Battery Safety

- Batteries can be hazardous - especially rechargeable batteries and alkaline batteries.
- Never use rechargeable batteries for the activities in these instructions.
- Always take care that the battery leads do not touch together and short-circuit the battery. This can result in the battery getting hot and even melting the battery box.
- Always remove the battery from your kit when you have finished using it.
- Always store batteries safely where they cannot touch any metal objects.
- Never dispose of batteries in a fire. Put them in a special battery collection unit or in the normal household waste.

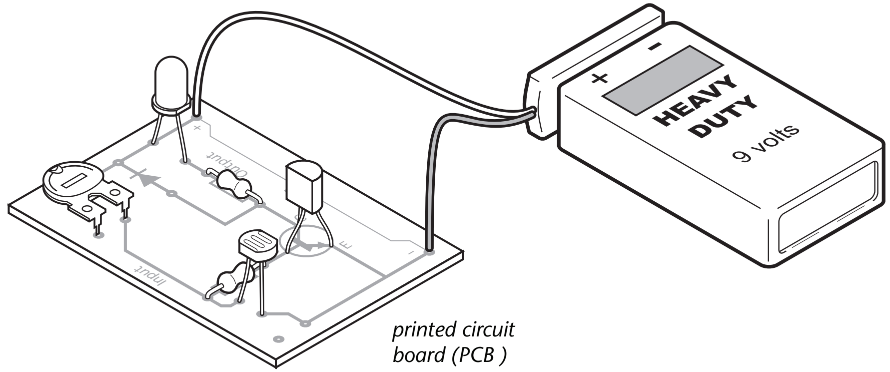
Electronics

Contents

What next?

If you have made all the circuits, you have made a good start in electronics. Although the number of components you have is quite small, you can now start to add to them so that you can alter the circuits and even make up new ones. Maplin sells a number of books that will help you to go forward – plus a wide range of kits and modules that will also give you a head start

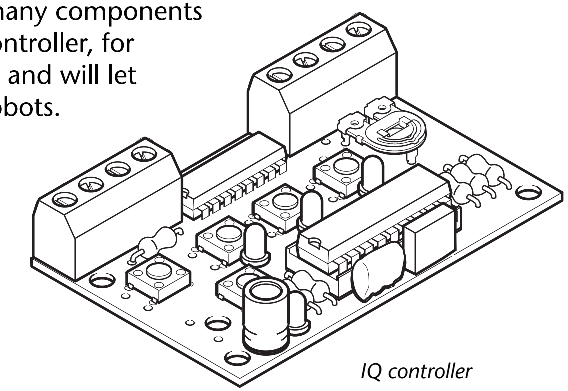
After the prototyping stage, circuits are normally made on a printed circuit board (PCB for short). This consists of a copper tracks to which the components are soldered using a soldering iron. These are easy to use once a teacher or adult has shown you how.



printed circuit board (PCB)

Finally, circuits are normally packaged in suitable boxes or containers. Sometimes you can find used packaging such as old VHS video cases that will do the trick. If not, Maplin will have a wide range of cases you can buy off the shelf.

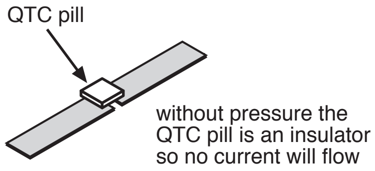
Integrated circuits have actually made electronics easier than it used to be because so many components are assembled inside. The IQ controller, for example, is easy to programme and will let you to control things such as robots. With modern components and new materials like QTC, you can start creating things that nobody has yet done – and become part of a new generation of electronics designers.

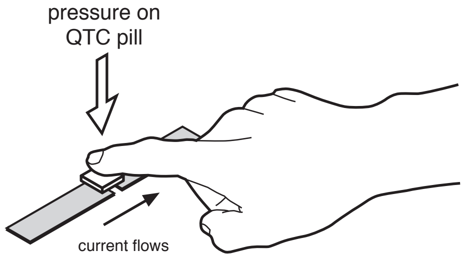

IQ controller

QTC

QTC stands for quantum tunnelling composite and is one of the strangest and most recent materials to come on the market. As you investigate the QTC in your kit electronics designers all over the world are coming up with new ideas for its use.

QTC is normally an insulator but if you squeeze it gently, it becomes an almost perfect conductor. It is so amazing, it actually 'teleports' electrons across tiny gaps inside it. This is why designers are so excited and have already made clothing with built-in QTC switches for controlling iPods and other equipment.

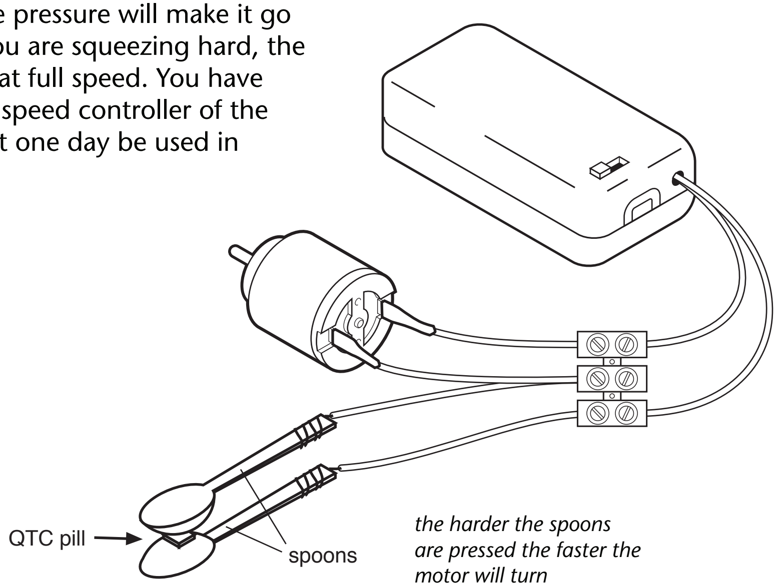




when the QTC pill is pressed it becomes a conductor so current will flow through it

Circuit 29 - QTC switch

Make a circuit as shown and wrap the bared ends of the stranded wires tightly around a couple of teaspoons. When you touch the ends together, the motor will run. Now place the QTC pill between the two spoons and try again. When you apply gentle pressure, the motor will not run. If you press harder, it will start to run – and more pressure will make it go faster. When you are squeezing hard, the motor will run at full speed. You have made a simple speed controller of the type that might one day be used in power tools!



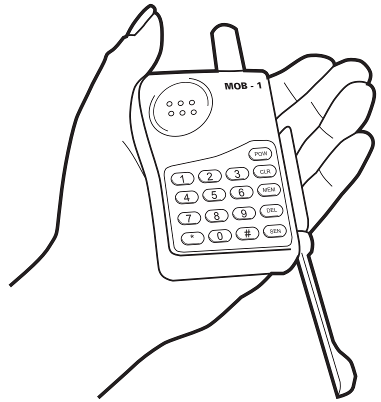
the harder the spoons are pressed the faster the motor will turn

ELECTRONICS

Your kit contains a range of components used by professional circuit builders. Before you start building anything, transfer the components from the box into the case provided.

Introduction

The modern world is driven by electronics from the chips in credit cards to the complex processors in laptop computers. Progress in electronics has been very rapid indeed and few people will realise, for example, that the electronics in a mobile phone would virtually have filled a building the size of St Paul's cathedral just 50 years ago!



This electronics kit is designed to give you a knowledge of basic electronics so that you can:

- understand how things work
- enjoy making electronic circuits
- design and make new circuits of your own

Many people are turned off electronics because they are thrown in at the deep end and never quite get to understand enough to give them confidence. This kit uses just a few components, but if you really get familiar with them, you can make real progress later with other more advanced Maplin kits and components.

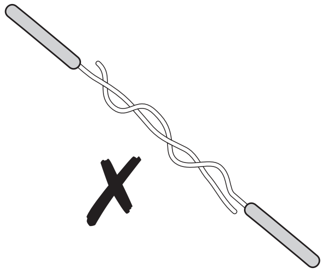
How to use the kit

If you are a complete beginner to electronics – whatever your age – it is a good idea to start from page 1. If you know some of the basics, then you can skip to level 2 or 3 circuits. At each level there are ideas for things to make. Don't be afraid to experiment. If you have an idea, try it out. Although components might sometimes get damaged, you can get spares from your local Maplin store at very low cost.

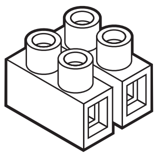
Level 1

Getting started

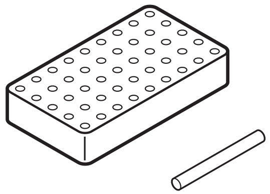
First of all, you have to be able to connect parts or components together. There are several ways of doing this without using solder which makes a kind of welded joint. The worst way is the birds nest method where you try to twist wires around to make things join up. Usually you will get a dry joint. This is one that looks OK but in fact does not conduct electricity.



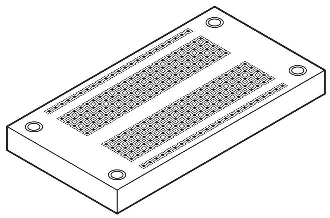
Here are three better ways of connecting things:



Terminal blocks with screws



Matrix block with holes and pins

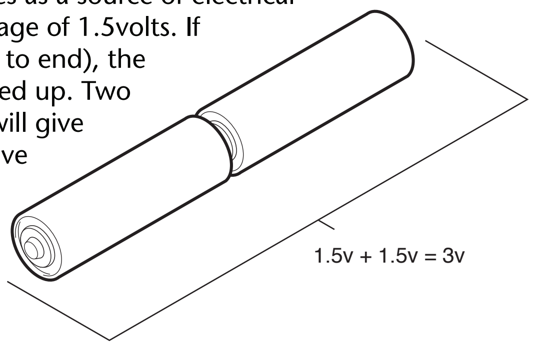


Breadboard

We will start by using the first two and then go on to the breadboard which is used by professional electronics engineers to try out ideas.

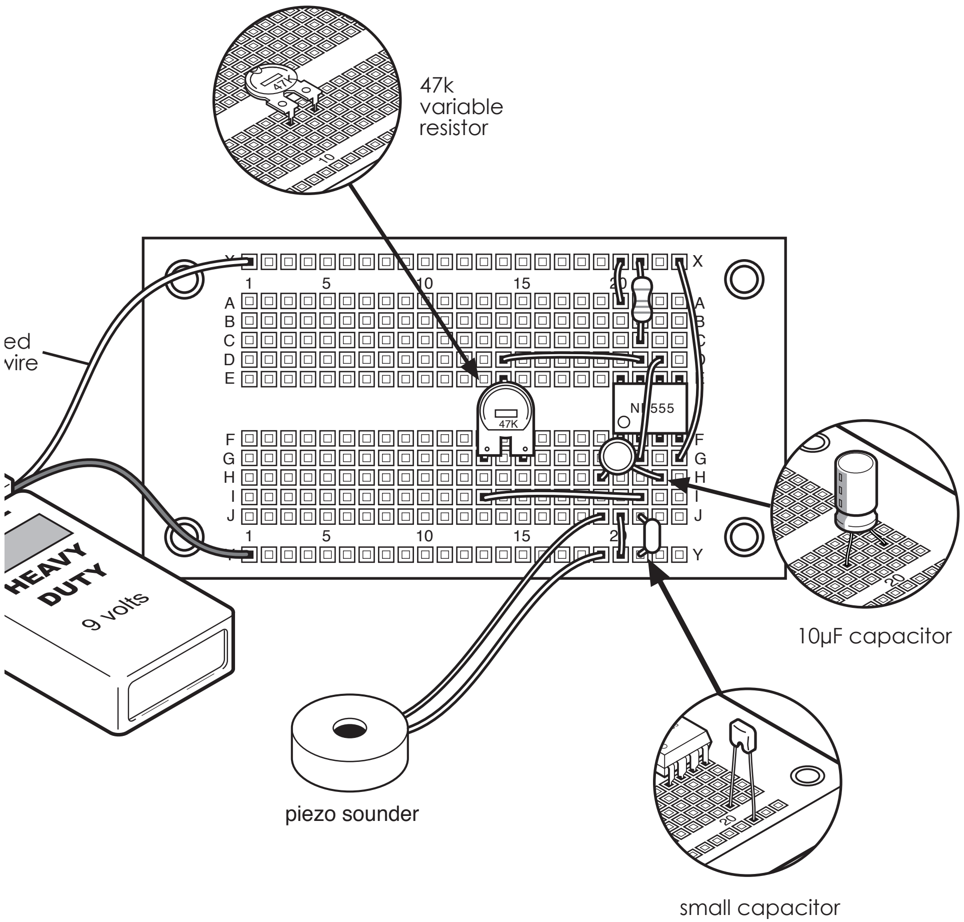
A few basics

You will be using AA size batteries as a source of electrical energy. These have a stated voltage of 1.5volts. If you connect them in series (end to end), the voltages of the batteries are added up. Two AA batteries in the battery box will give 3v. Four batteries in the alternative box will give 6v. Six batteries would give 9v – and so on.



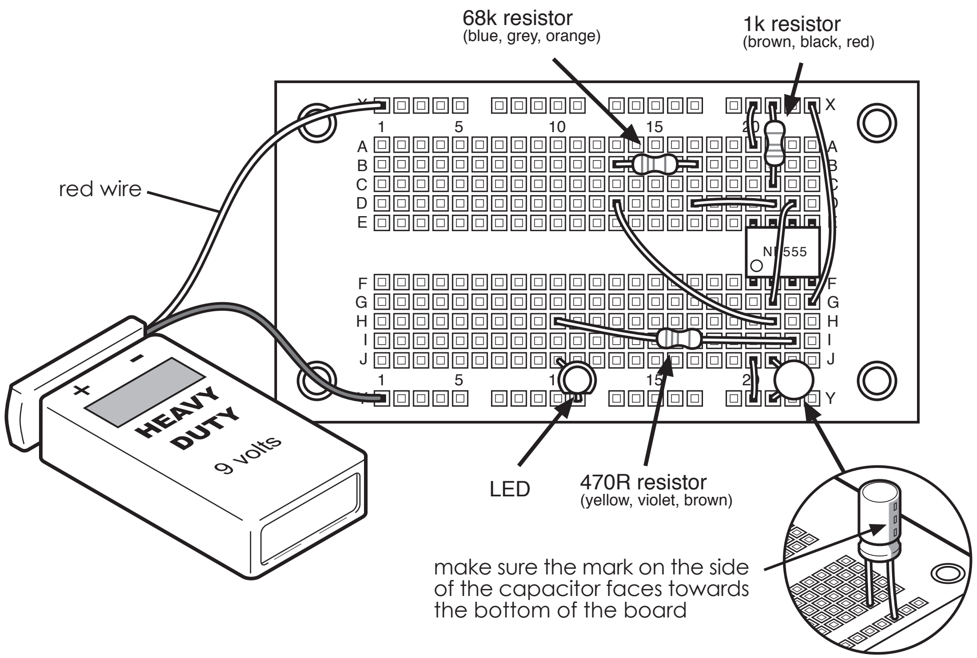
Circuit 28 - Sound generator

If you use a 47k variable resistor in the circuit and swap the capacitors as shown you can make a simple sound generator. Adjusting the resistor creates different frequencies. As we get older we lose the capacity to hear higher pitched sounds. Try using this circuit to test the hearing of different people. You might be able to hear higher frequencies than your parents.

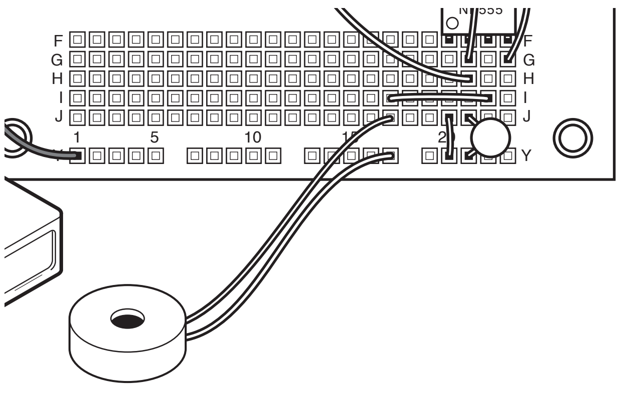


Circuit 27 - Flasher

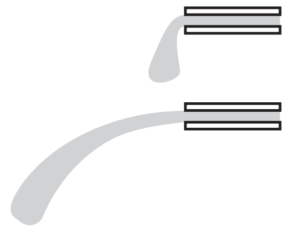
Connected in a slightly different way, the 555 chip will switch the LED on and off automatically. It will do this faster or slower – depending on the values of the resistor and capacitor. You can experiment with these values and put in a variable resistor in place of the fixed 68k resistor to change the speed of flashing.



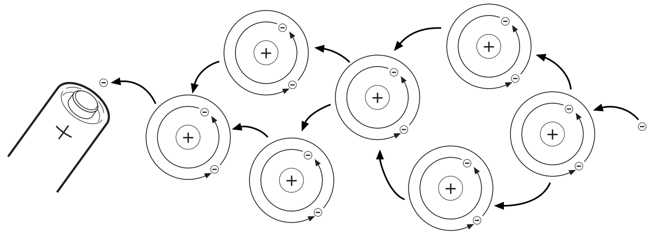
If you connect a speaker to the output pin 3, you will get a buzzing noise instead of a light flashing. If the speed of switching is very high, this can become a high pitched whistle.



If we compare electricity to water, current is the amount of water flowing and voltage is the pressure. If you increase voltage, more water will flow. Think of a hosepipe at low pressure: the water dribbles out (low pressure) if the tap is partly open. Open the tap (high pressure) and more water comes out.



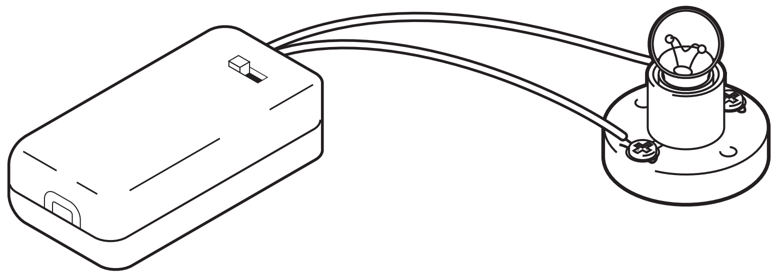
In fact the comparison with water can be a bit misleading because electricity is a different sort of 'stuff'. It is actually the incredibly rapid movement of electrons 'bumping'each other along in a conductor like a metal wire. Although these actually move from –ve to +ve in a circuit, we usually talk about current (the 'stuff') flowing from + to -. That's how we will describe it here.



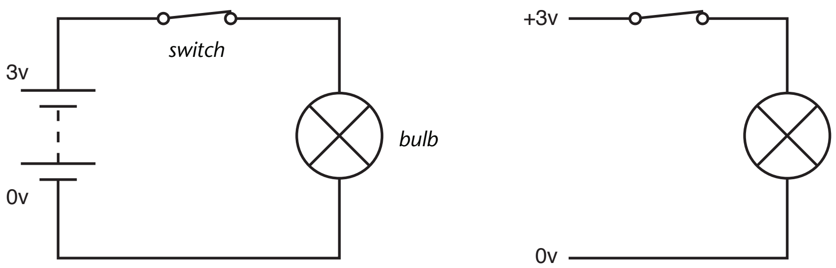
A circuit is a number of connected parts that control the flow of current. The simplest circuit you can make is with a battery and bulb.

Circuit 1

Insert 2 AA batteries into the battery box and screw a bulb into the bulb holder. Join the bulb to the battery box by passing the wires under the bulb holder screws and tightening them gently. When you switch on, the bulb should light up.



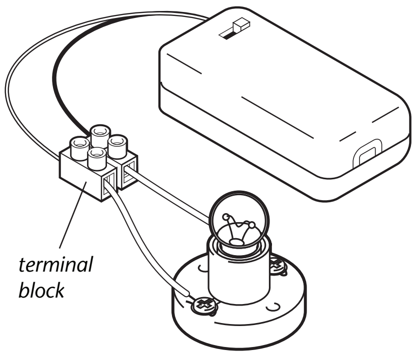
This is a good example to begin with because it is the simplest one you can make. Like the other circuits that follow, this is drawn as a diagram with symbols standing for the components and straight lines for connections. Like the London underground map, a circuit diagram isn't so much a real picture as a map that allows you to find your way around. The circuit diagram for the bulb circuit can be drawn in two ways:



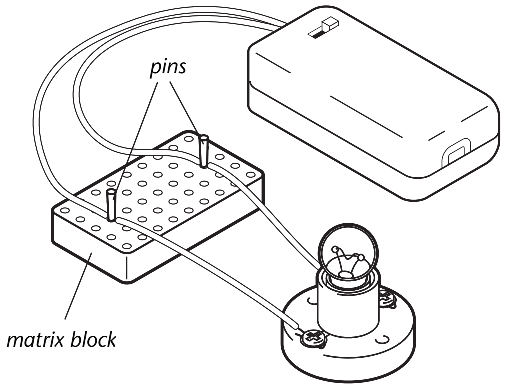
Most circuit diagrams use just the two lines or rails for + and – and don't show the battery each time.

Looking at the diagram, you will be able to follow the path that the current takes from +v through the switch to 0v

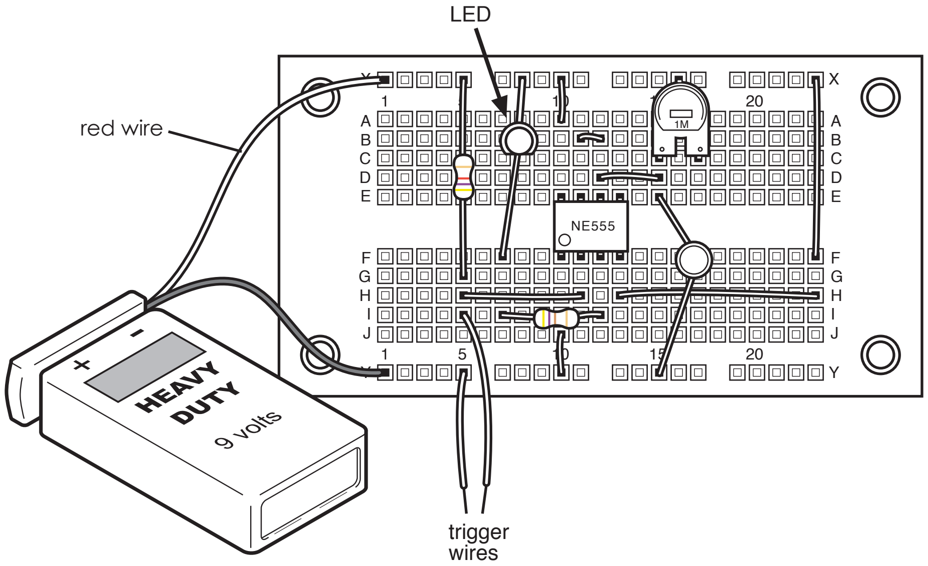
If you make the bulb circuit using a terminal block, it would look like:



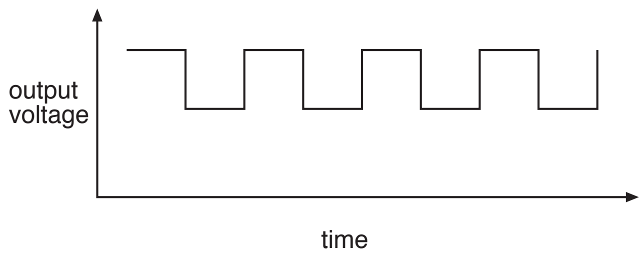
If you made the bulb circuit using a matrix block, it would look like:



If you want the LED to be 'off' during the timed interval and then turn 'on' at the end, you simply change the position of the LED.

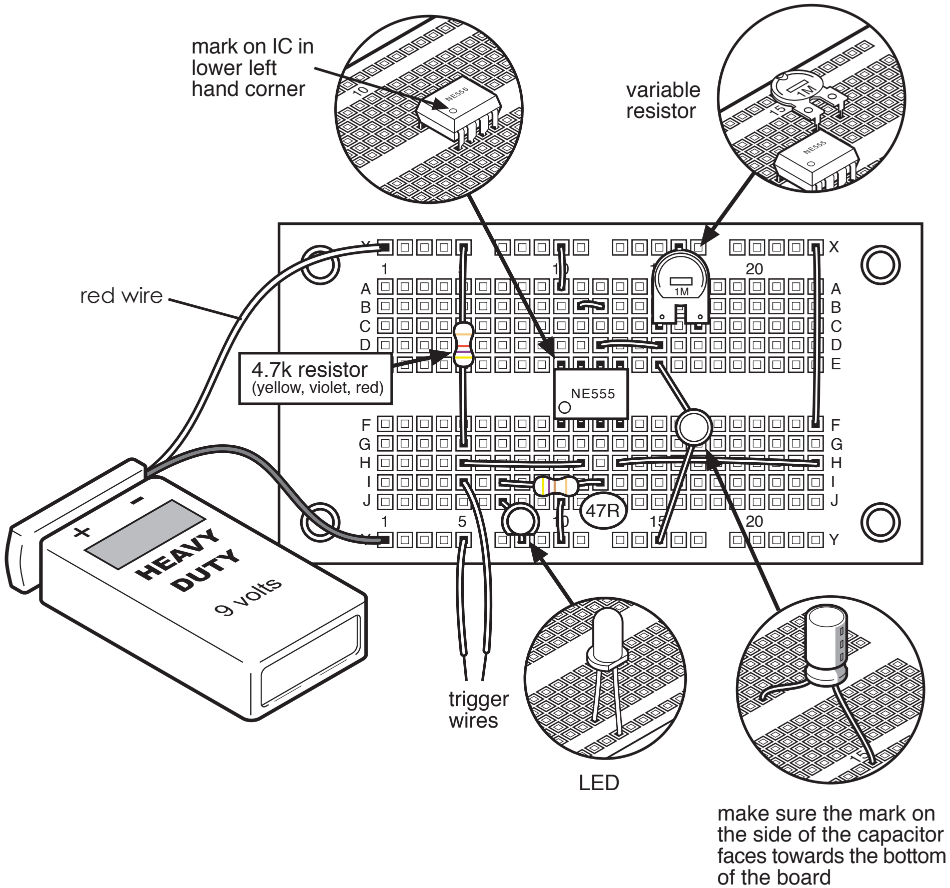


To show how the 555 timer is working, we sometimes draw a timing diagram. This shows how it switches on and off over a period of time.

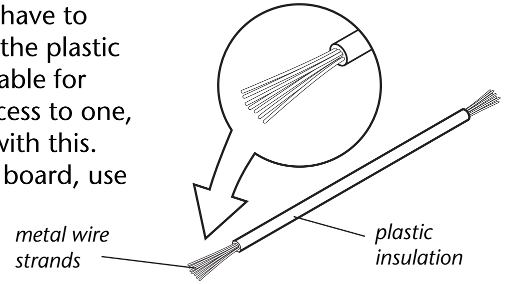


Circuit 26 - Timer

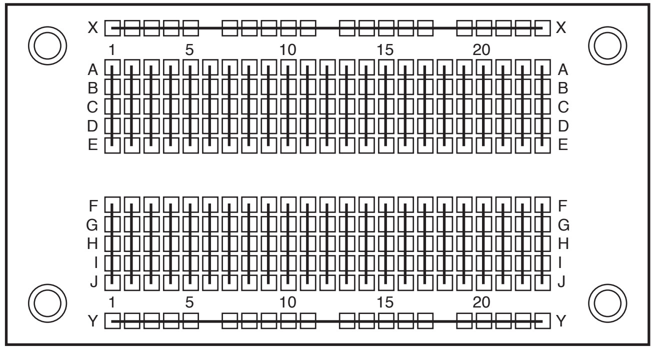
To make the 555 into a timer, it is connected as shown. When the flying lead (or press switch if you want) connects pin 2 to –v, the timing starts. The LED comes on and stays on until the end of the timed interval. The values of the capacitor and the resistor determine how long the timed interval will be for. You can experiment with these: the higher the values of each, the longer the timed interval. If a variable resistor is used, as shown in the diagram, the timed interval can be changed by adjusting the resistor.



Both of these circuits mean that you have to cut some insulted wires and strip off the plastic from the ends. Special tools are available for wire stripping. If you do not have access to one, you may need an adult to help you with this.
To push down the pins in the matrix board, use the top of an old pen.

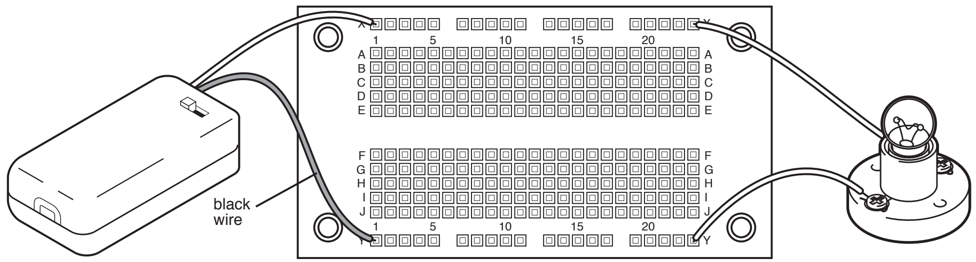


To use the breadboard, you first need to know a bit about it. The small holes are sockets into which you can plug the legs of components or connecting wires. These holes are joined up under the board in rows – as shown by the lines in the diagram. If you plug something into row A, it connects with anything else in that row. The two long rows top and bottom are normally used for the battery. The top row is + and the bottom 0v.

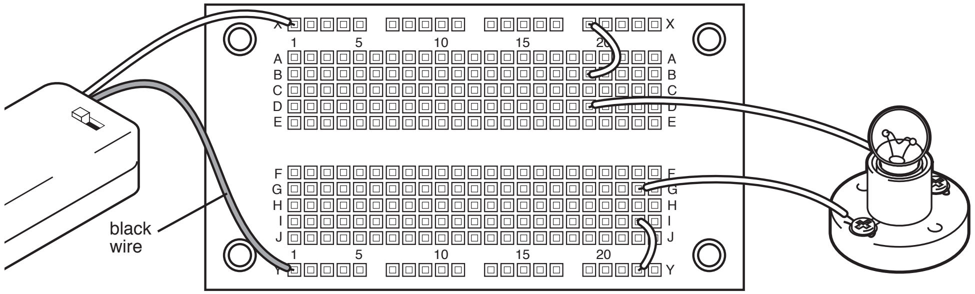


If you want to make the bulb circuit then:

- plug the battery leads into the top and bottom rows
- screw two 100mm lengths of non-insulated wire to the bulb holder as shown
- plug the other ends of the wires anywhere along the + and 0 rails



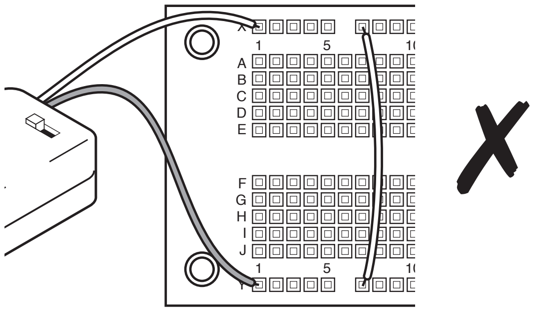
If you think about it, you can make up the same circuit in many different ways on the board. For example, plug the two bulb leads into two vertical rows and then make two small ‘U’ shaped pieces of wire to connect these to + and –. As long as you can follow a continuous path for the current, the circuit will work.



Making mistakes!

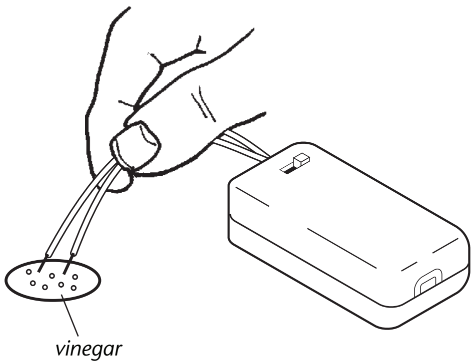
If you connect a wire from one rail to the other without anything in between, it is called a short circuit. A big current will flow and the battery will get flat very quickly.

If you make up the bulb circuit but use the wrong rows, current will not flow.



Finding faults

It is always annoying when something doesn’t work, but there are ways of finding faults. If your bulb circuit doesn’t work is it the bulb or batteries? First of all check on the batteries. You could put them into something else that does work – like a torch. Or, for example, you could try the acid test. Put a tiny drop of vinegar onto a shiny surface and hold the two wires in the drop. If it fizzes, the batteries have some life! If the batteries are good, make sure the bulb is screwed down. If this stills fails, it is probably a faulty bulb.

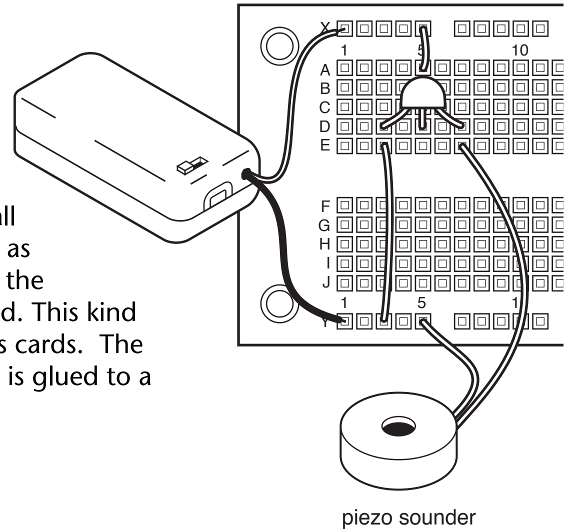


Integrated circuits and their use

Integrated circuits (ICs for short) are often now referred to as chips. They are complete circuits, some containing several million transistors, made by a special process. A chip can be small enough to just cover a full stop on a page, but most are contained in a larger package with legs so that they can be handled and connected. Like transistors before them, integrated circuits have revolutionised electronics and made personal computers, mobile phones and iPods possible.

Circuit 25 - Music chip

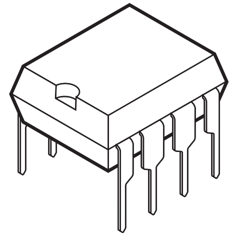
A very simple chip comes in a package that looks like a transistor. The one in you kit has a short tune in its memory and will play this if connected to a small speaker. If you make up the circuit as shown, the piezo speaker will play the tune when the battery is connected. This kind of chip is used in musical greetings cards. The sound will be louder if the speaker is glued to a card surface.



555 timer

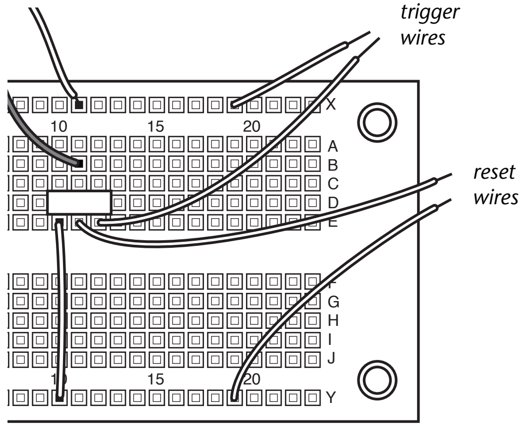
The music chip is dedicated to playing back a stored tune and will not do anything else. However, the larger 555 timer chip can be put to all sorts of uses. Two of the legs or pins are for connection to +v and –v and the others are connected according to what you want to do. The 555 is used most often one of two ways:

- as a timer
- as a multi-vibrator – flashing an LED or making a sound.



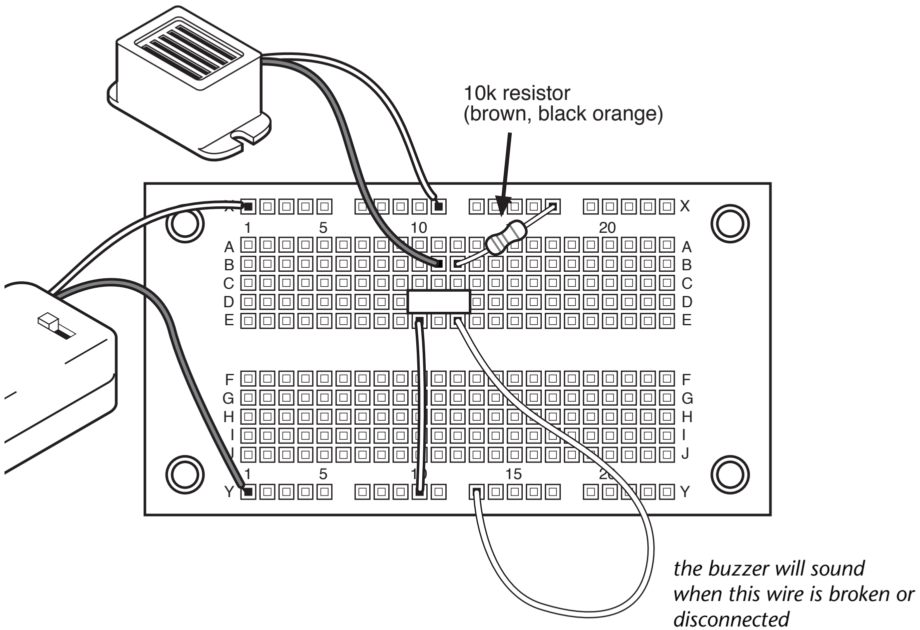
555 timer IC

An alternative way of turning the thyristor off is to bypass it. This happens if you connect a switch (or piece of wire) from anode to cathod as shown in the diagram. When this connection is made for just a split second, the thyistor is 'robbed' of current and turns off.



Circuit 24 - Breaking wire alarm

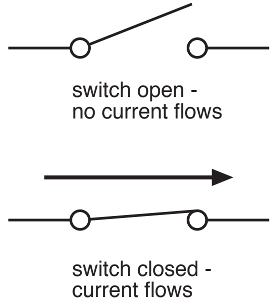
Sometimes alarms are made to sound when you break a connection. This might be a length of fine wire or foil tape on a window. To enable this to happen, the thyristor is connected in a slightly different way as shown on the diagram. When the wire or foil link is in place, current will flow via the resistor from +v to –v. When the link is broken, current will now flow to the thyristor gate and cause it to turn on.



The circuits that follow are for testing other circuits!

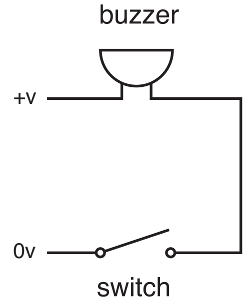
Switches

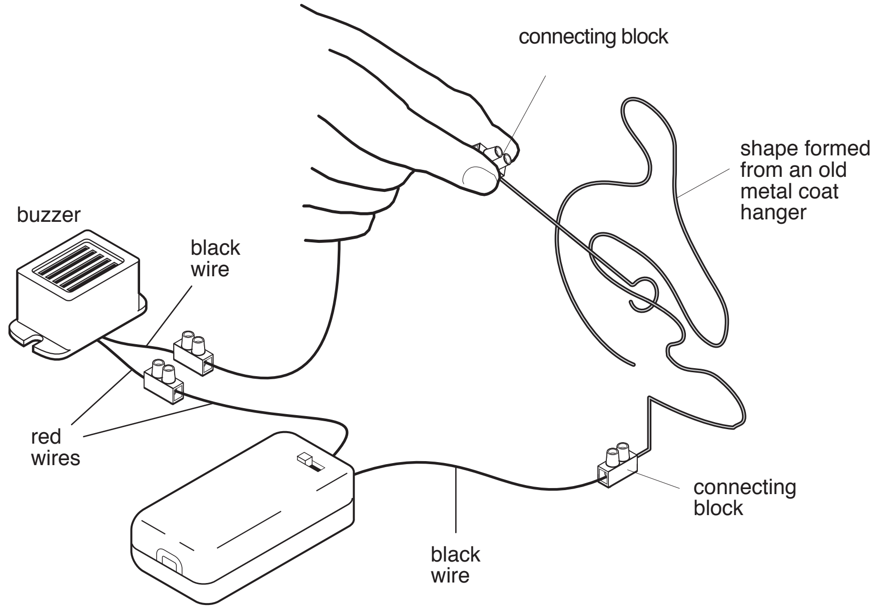
Your battery box has an on/off switch. This allows current to flow in a circuit or stops it. The symbol for a simple switch really explains how it works. When in the 'off' position, the switch makes a gap in the circuit. In the 'on' position, it lets current flow normally.



Circuit 2

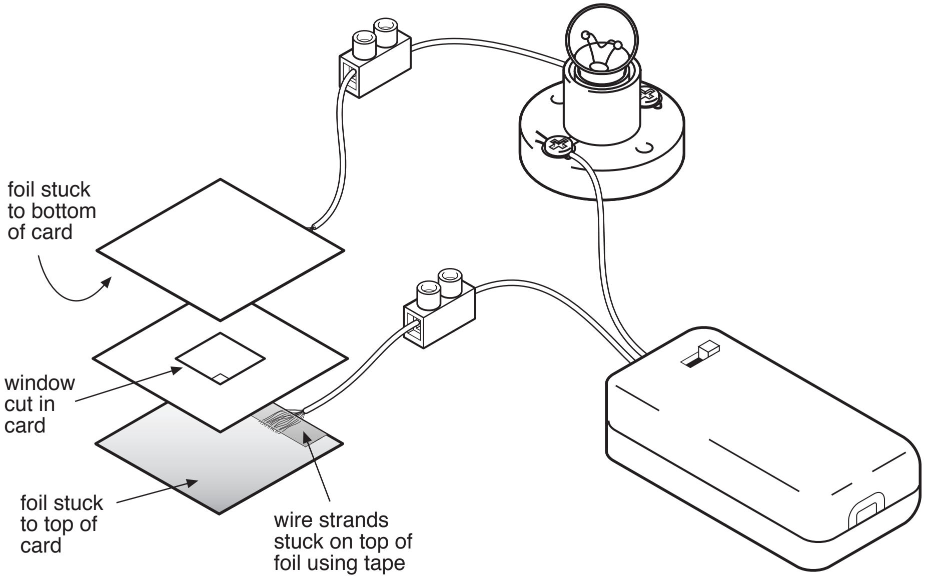
Switches come in many shapes and sizes, but you can also make your own. A popular 'steady hand' game (sometimes called 'buzzwire') is really just a switch. The circuit shows a switch and buzzer. When the switch is 'on', the buzzer sounds. Instead of using a switch in the circuit, you connect one end of the circuit to a bent wire and the other end to a loop of wire as shown. You can do this with the terminal blocks. The game can be made more difficult by making the loop smaller.



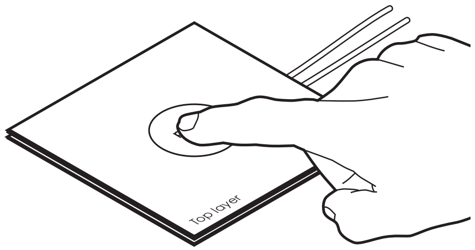


Another type of switch you can make is called a membrane panel. These are used in real life in things like thin calculators and vending machines.

- Cut three pieces of card from an old cornflakes box – each about 80mm square. In the centre of one piece cut a hole about 10mm square.
- Cover the faces of the other two cards with kitchen foil - using stick glue.
- Strip off the insulation from two lengths of wire and stick the bare ends onto the foil with tape. Then put all three cards together as shown and connect up to a battery and bulb.



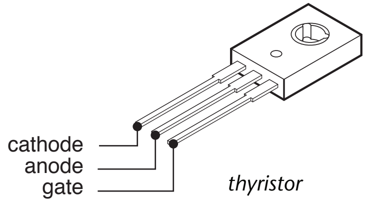
Normally your homemade switch is 'off' because the two foils cannot touch each other. But if you press in the centre, the two foils come together through the hole and the switch is 'on' for as long as you press it. You can decorate the top card with stickers etc. to make it look like a real membrane switch.



Level 3

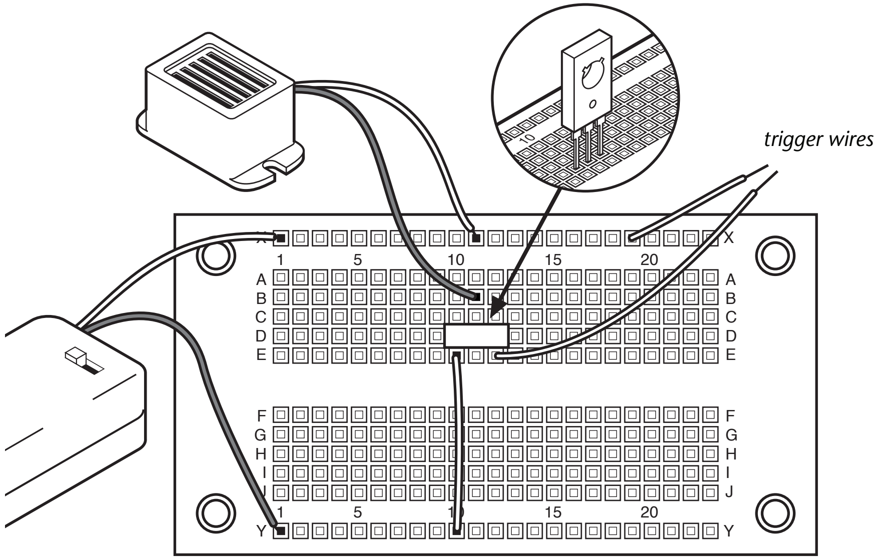
Thyristor

The thyristor is a bit like a transistor but once switched 'on' it stays 'on' until the supply current is turned off. This makes it very useful for alarms when you want something to stay sounding automatically. Like the transistor, the thyristor has three legs but these are called gate (instead of base), anode (instead of collector) and cathode (instead of emitter). The thyristor in your kit is also able to pass much higher currents than the transistor – up to 3 amps.



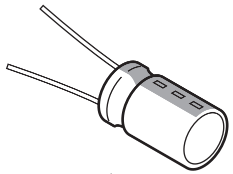
Circuit 23 - Basic alarm

The thyristor is connected and works like the transistor. When no current flows to the gate, the thyristor is turned off and no current flows anode to cathode to make the buzzer sound. If you connect the gate of a thyristor to +v for just a fraction of a second, the thyristor turns on and stays on. It stays on until you switch off the battery. When you switch on again the thyristor is 'off' until 'triggered' by connecting the gate to +v.



Capacitors

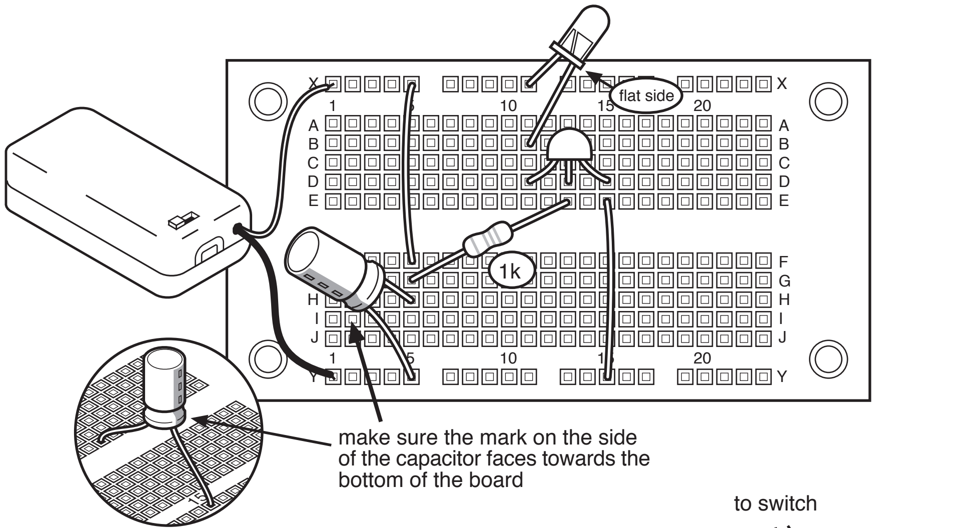
A capacitor is something that stores electricity – a bit like a rechargeable battery. The amount it can store is measured in units called Farads. This is a very large unit and many capacitors are marked in micro-farads (µF). These units are one millionth of a farad. A capacitor can be charged up by connecting it the correct way around to a battery. It then discharges when connected to something else.



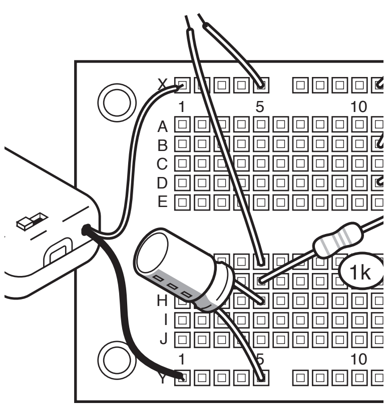
capacitor

Circuit 22 - Simple timer/alarm

As a capacitor discharges, it can be used for timing. Make up the circuit shown. When you switch on, the LED will light up and at the same time the capacitor will charge up. When you switch off, the capacitor will now work like a second battery and keep the transistor switched on. After a time, the capacitor will be discharged or 'flat' and the LED goes off.

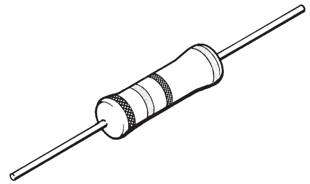


Usually, an alarm circuit needs to stay 'on' for a time whatever happens to the switch that triggered it. The capacitor circuit makes a good alarm because it keeps the LED going (or a buzzer sounding) for a period of time. Instead of the battery box switch, you can substitute a switch connected to a door or window. Even if this is 'on' for just a second or so the capacitor charges up and keeps the LED on for a much longer time.



Resistors

A resistor limits the flow of current and can provide different voltages at different places in a circuit. Resistance is measured in ohms and the higher the number the greater the resistance. A 1,000,000 ohm resistor is almost an insulator and 1ohm resistor a good conductor. Instead of writing resistance values with lots of 0s, we use symbols as follows:



R stands for anything under 1000
k stands for 1000
M stands for one million

For example: 1k = 1000 ohms   3M = 3,000,000 ohms

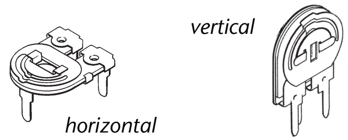
We also use the letter in place of decimal points so:

1k2 = 1.2k or 1,200 ohms   4M7 = 4.7M or 4,700,000 ohms

Ordinary resistors look similar except for the colour bands which tell you the value. Look at the colour sheet in your kit so that you can pick out the resistors that you want.

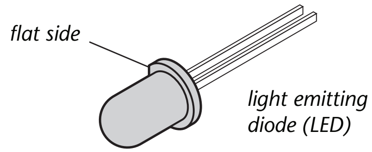
Variable resistors

The value of these resistors can be altered. The ones in your pack go up to 47k and 1M.



Light Emitting Diodes (LEDs for short)

LED stands for Light Emitting Diode. This is a component that gives out light when current flows through it. However, you must remember three things about LEDs:



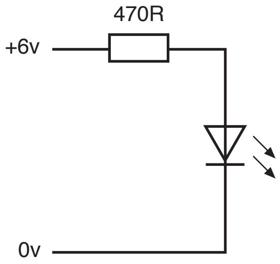
1. an LED only works one way around. Look carefully at the plastic case and you will see a small flat part. This is always next to the leg you connect to 0v;

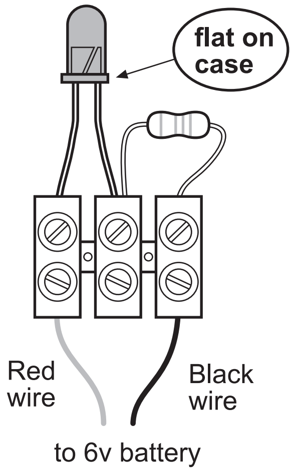
2. an LED can burn out if you connect it directly to the battery. It should always be used with a resistor in series. The resistor limits the flow of current;

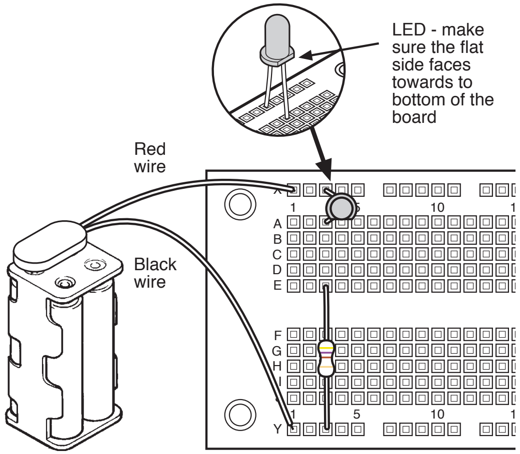
3. LEDs need at least 2.2 volts so you will need a 3v battery, not 1.5v.

Circuit 3

This shows the circuit diagram for an LED indicator lamp. It uses a 470R resistor (yellow, violet, brown) and any one of the coloured LEDs. The following pictures show how the circuit can be built using the terminal blocks and the prototype board. Note that the 6 volt battery box is needed.



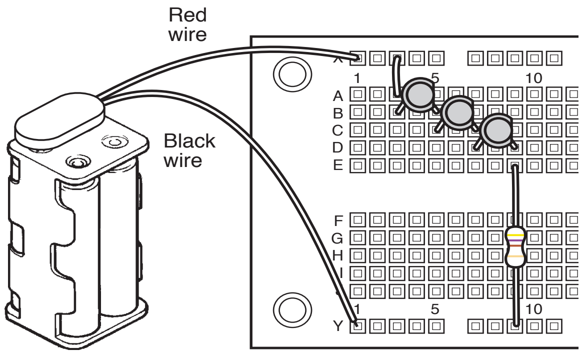




Try swapping different value resistors. You will find that the higher the value, the dimmer the LED gets.

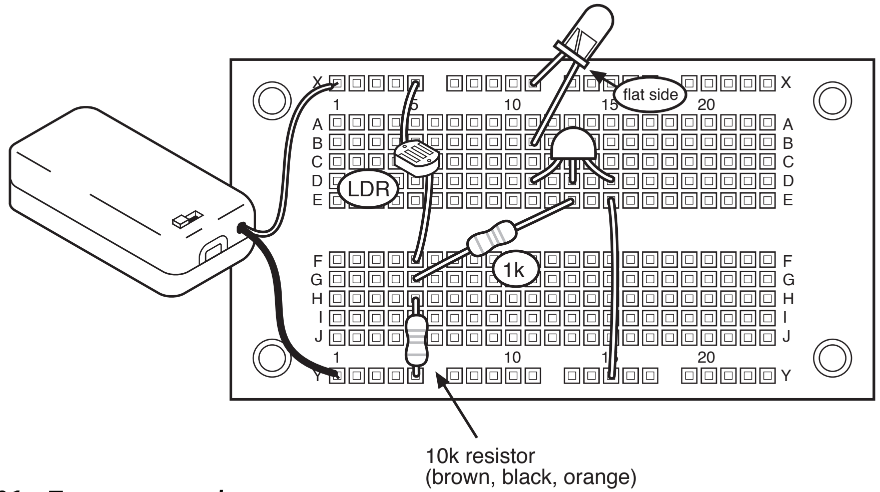
Circuit 4

You can connect two or more LEDs in series but they get dimmer the more that you use.



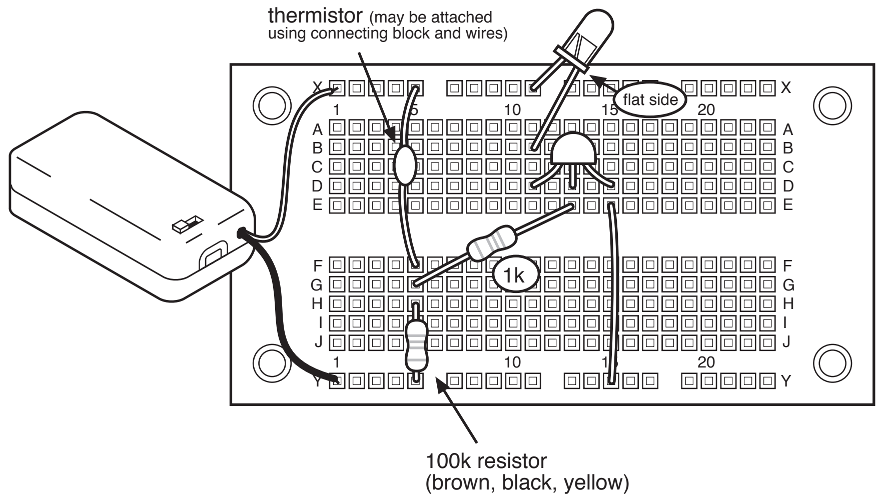
Circuit 20 - Light alarm 2

In this circuit, the LDR is connected to a second resistor in a circuit called a potential divider. This ‘divides’ the voltage of the battery. When the top resistor (LDR) has a high resistance in the dark, very little current flows to the transistor base and to –v. When it is lit up, enough current will flow to turn on the transistor and the LED comes on. If you want, you can now use a buzzer instead of an LED. This circuit can be used as a warning if, for example, a valuable vase is lifted off a base containing the LDR.



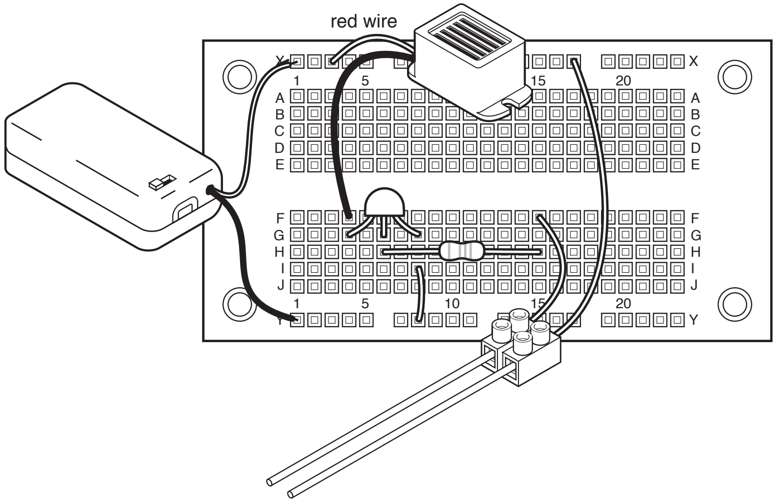
Circuit 21 - Temperature alarm

The sensor for temperature is a special resistor called a thermistor. Its resistance falls when it gets warmer. If it is used in a circuit like the previous one, the LED or buzzer comes on when the thermistor gets warm. This circuit can be used, for example, if the temperature of bath water goes above a safe level.



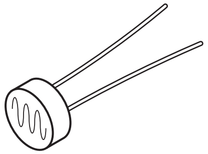
Circuit 18 - Water level alarm with a buzzer

This is the same as the LED water alarm circuit but uses a buzzer in place of the LED



Circuits with sensors

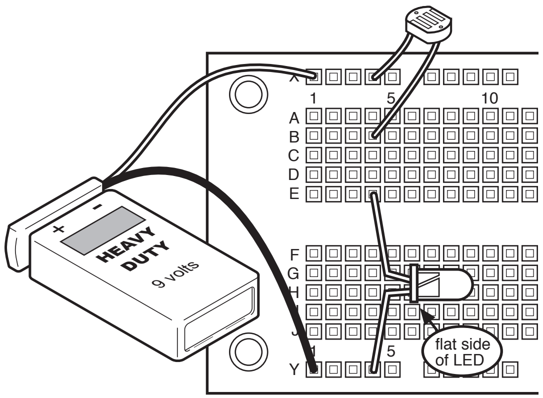
The transistor circuits can be made to work using sensors. The simplest sensors are special resistors which can detect changes in light or temperature levels. For light, we use a light dependent resistor (LDR for short). This has a high resistance in the dark (about 100k) and a low resistance in bright light (about 100R).



light dependent resistor (LDR)

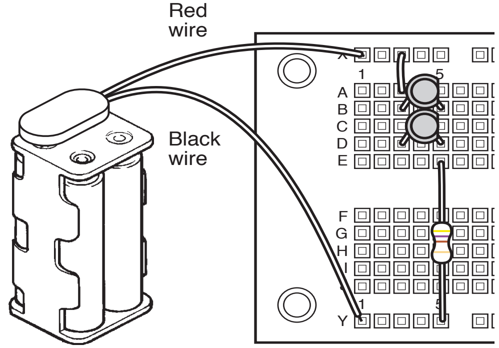
Circuit 19 - Light alarm 1

We can use an LDR in a very simple circuit with an LED to show light level. When the LDR is dark, not much current passes and the LED stays 'off'. When the LDR is lit up, its resistance drops and enough current passes to light up the LED. This circuit is simple but is not very sensitive and may damage the LDR. It is better to use a transistor.



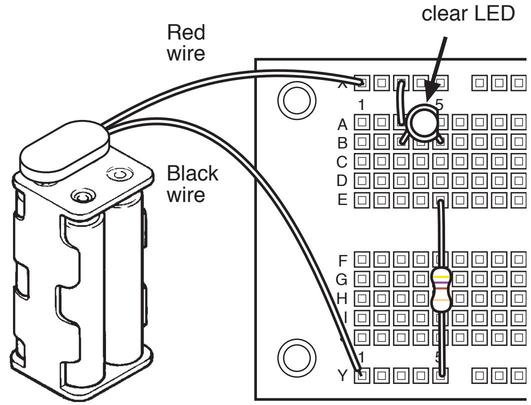
Circuit 5

You can connect LEDs in parallel. This circuit shows them sharing a resistor.



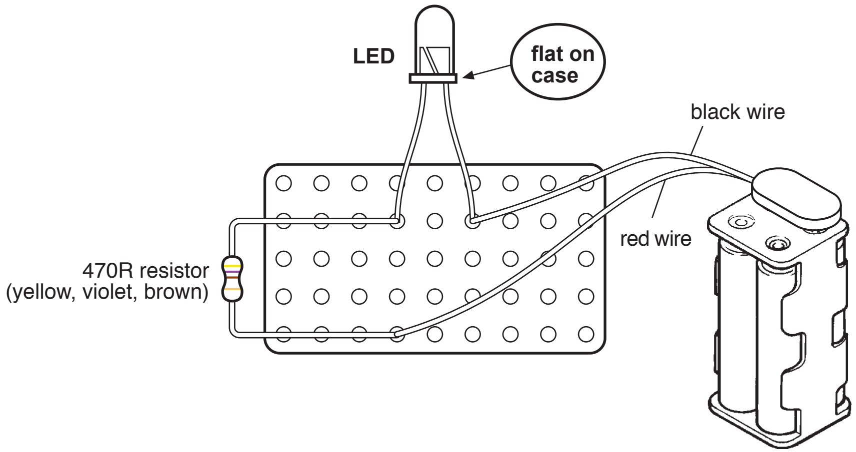
Circuit 6

This circuit uses one of the high bright red LEDs. It looks clear to begin with, but gives a really bright light. These LEDs are now used in traffic lights, car rear lights and cycle lights.

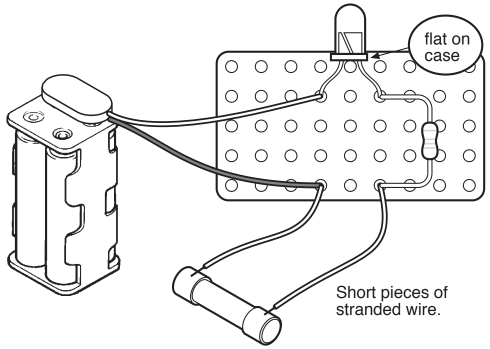


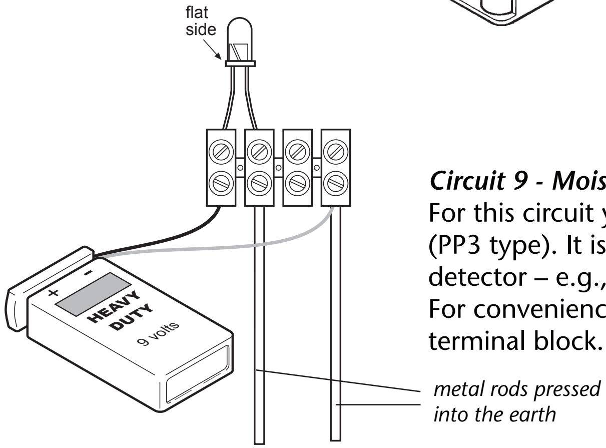
Circuit 7 - Battery tester

The circuit shown here gives an indication of battery condition. The LED will light up if the battery can source enough current. It is shown constructed on a matrix block.



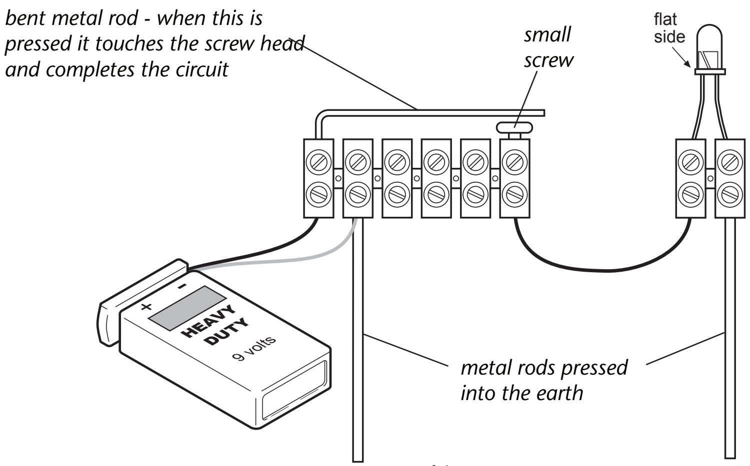
Circuit 8 - Fuse tester
This circuit is used for testing fuses and for checking connections from 'A' to 'B'. If the fuse wire is broken no current will flow in the circuit.





Circuit 9 - Moisture meter
For this circuit you need a 9v battery (PP3 type). It is a simple moisture detector – e.g., for potted plants. For convenience, it is made using a terminal block.

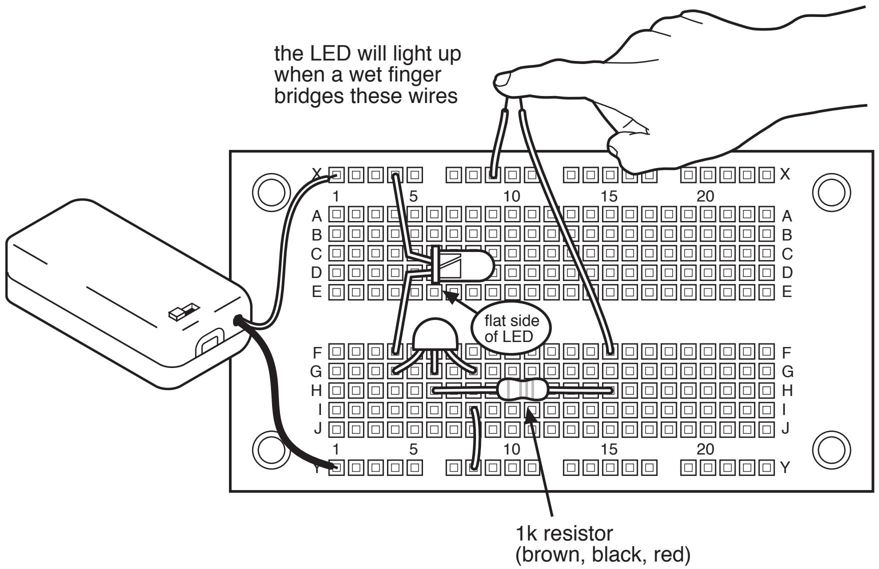
Circuit 10 - Signals through the earth
Not many people know that the earth is often used as for passing electrical current. There is so much of it, it makes a near perfect conductor! If you want to signal in morse code (dots and dashes) to someone else then you can make up a simple transmitter and receiver as shown. The earth in this circuit is acting as one of the wires and so you only need one length of wire laid over the ground.



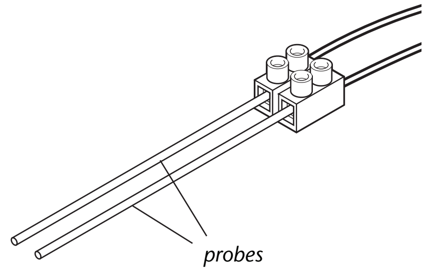
Circuit 16 - Dampness indicator
We need a circuit to show that something is moist – like the dampness in the wall of a house. In Circuit 9 we saw that you could detect water with an LED. But that circuit is not very sensitive and needs a 9v battery to work. In this circuit only a tiny current has to pass to the base to turn the transistor on and light up the LED.

Make the circuit up on the prototyping board as shown so that your finger can bridge across the wire to +v and the base resistor leg. If you touch across with a dry finger, nothing happens. If you now try again after licking it, the LED comes on. The tiny current that flowed through your moist skin was enough to turn it on.

This kind of circuit is used in American lie detectors which sense moisture caused by perspiration if you lie.



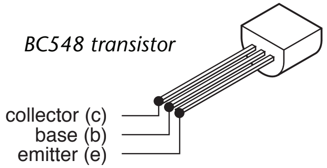
Circuit 17 - Water level alarm
This is the same as circuit 16 except that the wires are connected to two probes. The probes can be made from some plain wire held in a terminal block. When water gets between the probe wires, base current flows and the transistor will turn on.

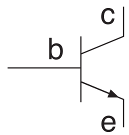


Level 2

Transistors

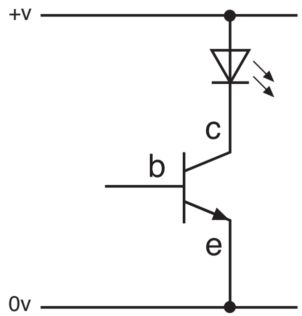
Transistors are at the heart of all electronic circuits. Computers, mobile phones and iPods use millions of them. It is surprising, though, what you can do with just one or two.





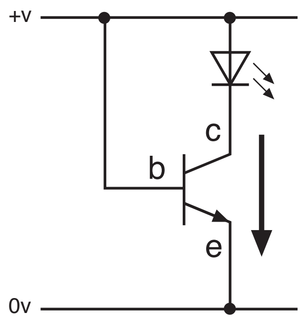
circuit symbol

We will be describing the transistor as an electronic switch. It has three legs called emitter (e for short), collector (c for short) and base (b for short). The transistor is connected into a circuit with the emitter and collector legs in place of a normal switch. The example shows a hi-bright LED that needs to be turned on and off.



If you connect everything up, nothing happens! The transistor is switched off. If you now connect the base to positive using a piece of wire, the LED comes on. When a current flows base to emitter, the transistor switches on and a large current flows collector to emitter turning on the LED.

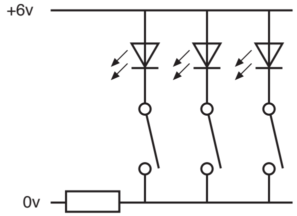
So, why not just use a normal switch in the first place? The answer is that in a circuit you sometimes only have a small current to switch on something that needs more. The following circuit is an example:

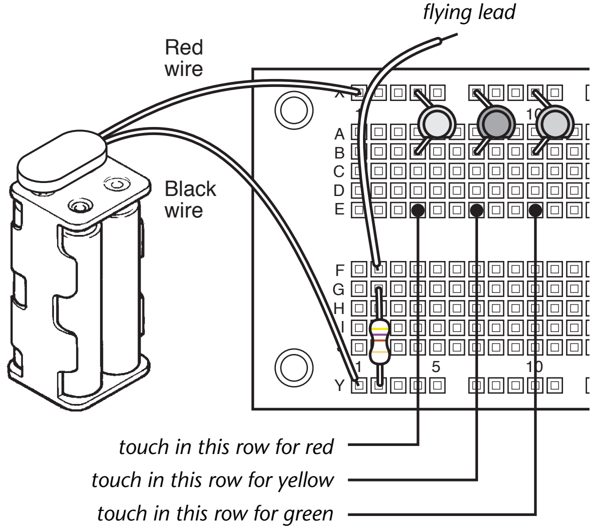


when a small current flows into the base the transistor 'switches on'

Circuit 11 - Traffic lights

This circuit enables you to show the sequence of traffic light signals using a flying lead to connect onto the LEDs. This is shown on the diagram as a switch.

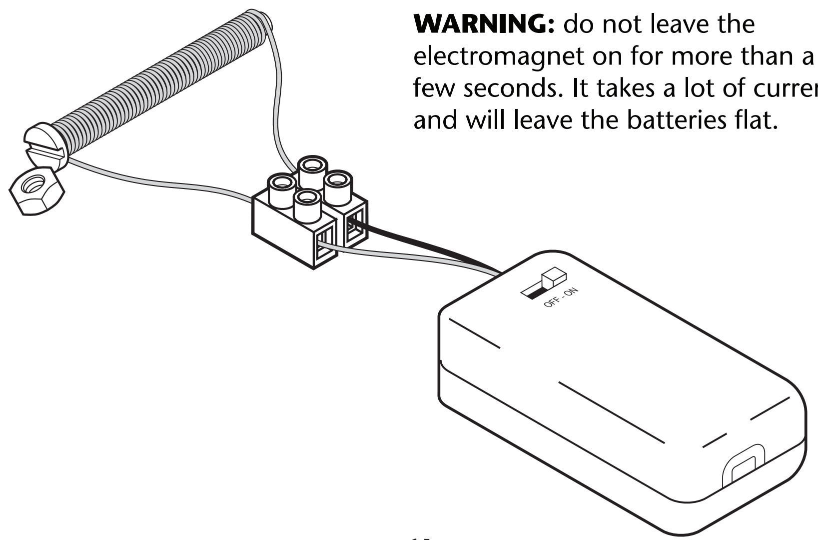




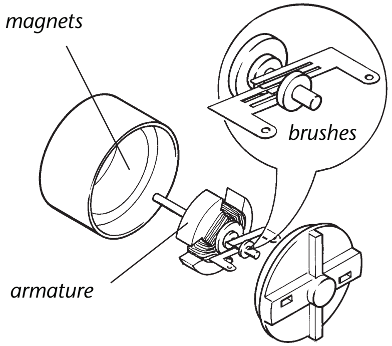
Electric magnets and motors

When a current flows through a wire, it becomes slightly magnetic. If the wire is coiled around steel, this also becomes magnetic. If you wrap several coils of the insulated wire around a long screw you have an electromagnet – something that is magnetic only when you pass current. Try it out. Take about 300mm of the insulated wire and strip the insulation off both ends. Wrap it around a screw and connect to a battery as shown. When the switch is 'on' the nail will be magnetic and pick up things like paperclips.

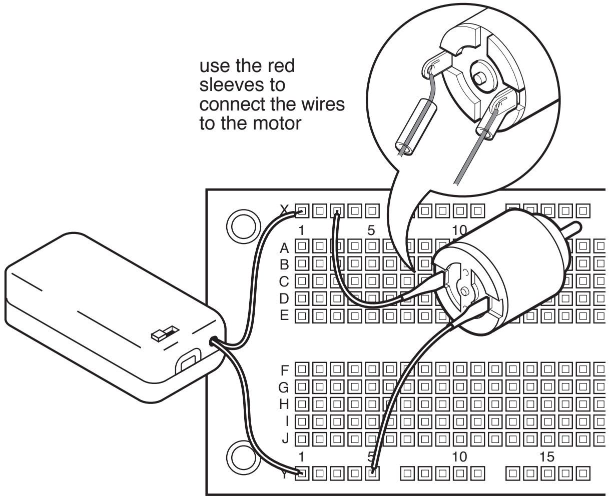
WARNING: do not leave the electromagnet on for more than a few seconds. It takes a lot of current and will leave the batteries flat.



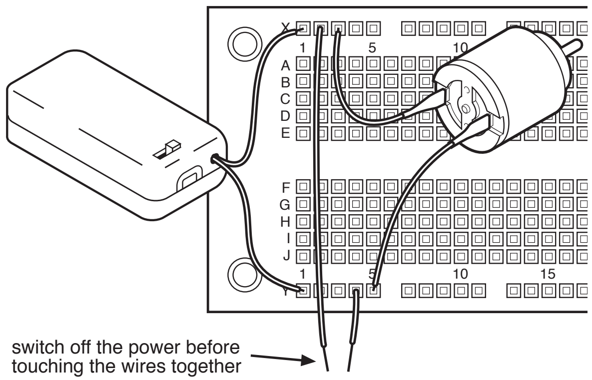
A cheap electric motor contains two ordinary magnets and an electromagnet called an armature. When current is supplied to the motor it passes to the copper wire in the armature through contacts called brushes. The armature then turns between the two magnets. The more current supplied to the motor, the faster it turns.



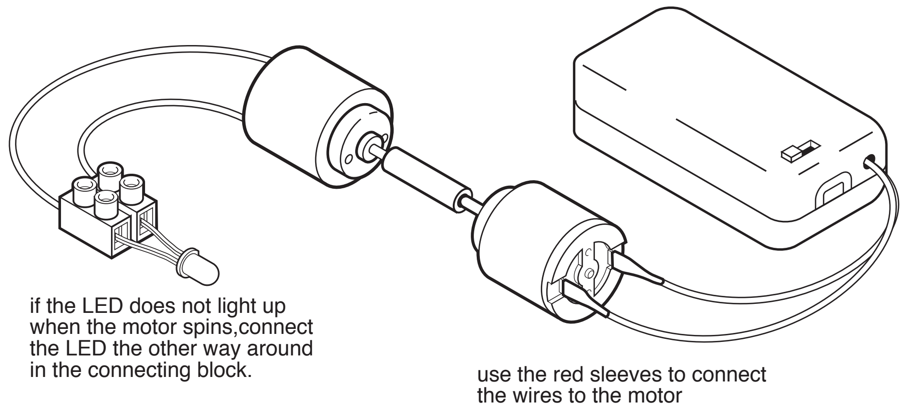
Circuit 12 - Motor control
Connect two leads with bared ends to the motor as shown. Connect these to the battery box using the prototyping board. When you switch on the motor will run. If you swap over the leads from + to 0, the motor will run in the opposite direction.



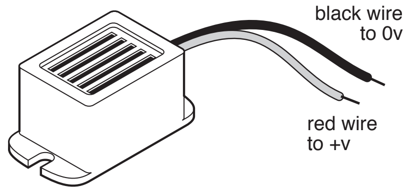
Circuit 13 - Electric brake
When you switch off, the motor takes a bit of time to stop. If you connect a piece of wire across the motor terminal (a short circuit) the moment after you switch off, the motor will stop instantly. This is because the motor is acting as a generator and the wire makes it do work.



Circuit 14 - Electric generator
The motor will also work as a generator if you can turn the spindle fast enough. To try this out, fix a second motor to the first one using a small length of rubber tubing. Now connect a high bright LED to the second motor. Because it is a diode, you may have to swap its legs around to get it to work. The first motor powers the second and this generates current for the LED.



Buzzers and sounders
Buzzers or sounders come in many shapes and sizes. The one in your kit works from as low as 1.5v and makes quite a noise! But it has to be connected the right way round: red lead to +v and black lead to 0v.



Circuit 15
When you turn on the buzzer in this circuit, it will sound at full volume. If you connect the buzzer via long leads, you will have a door buzzer circuit.