wire in position for test point 2 (TP2).



TESTING

- Use a small screwdriver to turn the preset variable resistor VR1 to its middle position.
- Attach a 6V battery to the battery connector.
- Measure the voltage between the output of this section and the bottom track.
- The + ve lead from the meter should go to TP2 and the -ve lead to TP3.
- Cover the LDR. The voltage on the meter should decrease.
- Adjust the position of VR1 with a small screwdriver. The reading on the meter should change.



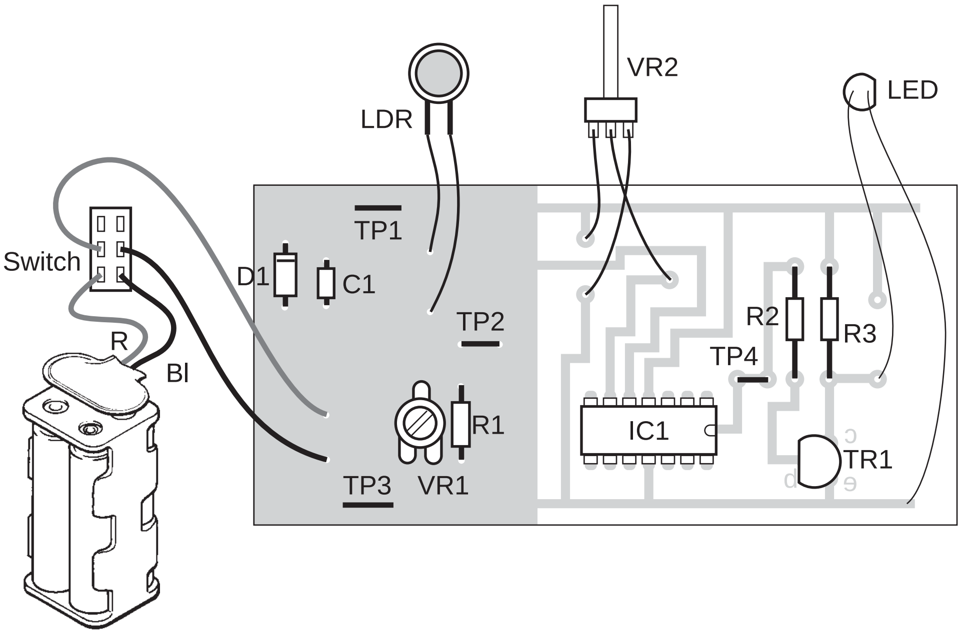
FAULT FINDING

FAULT	ACTION
The reading on the meter does not change when the LDR is covered	Make sure VR1 is in its middle position. Check all the joints are soldered correctly. Set the correct resistance range on the multimeter. Disconnect the battery and measure the resistance between the legs of the LDR - it should vary as the LDR is covered and uncovered.
The measurement is constantly around 5.5 V	Check the legs of the LDR are not touching each other.
The measurement is constantly 0 V	Check all the joints are soldered correctly. Check the voltage between TP1 and TP3 is around 5.5 V.

FINISHING OFF

When you are sure that this section is working correctly, snip off the ends of the leads with a small pair of cutters.

Of the four sections on your circuit, you have now completed the first two.



Before you go onto the next section:

- Describe the tests you have done on this section.
- Report any faults you have found. Describe the cause of each fault and how you repaired it.
- Describe what this part of the circuit does.

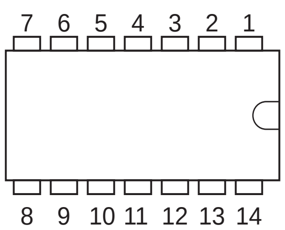
THE COMPARATOR

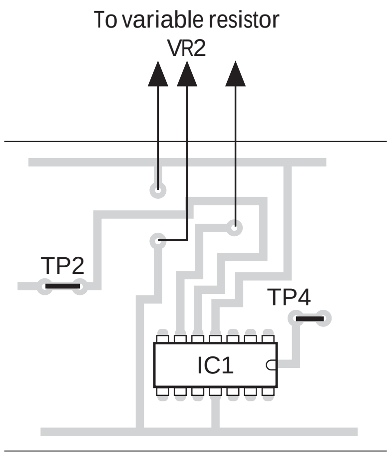
You will need the following components:

COMPONENT	CIRCUIT REFERENCE
An LM324 integrated circuit (IC)	IC1
A 14 pin integrated circuit holder	
A 10 kΩ preset variable resistor	VR2
3 x 100 mm lengths of wire	
1 x 10 mm length of tinned copper wire	TP4

ASSEMBLY

- Make sure the battery is disconnected before you start.
- Solder three wires from the PCB to the variable resistor VR2.
- Solder the IC holder into the two lines of seven holes. It can go either way round.
- **Do not attempt to solder the IC directly into these holes - you may damage it.**
- Look for a small notch at one end of the IC. **This end of the IC must be at the same end of the holder as the pad that has an arrow pointing at it.**





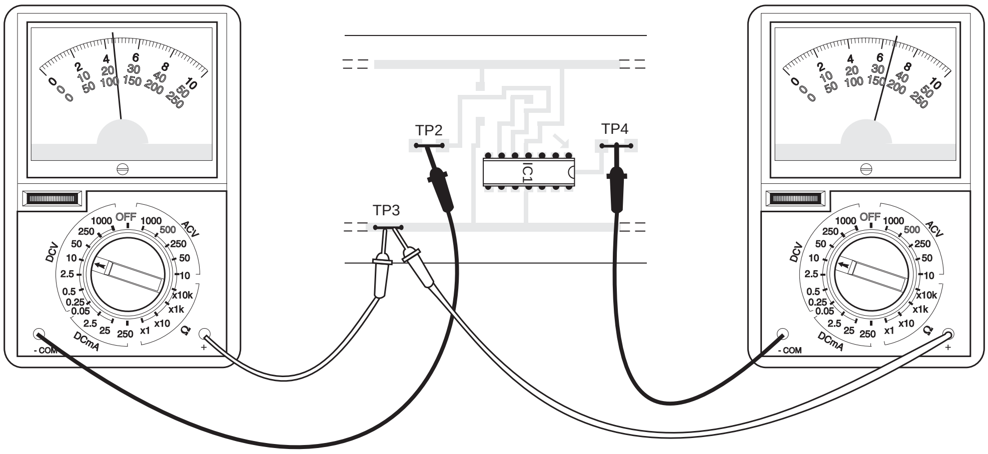
- When you are sure which way round the IC goes, insert it carefully, but firmly, into the holder taking care to ensure **all** of the pins go into the holes.
- Finally, solder a 10 mm length of tinned copper wire into position for test point 4 (TP4).

TESTING

- Turn the variable resistor to its middle position.
- Attach a 6V battery to the battery connector.

There are two tests you need to do. Both tests compare the signal on the input (TP2) with the signal on the output (TP4).

You measure the voltage between each test point and the bottom track (TP3) using two meters. The + ve leads should go to the input and output points (TP2 and TP4) and the **-** ve lead to TP3.



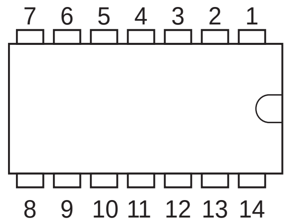
TEST 1

- Vary the input signal by covering and uncovering the LDR.
- Check that, when the input signal is below a certain level, the output is off (0 V) and that when the input signal is above this level, the output is on (around 5.5 V).
- Write down the value of the input signal that causes the output signal to switch between 0 and 5.5 V.

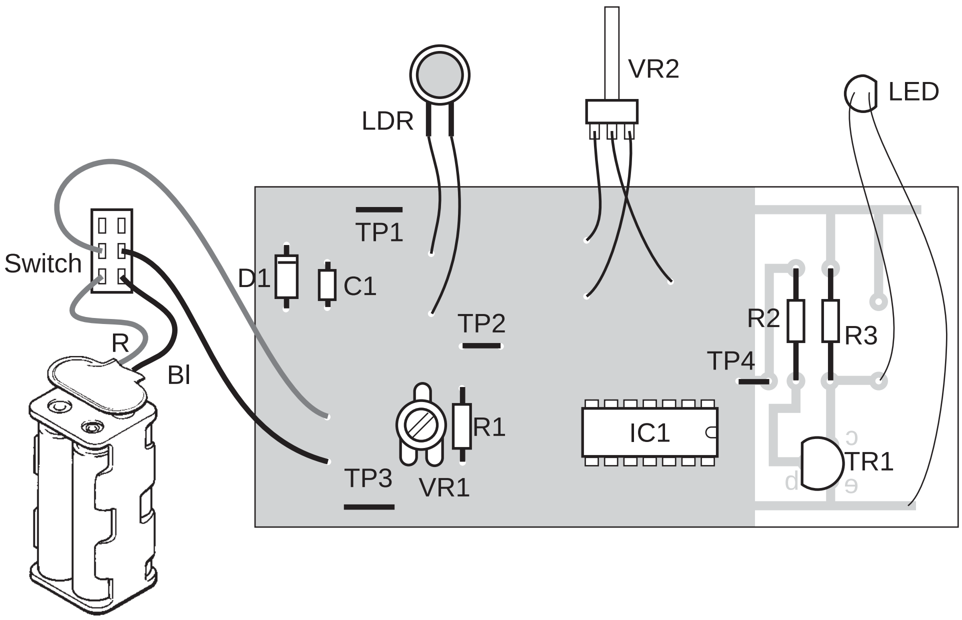
TEST 2

- Turn the variable resistor knob.
- Check that this changes the value of the input signal, causing the output to switch between 0 and 5.5 V.

FAULT FINDING

FAULT	ACTION
If either test fails: 	FIRST disconnect the battery. Check that you have got the IC in the correct way around. SECOND reconnect the battery. Use the meter on the DC 10 V range to check that: • Pin 11 is at 0 V. • Pin 4 is around 5.5 V. • The signal on pin 5 is the same as the signal on the input. • The signal on pin 6 changes as you turn the variable resistor. • The signal on pin 7 is the same as the signal on the output.
If any of the above meter readings are not as they should be:	Check the soldering - Use a magnifier to check that there are no small bridges of solder between the pins of the IC.

When you are sure that this section is working correctly, trim the ends of the leads with a small pair of cutters. Of the four sections on your circuit, you have now completed the first three.



Before you go onto the next section:

- Describe the tests you have done on this section.
- Report any faults that you have found and describe the cause of the fault and how you repaired it.
- Describe the sections you have built so far.

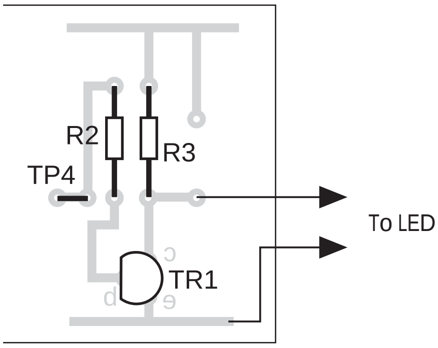
THE TRANSISTOR/SWITCH INDICATOR

You will need the following components:

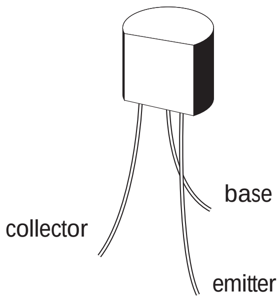
COMPONENT	CIRCUIT REFERENCE
A BC237 transistor	TR1
A 2.2 kΩ resistor	R2
A 330Ω resistor	R3
A light emitting diode	LED
2 × 100 mm wire	

ASSEMBLY

Make sure that the battery is disconnected before you start.

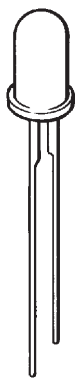


- Solder the transistor in place first.
  The three legs must go in the correct holes.
  The collector goes into the hole marked **c** in the diagram, the emitter to hole **e** and the base to **b.**
- The 2.2 kΩ resistor and the 1 kΩ resistor are mounted in the position shown in the diagram above. Resistors can go in either way round.



Transistor

- Like the LDR and the variable resistor, the LED is attached to the board by 100 mm wires.
- Solder the wires onto the PCB. Sleeve each wire with 15 mm of black sleeving.
- Solder the wire from the 0 V track on the PCB to the shorter leg of the LED. The other wire is soldered to the longer leg.



LED

TESTING

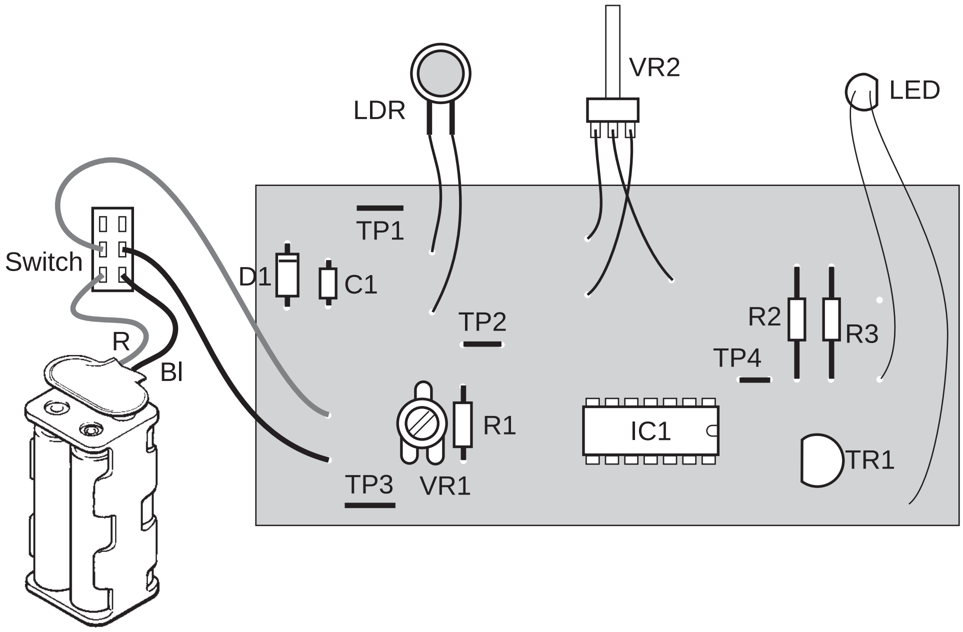
- Attach a 6V battery to the battery connector.
- Check that, when you cover the LDR, the LED comes on. When the LDR is in bright light, the LED should be off.
- Adjusting the variable resistor should change the amount of light needed to switch off the LED.

FAULT FINDING

Check that your transistor and LED are in the correct way around.

When you are sure that this section is working correctly, trim the ends of the leads with a small pair of cutters.

FAULT	ACTION
The LED is always on	Check the solder joints on the transistor and the 2.2 kΩ resistor.
The LED is always off	Check the solder joints on the LED and the 1.1 kΩ resistor.



You have now completed the circuit! Write a report that:

- Describes the tests you have done on this section.
- Reports any faults you found and describe the causes of the faults and how you repaired them.
- Describes what the sections you have built so far do.
- Describes what the whole circuit does.