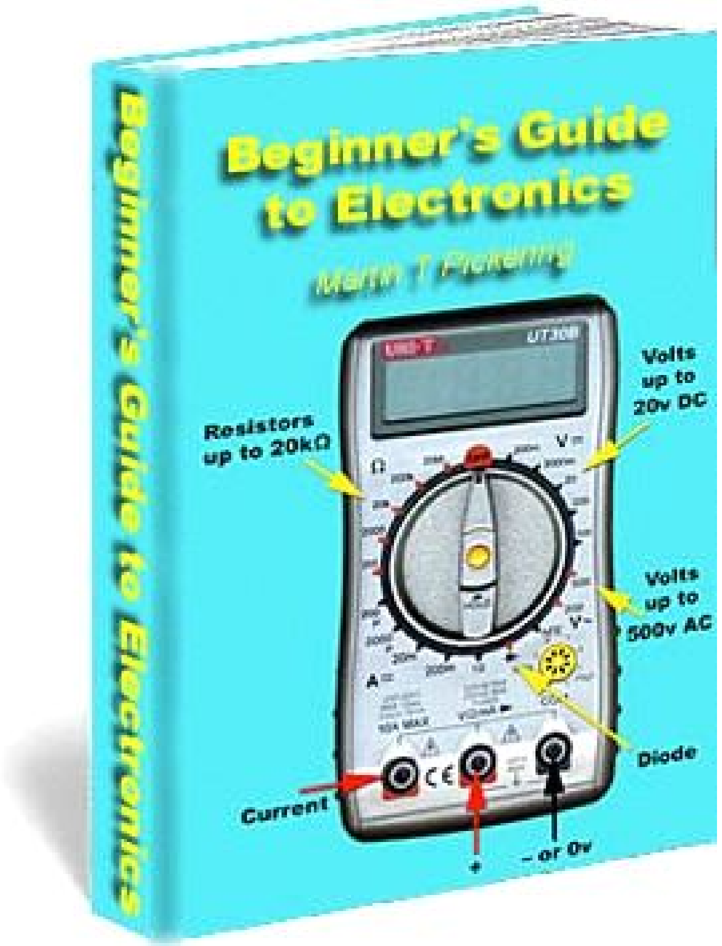
Beginners Guide to Electronics



by Martin T. Pickering

Last updated on September 13, 2007

Order kits at http://www.satcure.co.uk/accs/kits.htm

Electronics for Beginners

This book gives simplified explanations of how certain electronic components work in a circuit. It also gives **practical examples** of building some simple projects.

The physics isn't very accurate and it doesn't attempt to explain the ins and outs of "electrons", "atoms" and such like.

Instead, it will give you an understanding of what the components actually DO so that you can immediately begin to design your own simple circuits with them. Some practical examples are included.

The book forms an excellent basis for any **electronics course in school or college** and may be copied as many times as required within the educational premises. It may not be copied or sold for any other purpose.

I first became interested in electronics when I was age 10 (as long ago as 1961). In those days, transistors were only just being introduced and most equipment still used thermionic valves or "tubes" as the Americans would call them. Much of my learning was by practical experiment. I blew my Dad up only once by connecting 350 volt capacitors the wrong way round; electrocuted the window cleaner (but not fatally) and gave myself several high voltage shocks during the learning experience. This is not to be recommended so just remember that voltages in excess of 50 volts can be painful, if not downright dangerous.

Anyway, I hope you enjoy my little book. I guarantee that it will be more interesting than any previous electronics course at school or college and you'll understand how the components work after just a few minutes - not the fifteen years that it took me to get a grip on it!

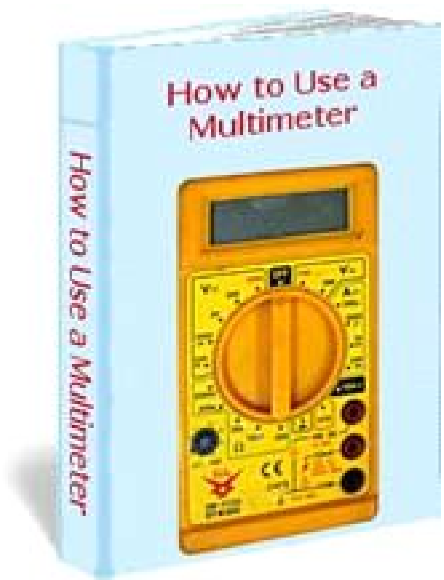
 See my other sites:-
http://www.glodark.co.uk and .com
http://www.The-Cool-Book-Shop.co.uk
http://www.satcure.co.uk/accs/kits.htm and .com and .net
http://www.satcure-focus.com
http://www.your-book.co.uk
http://www.marketingtips.uk.com
http://www.podcaststingers.com

At the time of writing you can find other tutorials at:
http://pw1.netcom.com/~pow/OnlineTutorials.html

ISBN 1-905964-06-4 -> **978-1-905964-06-2**

Copyright

Thanks! *Martin Pickering*



What's the Difference between A.C. and D.C.?

Everyone knows that a battery cell gives "d.c." or "direct current" which means that a steady voltage is available to drive your radio or whatever. Less well understood is "a.c." which stands for "alternating current". However, it's important to understand the difference because it could cost you money! You wouldn't dream of connecting your 12 volt radio directly to a mains power plug because you know that it gives at least 230 volts. But do you know that a 12 volt a.c. transformer can do almost as much damage? The reason is that electronic equipment needs not only LOW voltage but low D.C. voltage. Let's take a quick look at the method of making electricity.

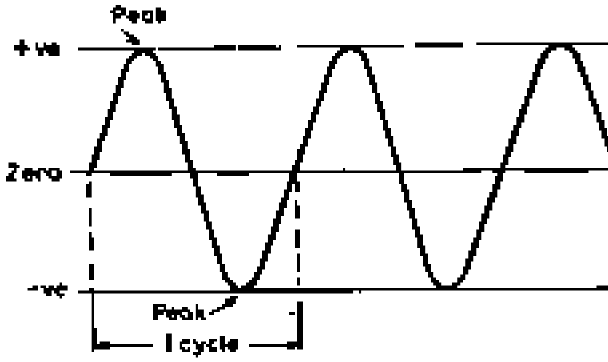
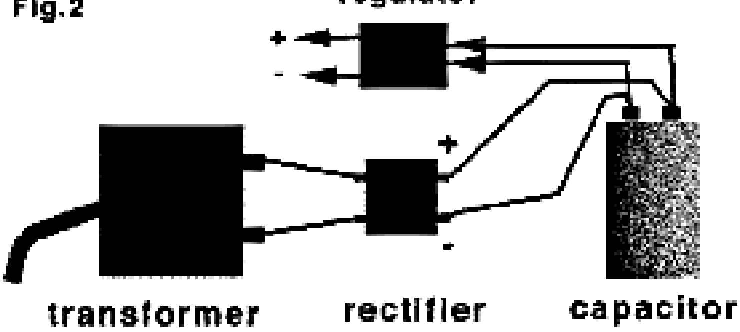


Fig.1

In a power station, electricity can be made most easily and efficiently by using a motor to spin magnetic wire coils. The resultant voltage is always "alternating" by virtue of the motor's rotation. Fig.1 indicates how the voltage goes first positive then negative - rather like turning a battery cell continually backwards and forwards in its clip.

Now, alternating voltage can be carried around the country in cables far more efficiently than direct current where the voltage is fixed. So the electricity that arrives at your house is still alternating voltage. Electric light bulbs and fires can run quite happily from 230 volt a.c. Other equipment such as televisions have an internal power supply which converts the 230 volts a.c. to a low d.c. voltage that is safe and acceptable to the electronic circuits. How is this done?

Fig.2



There are several ways but the simplest is to use a transformer to reduce the voltage to, say 12 volts a.c. (Fig.2) This lower voltage can be fed through a "rectifier" which combines the negative and positive alternating cycles so that only positive cycles emerge. This "rectified" voltage (Fig.3) is suitable for running things like filament bulbs and electric trains but it is still no good for electronic circuits. So a so-called "12 volt dc supply" may be no good for electronic devices. What you need is "regulated d.c." which truly simulates the steady voltage that you get from a battery.

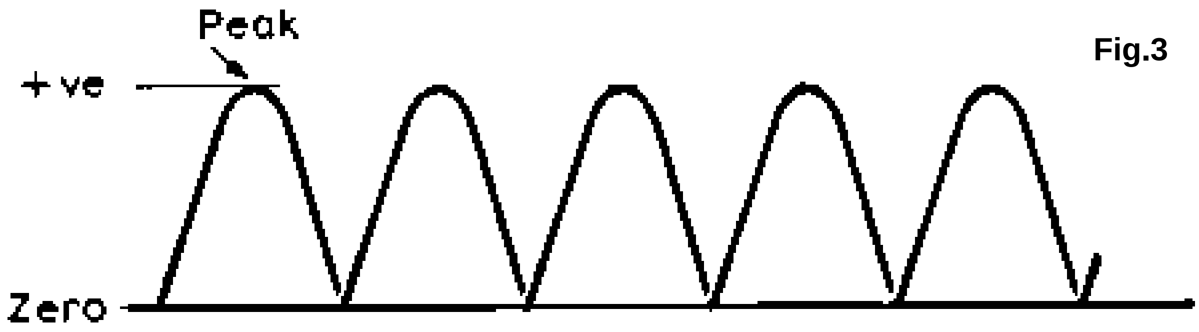


Fig.3

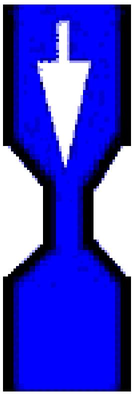
The first step is to connect a large value capacitor to the output of the rectifier. A capacitor acts as a voltage reservoir and has the effect of smoothing the "ripples". This is still not the same as a battery produces but it's often good enough for charging batteries

Fig.4

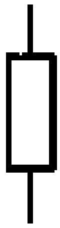
in mobile phones, personal stereo equipment and similar (Fig.4).
The final step is to pass this "rippling d.c." through a regulator unit. This effectively chops off the ripple to leave almost pure "regulated d.c." at a steady voltage.
So, to provide a suitable voltage for electronic circuits you need a power supply which gives a "regulated d.c." output. If your power supply doesn't use those words then it may not be suitable for use with electronic circuits. In this case, saving cost might lead to expensive smoke!

The high-quality Regulated Power supply is capable of supplying up to 1.5 Amps (1500 milliamps) of current. A rotary switch provides selection of 3, 4.5, 6, 7.5, 9 or 12 volts "regulated d.c." It has a multitude of uses, including speed control for a mini drill. See catalogue. http://www.satcure.co.uk

How does a Resistor Work?



Imagine water flowing through a pipe. If we make the pipe narrow then this will restrict the flow of water. If we force the water (current) through the narrow gap by increasing the pressure (voltage) then energy will be given off as heat. In addition, there will be a significant difference in pressure (voltage) above and below the restriction. As an example, imagine pumping up a tyre by hand. The narrow pipe of the pump gets hot doesn’t it?



In electronics we use a resistor when we need to reduce the voltage applied to a circuit. On the right is the symbol used to represent a resistor. You may also see it drawn as a zigzag line.

A resistor is defined by several parameters:
Resistance in Ohms (Ω)
Heat Dissipation in Watts (W)
Manufacturing tolerance (%)

Resistor Colour Code

The value of a resistor is either printed in normal characters or, more usually, as coloured bands. Here is an example.
The first band is red, indicating the number 2.
The second band is also red, indicating 2.
The third band is yellow, indicating 4 zeros.
The fourth band is gold, indicating 5% tolerance.
(Silver would indicate 10%, brown = 1%, red = 2%)
This resistor is 220000 Ohms in value, often written as 220kΩ
As the tolerance is 5%, the actual resistance lies between 209000 and 231000 or 209kΩ and 231kΩ due to manufacturing inaccuracies.

0 = Black
1 = Brown
2 = Red
3 = Orange
4 = Yellow
5 = Green
6 = Blue
7 = Violet
8 = Grey
9 = White

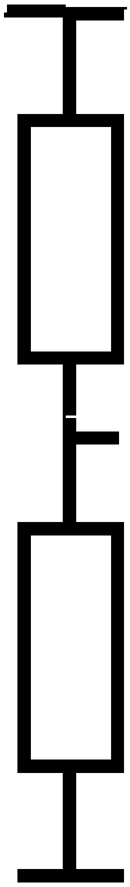
The colour code is essential and the only way to learn it is by practice. Take a box full of resistors. Work out the value of each then check with a meter to see if you are correct.
Note that the last band on the resister indicates the tolerance. (The first band is usually slightly broader than the rest).
In a 1% resistor, there may be an additional band if more accuracy is needed.
Thus a 1% 220kΩ resistor would be coloured →

Red (2)
Red (2)
Black (0)
Orange (000)
Brown (1%)

This time the first THREE colours indicate actual numbers.
The fourth colour indicates the number of zeros.
The fifth colour indicates the tolerance.

Here are two resistors connected "in series". The total resistance from end to end is equal to the sum of the values of both resistors. So, if each resistor has a value of 2200Ω (2k2) then the total value will be 4k4.
Resistors connected "in parallel" have a total resistance that can be calculated as

$$\frac{(R1xR2)}{(R1+R2)}$$



Two resistors can be used to set a specific voltage. For example, if two resistors are connected as shown (left) and a voltage of 10 volts is applied to the ends, then if both resistors are of equal value, the voltage at the centre connection will be 5 volts. The voltage is divided between the two resistors.
There is a very important equation known as "Ohms Law".

$$I = V/R$$

Current (in mA) = Volts divided by Resistance (in kΩ) or
Current (in Amps) = Volts divided by Resistance (in Ω)
We can turn this around to calculate voltage so V = I x R or resistance R=V/I

A resistor drops voltage by turning excess power into heat. The amount of power turned into heat can be calculated from

$W = V \times I$ *(Watts = Volts x Amps)*

Substituting for I from Ohms Law in this equation gives
W = V x V/R or

$$W = V^2/R$$

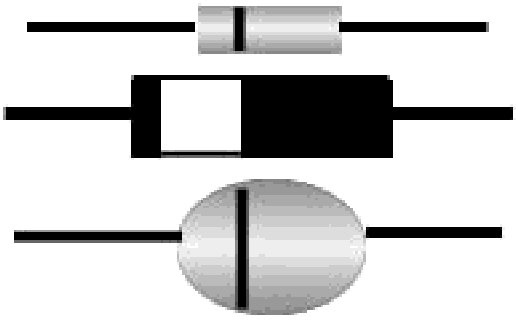
Or substituting for V in the above equation gives
W = I x I x R or

$$W = I^2R$$

From these equations we can work out the required "Wattage" of any resistor provided that we know the value of any two of the three variables, Voltage, Current and Resistance.
Suppose we have a 10Ω resistor with 10 volts across it.
W = V2/R gives 10 x 10/10 = 10 Watts
or, from Ohms Law, I = V/R = 10/10 = 1 Amp
W = V x I gives 10 x 1 = 10 Watts

How do Diodes Work?

A diode allows current to flow in only ONE direction.
If the cathode end (marked with a stripe) is connected so it is more negative than the anode end, current will flow.
The picture shows three types of diode:



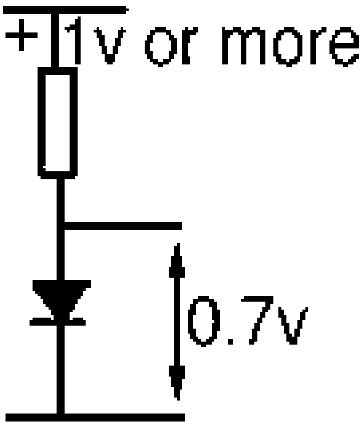
Small signal diode

Rectifier diode

Soft fast recovery diode

A diode has a forward voltage drop. That is to say, when current is flowing, the voltage at the anode is always higher than the voltage at the cathode. The actual Forward Voltage Drop varies according to the type of diode.

For example:



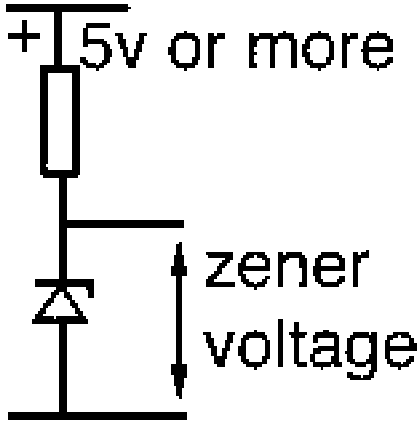
Silicon diode = 0.4 to 0.7v dependent on type
Schottky diode = 0.3v
Germanium diode = 0.2v

In addition, the voltage drop increases slightly as the current increases so, for example, a silicon rectifier diode might have a forward voltage drop of 1 volt when 1 Amp of current is flowing through it.
An **LED** is also a diode. Red = 1.8v. Blue = 4.0v typical

A **ZENER** diode allows current to flow in both directions. In the "forward" direction, no current will flow until the voltage across the diode is about 0.7 volts (as with a normal diode). In the reverse direction (cathode more positive than the anode) no current will flow until the voltage approaches the "zener" voltage, after which a LOT of current can flow and must be restricted by connecting a resistor in series with the zener diode so that the diode does not melt!

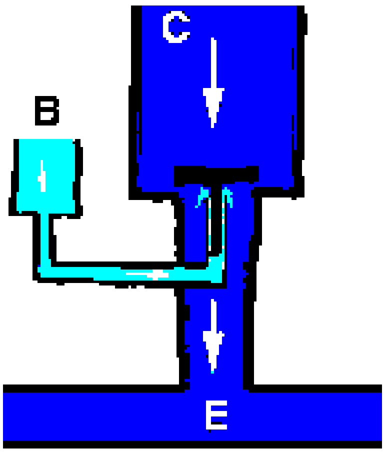
Within a certain supply voltage range, the voltage across the zener diode will remain constant. Values of 2.4 volts to 30 volts are common. Zener diodes are not available in values above around 33 volts but a different type of diode called an **AVALANCHE** diode works in a similar way for voltages between 100v and 300v.

(These diodes are often called "zener" diodes since their performance is so similar.)



Zener diodes are used to "clamp" a voltage in order to prevent it rising higher than a certain value. This might be to protect a circuit from damage or it might be to "chop off" part of an alternating waveform for various reasons. Zener diodes are also used to provide a fixed "reference voltage" from a supply voltage that varies. They are widely used in regulated power supply circuits.

How do Transistors Work?



Thousands of textbooks have been written to explain electronics and I haven't found a single one that can explain the operation of a transistor in simple terms. They all make it seem so complicated! It’s not.

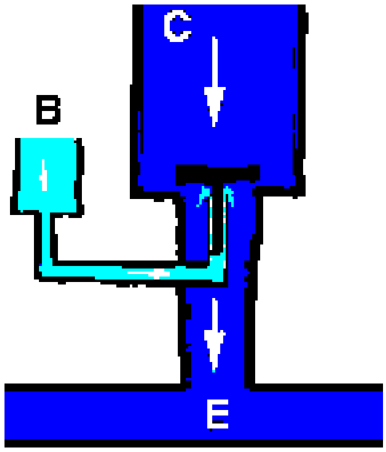
Let's see if I can do better. Here is a picture of a transistor. My transistor runs on water current. You see there are three openings which I have labelled "B" (Base), "C" (Collector) and "E" (Emitter) for convenience. By an amazing coincidence, these also happen to be the names used by everyone else for the three connections of a transistor!

We provide a reservoir of water for "C" (the "power supply voltage") but it can't move because there's a big black plunger thing in the way which is blocking the outlet to "E". The reservoir of water is called the "supply voltage". If we increase the amount of water sufficiently, it will burst our transistor just the same as if we increase the voltage to a real transistor. We don't want to do this, so we keep that "supply voltage" at a safe level.

If we pour water current into reservoir "B" (the base “voltage pressure”) this current flows along the "Base" pipe and pushes that black plunger thing upwards, allowing quite a lot of water to flow from "C" to "E". Some of the water from "B" also joins it and flows away. If we pour even more water into "B", the black plunger thing moves up further and a great torrent of water current flows from "C" to "E".

So what have we learned?:

1. A tiny amount of current flowing into "B" allows a large amount to flow from "C" to "E" so we have an "amplification effect". We can control a BIG flow of current with a SMALL flow of current. If we continually change the small amount of water flowing into "B" then we cause corresponding changes in the LARGE amount of water flowing from "C" to "E".



For example, if we measure the current flow in gallons/minute: Suppose 1 gallon/minute flowing into "B" allows 100 gallons/minute to flow from "C" to "E" then we can say that the transistor has a "gain" or "amplification" factor of 100 times. In a real transistor we measure current in thousandths of an Ampere or "milliamps". So 1mA flowing into "B" would allow 100mA to flow from "C" to "E".

2. The amount of current that can flow from "C" to "E" is limited by the "pipe diameter". So, no matter how much current we push into "B", there will be a point beyond which we can't get any more current flow from "C" to "E". The only way to solve this problem is to use a larger transistor. A "power transistor". This tends to have a lower “gain” so is less efficient.

3. The transistor can be used to switch the current flow on and off. If we put sufficient current into "B" the transistor will allow the maximum amount of current to flow from "C" to "E". The transistor is switched fully "on". If the current into "B" is reduced to the point where it can no longer lift the black plunger thing, the transistor will be "off". Only the small "leakage" current from "B" will be flowing. To turn it fully off, we must stop all current flowing into "B". Notice that we need a certain amount of “voltage pressure” in reservoir “B” before the plunger will move at all. This voltage is approximately 0.6 volts for a silicon transistor. Remember that. You’ll use it, later. If B is less than 0.6 volts, no current can flow at all. But *it can’t be more than 0.6 volts* because the black plunger thing opens and relieves the pressure.

In a real transistor, any restriction to the current flow causes heat to be produced. This happens with air or water in other things: for example, your bicycle pump becomes hot near the valve when you pump air through it. A transistor must be kept cool or it will melt. It runs coolest when it is fully OFF and fully ON. When it is fully ON there is very little restriction so, even though a lot of current is flowing, only a small amount of heat is produced. When it is fully OFF then NO heat is produced. If a transistor is half on then quite a lot of current is flowing through a restricted gap and heat is produced. To help get rid of this heat, the transistor might be clamped to a metal plate which draws the heat away and radiates it to the air. Such a plate is called a "heat sink". It often has fins to increase its surface area and, thereby, improve its efficiency.

Getting Technical

The difference between PNP and NPN transistors is that NPN use electrons as carriers of current and PNP use a lack of electrons (known as "holes"). Basically, nothing moves very far at a time. One atom simply robs an electron from an adjacent atom so you get the impression of "flow". (It's a bit like "light pipes" used at disco parties. The light doesn't really move). In the case of "N" material, there are lots of spare electrons. In the case of "P" there aren't. In fact "P" is gasping for electrons. Clear as mud isn't it?

OK, bear in mind that the Base is only a few atoms in thickness - almost a membrane - so any electrons allowed into the base "membrane" act as a catalyst to allow other electrons to break through from collector to emitter.*

Imagine a pool of water near the edge of a table. It rests there with surface tension holding it in place. Now put one tiny drop of water on the table edge and let it touch the pool of water. Suddenly, the pool drains onto the floor as gravity takes over! Your tiny drop provided the catalyst to get it moving. So the base electrons do a similar job for the "pool" of electrons in the emitter - helped by the "gravity suction" of the power supply voltage on the collector.

A transistor doesn't "increase" current. It simply allows power supply current to pass from collector to emitter* - the actual amount depends on the (small) current allowed to flow into its base. The more electrons you allow into the base, the more (x 100) that flow from collector to emitter*. I put "x 100" because that is the typical gain (amplification factor) of a transistor. For example, one electron put into the base could allow 100 to escape from collector to emitter*.

The best way to understand this is to get your soldering iron and start building!

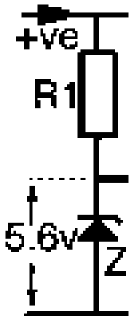
* *The purist might argue that current flows from emitter to collector - dependent on whether we are discussing electron flow or "hole" flow. I don't want to get involved in the real physics of current flow. You don't need to know this to understand a circuit.*

This discussion relates to Bipolar transistors. Other types of transistor such as "FETs" (Field Effect Transistors) are in common use and work in a slightly different way in that the **voltage** applied to the "gate" terminal controls the current flowing from "cathode" terminal to "anode" terminal. In effect, a FET is simply a semiconducting (one-way) resistor whose value is controlled by the voltage applied to its "gate".

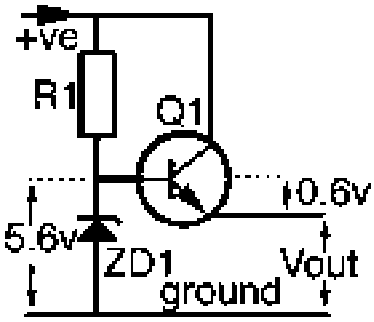
A thermionic valve or (American usage) “tube” also uses a similar principle whereby electrons are emitted by a hot cathode and collected by an anode. The voltage applied to a grid of wires, strung inbetween, controls the flow of current from cathode to anode.

Example Transistor Circuits

One of the most commonly used circuits is that of the VOLTAGE REGULATOR.
The simplest voltage regulator uses just a resistor and a zener diode. In the circuit diagram you can see a resistor (R1) and a zener diode (ZD1) connected across a power supply. The resistor is connected to the positive (+ve) supply wire and the zener diode anode is connected to the zero volt (ground) wire. At the junction of these two components the voltage is clamped by the zener diode to its specified voltage - in this case 5.6 volts.



That method is OK for low currents but the resistor becomes too hot if larger currents are needed. To cope with this problem we can add the NPN transistor (Q1). Now the transistor passes the current required at the output.
What is the output voltage?



It is easy to calculate. The voltage at Q1 base connection is 5.6 volts.
The voltage between base and emitter of a silicon transistor is always 0.6 volts if the transistor is "on". (Remember the pevious “Base voltage reservoir” discussion?)
So the voltage at the Q1 emitter (Vout) must be 5.6 - 0.6 = 5.0 volts.
The output voltage will remain at a constant voltage of 5.0 volts provided that the input voltage from the supply is more than 6 volts (the zener voltage plus a little to compensate for that "lost" across the resistor).
In fact the input voltage can be swinging up and down between, say, 6 volts and 12 volts and the output voltage at Q1 emitter will still be a steady 5.0 volts.
The limiting factors are the amount of heat generated by R1, ZD1 and Q1 since all excess voltage must be shed as heat. The "wattage" ratings of the individual components must be calculated to suit:

1. The average input current (through R1 and ZD1) and
2. the output current (through Q1)....

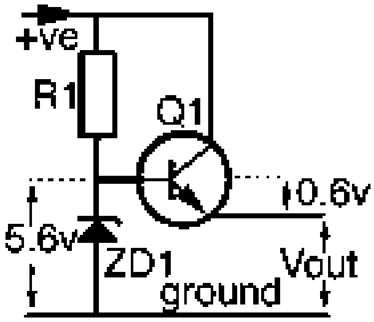
... can be calculated from Ohms Law and
is decided by whatever the regulator is to supply voltage to.

Ohms Law I = V/R

V = Volts
I = Amps if R = Ohms or
I = mA if R = kΩ

Let's assume the following:

The circuit which this regulator is driving needs 5.0v at a current of 100mA.



A BC337 transistor is suitable since it can handle current up to 800mA.

Its gain at 100mA is listed as 100 (minimum) so it's easy to see that it will need at least 1mA into its base to allow 100mA to flow from collector to emitter.

For the zener diode let's choose a BZX55C5V6. This will need a minimum of 10mA of current to produce a stable voltage. So Q1 requires 1mA, ZD1 requires 10mA, making a total of 11mA through R1.
If the minimum supply voltage is, say, 7.8v then the minimum voltage across R1 is 2.2v.
(7.8 - 5.6 = 2.2)

Ohms law says that the resistance = V/I
= 2.2/11
= 0.2kΩ resistance
= 200Ω

Suppose the maximum supply voltage might be 9.6v.
Then the maximum voltage across R1 will be 9.6 - 5.6 = 4.0v.
From Ohms Law, the current through R1 will now be V/R

= 4.0/200
= 0.02A
= 20mA

Watts = Volts x Amps **milliWatts = Volts x milliAmps**

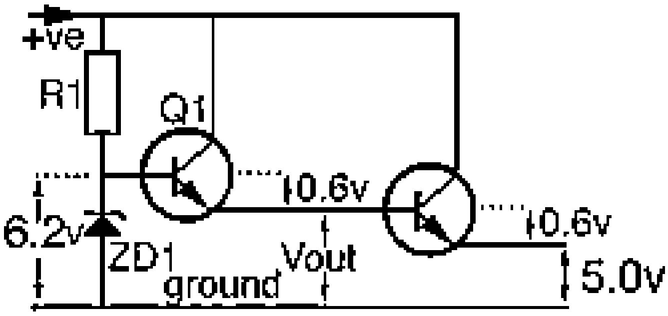
Watts = Volts x Amps so the minimum Wattage of R1 must be
4.0 x 0.02 = 0.08W - not a lot!
A standard 0.25 Watt resistor will be more than adequate for R1.

Let's check the zener diode rating under the worst conditions:

The voltage across ZD1 will still be 5.6v
The current in the worst case will be 20mA, assuming none goes through Q1.
So the Wattage of ZD1 must be at least 5.6 x 0.02 = 0.112W
= 112mW
A BZX zener diode will dissipate up to 500mW so the circuit is safe.

To provide 5 volts at up to 100mA, the final design will use:

R1 = 200Ω 0.25W
ZD1 = BZX55C5V6
Q1 = BC337



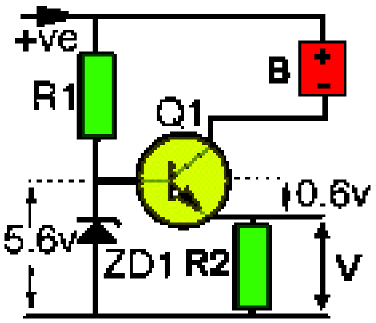
The first circuit can be improved upon to provide more current. All we need to do is to add a second transistor (which has a higher rating to handle the extra current) and change the zener diode to clamp at 6.2 volts in order to compensate for the b-e voltage of BOTH transistors.

6.2 - 0.6 - 0.6 = 5.0 volts

If the first transistor provides 5.6 volts at 100mA (0.1 Amps) and the gain of the second transistor is 50 then it can provide 5.0 volts at 0.1 x 50 = 5 Amps. Be sure to use a power transistor rated at 5 Amps or more!

The final design can use:
R1 = 200Ω 0.25W
ZD1 = BZX55C6V2
Q1 = BC337
Q2 = 2N3055 (on a suitable heat sink)

Note:
The combined gain of both transistors is 100 x 50 = 5000. We could not use just one transistor because no ordinary transistor capable of handling 5 Amps can have a gain of 5000. We could, however, use a "Darlington Pair" transistor which has two transistors (connected as above) in one package with just three wires.



Constant current generator used to charge a NiCad battery

This simple circuit can be used to provide a constant current, regardless of the input voltage. Again, the results are simple to calculate by using Ohm's Law.
Suppose we have a NiCad battery of 9 volts and we need to charge it with a current of 40mA.

We connect a transistor and a zener diode as shown. It's easy to see that the voltage across resistor R2 will be 5 volts. So to get 40 mA to flow through R2 its resistance must be ... what?

Ohms Law I = V/R V = Volts
I = Amps if R = Ohms or
I = mA if R = kΩ

So 40 = 5/R
R = 5/40 kΩ
R = 0.125 kΩ
R = 125 Ω

If 40 mA is flowing through R2 then most of that is coming via the collector-emitter junction of the transistor and must, therefore, be flowing through the battery. In practice, a little of the emitter current is also coming via R1 and the base-emitter junction. We can compensate for that by reducing the value of R so lets call it **R = 120 Ω** which happens to be the nearest standard value. The current through R is now approximately 41mA and the current through the battery is approximately 40mA.

What must the supply voltage be?

The supply voltage must be at least the sum of the voltages across the battery (9v) and across R (5v) and across the c-e junction of Q1 (probably less than 1 volt). So the minimum supply voltage has to be 9 + 5 + 1 = 15 volts.

You can use this simple method to design a constant current charger for any NiCad battery. Just make sure that the transistor current rating (Ic) is higher than the value of the required charging current. The previous notes about the zener diode and resistor R1 still apply.

Abbreviations

Although we use the Greek symbol Omega Ω to represent "Ohms" it is frequently written as "R". So, for example, a resistor of 47 Ohms may be written as 47Ω or 47R. A resistor if four point seven Ohms may be 4.7Ω or 4.7R but, because the decimal point may disappear during printing, it is common practice to put the letter in place of the dot. So you may see 4Ω7 or 4R7 representing four point seven Ohms, for example.

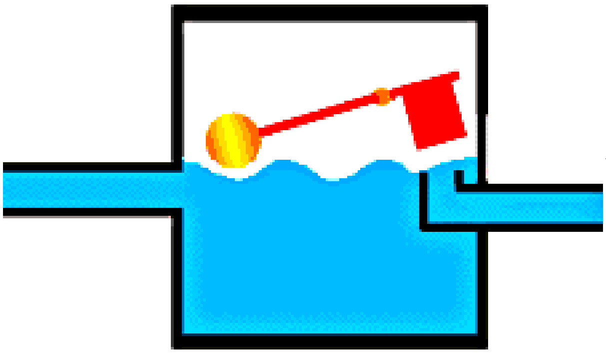
A thousand Ohms is called a "kiloOhm" and abbreviated to "K".
So, for example, 6800 Ohms may be written as 6.8kΩ or 6.8k or 6k8Ω or 6k8.

A million Ohms is a "MegaOhm" and abbreviated to "M".
So, for example, 1000,000 Ohms may be written as 1MΩ or 1M
3,300,000 Ohms may be written 3M3 or 3M3Ω or 3.3M or 3.3MΩ

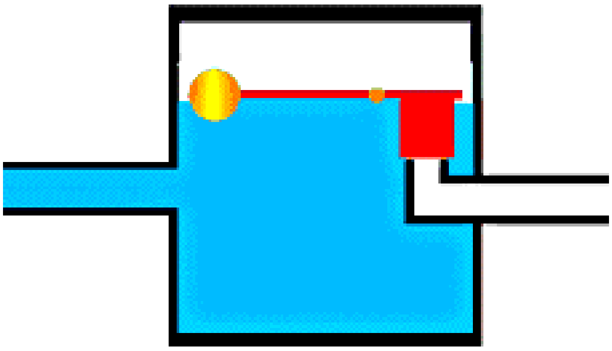
How does a Capacitor Work?

Think of water flowing through a pipe. If we imagine a capacitor as being a storage tank with an inlet and an outlet pipe, it is possible to show approximately how an electronic capacitor works.

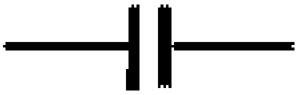
First, let's consider the case of a "coupling capacitor" where the capacitor is used to connect a signal from one part of a circuit to another but without allowing any direct current to flow.



If the current flow is alternating between zero and a maximum, our "storage tank" capacitor will allow the current waves to pass through.



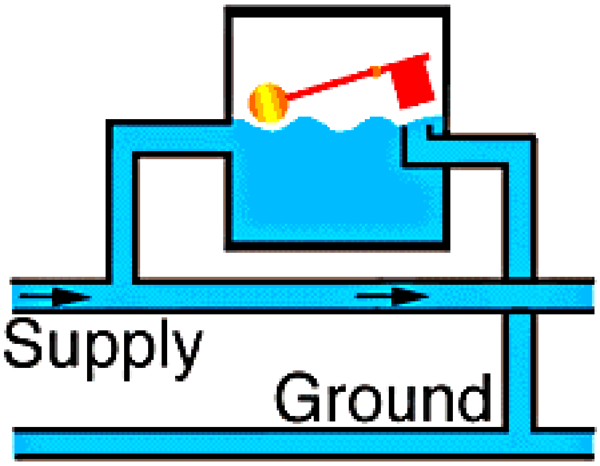
However, if there is a steady current, only the initial short burst will flow until the "floating ball valve" closes and stops further flow.



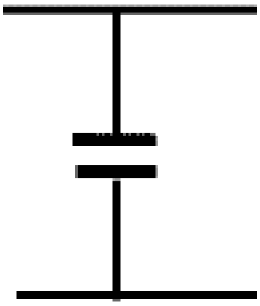
A **coupling capacitor** is represented like this

So a coupling capacitor allows "alternating current" to pass through because the ball valve doesn't get a chance to close as the waves go up and down. However, a steady current quickly fills the tank so that all flow stops.

A capacitor will pass alternating current but (apart from an initial surge) it will not pass d.c.



Where a capacitor is used to decouple a circuit, the effect is to "smooth out ripples". Any ripples, waves or pulses of current are passed to ground while d.c. flows smoothly.



A **decoupling capacitor** is represented like this

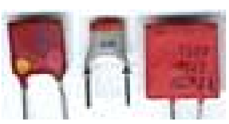
What does a capacitor look like?

"Plug-in" electrolytic used in power supplies where a high ripple-current must be tolerated. The large size indicates either high voltage rating or high capacitance value. This example is 47uF rated at 400 volts dc

Reservoir electrolytic capacitor used in power supplies where a large capacitance value is required. Poor tolerance, poor temperature stability and polarised. This example is 2200uF rated at 25 volts dc. Available at a higher price with better performance and reliability.

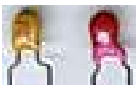
Small size low cost electrolytic used where high ripple current is not present. May be used for coupling or for decoupling but leakage current is high and reliability is low.

Ceramic disc capacitor used where a low-cost, small, accurate capacitance is required with good temperature stability.



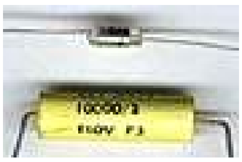
Silvered mica capacitor used where a small, accurate capacitance is required with good temperature stability. More expensive than ceramic disc. The one on the left is coded Yellow spot, Purple spot, Red spot (4 - 7 - 2 giving 4700pF or 4n7F)

Multilayer ceramic capacitor used where a high capacitance (up to 1uF) is required in a small space. Low voltage only and poor temperature stability but low impedance so very good for grounding low-voltage fast-risetime pulses.



Tantalum bead capacitors used where a high capacitance (up to 100uF) is required in a small space. Low voltage only (63v max.) and polarised but low impedance so very good for grounding low-voltage fast-risetime pulses. Relatively expensive. The left capacitor has its value printed on but the right hand one is coded Red body with a Red stripe and a White spot. That's 22uF but I don't know why!

Polyester film capacitors used where a low-cost medium capacitance (up to 4u7F) is required at a moderately high voltage with moderately good temperature stability and tolerance. Left hand example is resin-dipped (cheaper). Right hand example is resin-sealed into a moulded plastic box for better reliability. MKT capacitors are a good example of a type that use polyester called polyethylene terephthalate (PTPE).



Polystyrene film capacitors used where a small capacitance is needed with low tolerance spread (2% or better) and good temperature stability. Drawbacks include relatively high inductance and cost and susceptibility to cleaning solvents. Yellow example is of the "extended" type which is better sealed against ingress of liquids. Polystyrene capacitors are most often used in tuned circuits (oscillators and filters) where frequency stability is important.

Polypropylene dielectric capacitors offer very low dielectric losses and good temperature coefficient. Used in power electronics applications such as for mains interference suppression, switch mode power supplies and TV deflection circuits.

Polycarbonate dielectric capacitors offer a low temperature coefficient and lower dielectric losses at high frequency. Most often chosen for temperature stability.

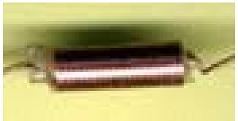
Paper dielectric capacitors. Now rarely used because of unpredictable tolerance, susceptibtibilty to moisture and difficulty of manufacture compared with modern plastic dielectric types.

More exotic types using, for example, PTFE (polytetrafluoroethylene) dielectric are used for demanding applications where the utmost temperature stability is required, however these offer no advantage in household or office appliances, being required only in aircraft/spacecraft or medical equipment where extremes of temperature prevail.

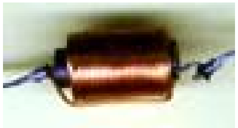
How do Inductors Work?

Whereas a resistor opposes (restricts) a flow of current, an inductor opposes a change of flow of current.
So, it allows the current to flow freely, but it will not let the current flow change rapidly. There is a delay and the change occurs more slowly than it would if the inductor were not in circuit.

A small inductor might look very much like a resistor. It will measure almost short-circuit because it is simply a few turns of wire.



Larger inductors can be seen to be coils of copper wire insulated with varnish

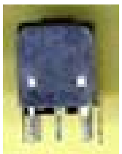


Inductors with even more turns are often called "chokes".

Some inductors have an opaque insulating sleeve. This sleeve is made from polyolefin which shrinks when heated.

This is a high frequency coil from a radio

A tiny coil with a metal screening can and an adjustable screw core



A small coil with a metal screening can and an adjustable screw core

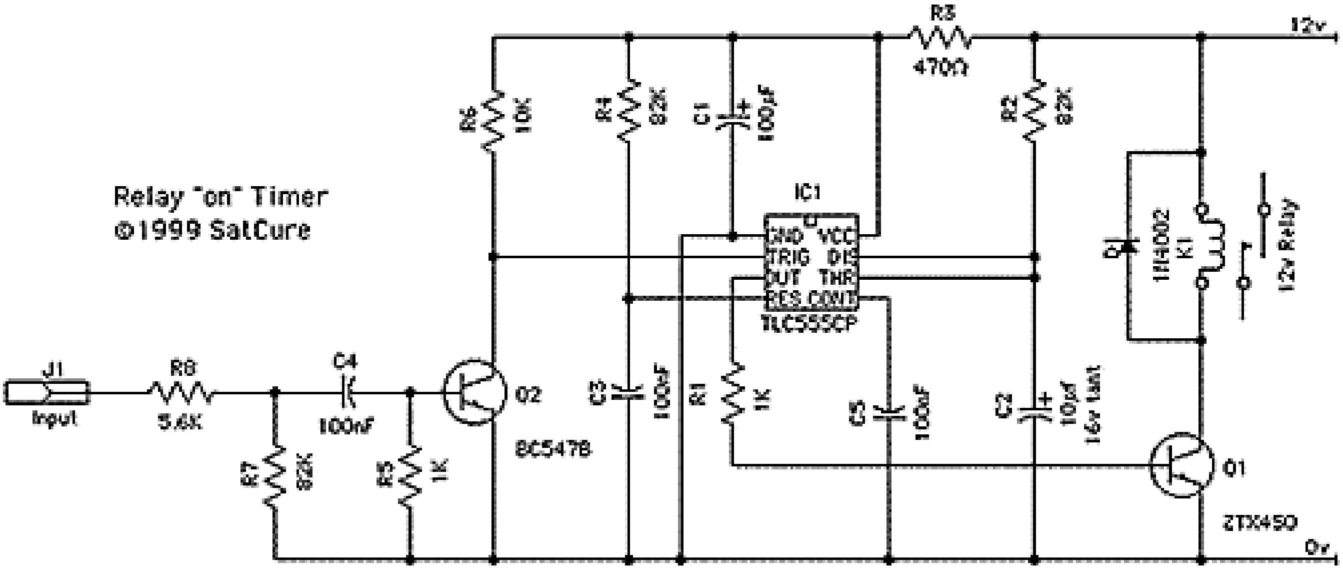
A small coil without a screening can

A larger choke is wound on soft iron laminations in the shape of "E and "I". This one looks very much like a transformer but is clearly a choke since it has only two connections. A transformer needs at least three.

A screw core made of compressed powdered iron called "ferrite"

Example Relay Timer Circuit

A relay is a coil of wire wound around a soft iron core. Current flowing through the coil turns the iron into a magnet which attracts a hinged iron lever which, in turn, closes or opens a set of contacts.



One of the most commonly used circuits is that of the 555 Timer I.C.
The circuit is designed to turn the relay on and hold it ON for one second after seeing a positive going input. To understand that a little better, imagine that the relay is connected so it feeds power to a car headlamp washer.

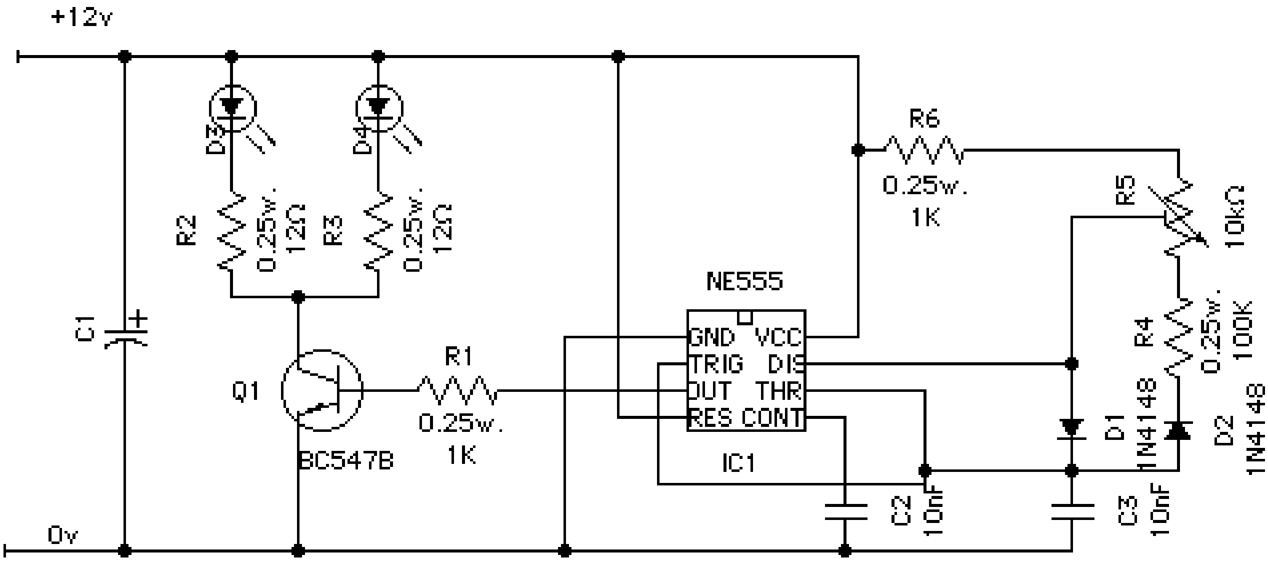
Suppose that the input is connected to the windscreen washer switch.
Each time the windscreen washers are turned on, the circuit receives a 12 volt input.
The timer I.C. will turn the headlamp washer on for just one second then turn off, regardless of whether the windscreen washer is still on or not.

The coupling capacitor, C4, requires a certain amount of time to discharge after seeing an input. So the relay can not be operated again by the headlamp washer switch until a short time has elapsed. This system removes the possibility of having the relay continually clacking on/off as the windscreen washer switch is operated.

The circuit has other uses, too.
The relay can be made to stay ON longer by increasing the value of R2 and/or C2 (which should be a Tantalum type).
A kit of parts is available from SatCure.
Note that not all "555" timer I.C.s will operate satisfactorily in this circuit. The TLC555CP is recommended.

Example LED Driver Circuit

Running an LED with pulses to get maximum brightness



Pulse-width control for High Brightness LEDs

To give maximum brightness an LED needs to be driven by a pulse circuit. In this way, it is possible to put 0.5 Amp current pulses through an LED at a frequency of around 100Hz which fools the eye into thinking that it sees a continuous light.
If the LED is run at 0.5 Amps for very long, it will burn out (usually within a fraction of a second). By keeping the pulse duration relatively short, we can avoid overheating the LED.

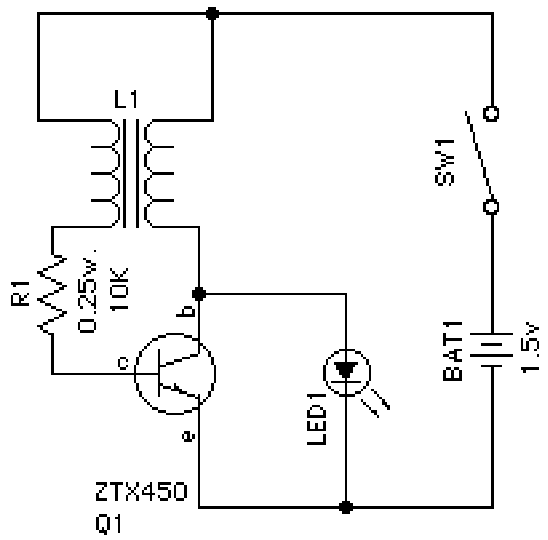
As the 555 I.C. can not supply a lot of current, a transistor is introduced to do this. Resistors R2 and R3 limit the maximum current in order to protect the LED and the transistor. Higher brightness will be achieved if a ZTX450 or ZTX650 is used for Q1, since the BC547B is not rated for very high current.

This circuit allows adjustment of the pulse width so that the maximum *average* current is no more than 50mA.

To ensure long LED life, it should be adjusted for maximum brightness then reduced slightly to an average current of around 40mA. One or two LEDs can be driven simultaneously. C1 can be around 1000uF and acts as a reservoir because the average battery is unable to supply half Amp pulses of current. The circuit can be run from a battery or dc supply of 9 to 12 volts.

Order kits at http://www.satcure.co.uk/accs/kits.htm

Example Micro-torch Circuit



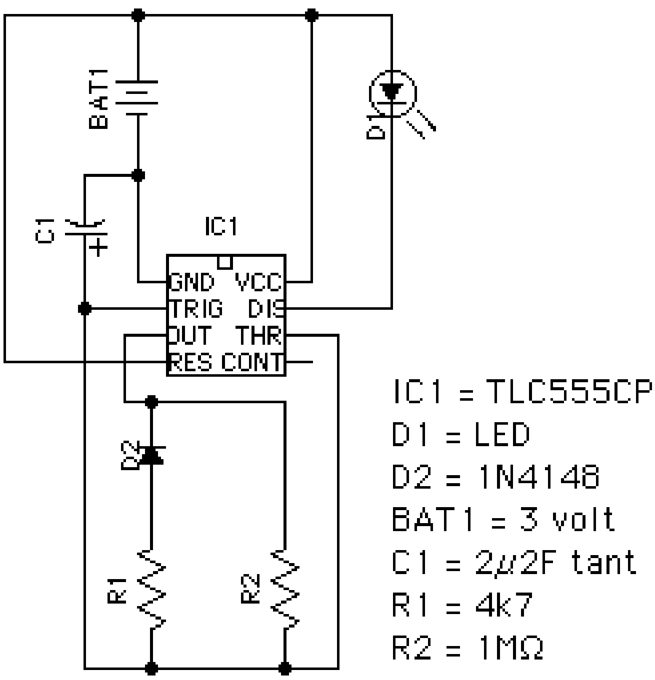
Running an LED off just 1.5 volts to make a Micro-torch

An Ultrabright white LED usually needs at least 4 volts across it before it will light. This simple oscillator circuit by Z. Kaparnik was published in "Everyday Practical Electronics" magazine (page 804 November 1999). It uses a single transistor and a transformer comprising just 20 turns of fine wire on a tiny ferrite bead to form an oscillator. The circuit will operate off an almost dead battery (just 0.75 volts) and produces around 30 volts with the LED disconnected. For extra brightness use a ZTX650.

Up to six LEDs may be connected in series.

Example LED flasher Circuit

Running an LED off just 3 volts to make a Flasher unit



This circuit uses the TLC555CP timer I.C. to flash an LED roughly twice every second. This particular type of 555 timer will run off only 3 volts so two 1.5 volt cells can be used. With "AA" cells, you can expect a battery life of up to 6 months. With larger "C" or "D" type cells it will last for years.

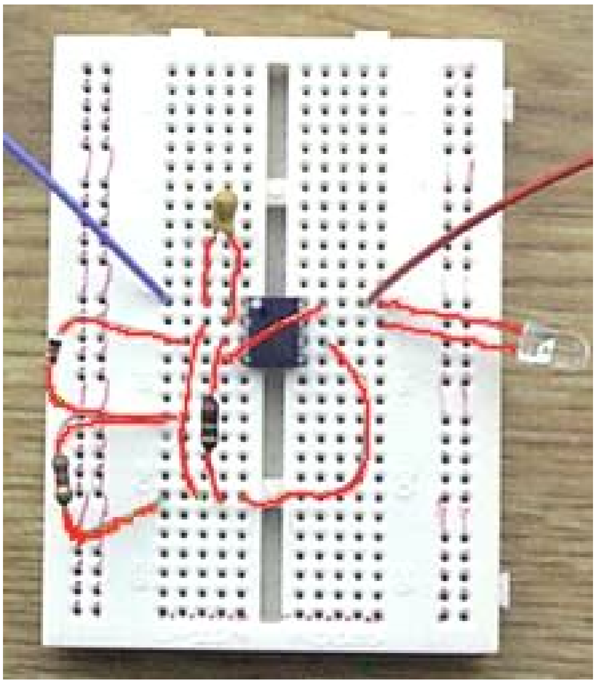
The circuit can be incorporated into a roadside lane marker bollard or used as a warning for other obstacles such as fences, scaffolding tubes or parked vehicles. It can also be suspended from light switch pull-cords to make them easy to find in the dark. Available as a kit from SatCure. The next pages show how to build it.

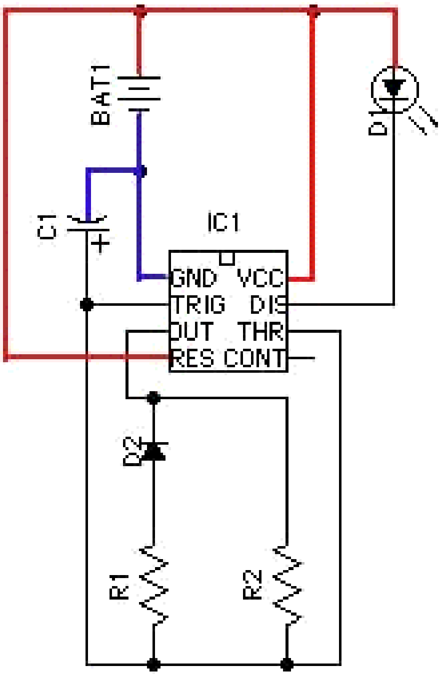
Breadboard

In the early days, circuits used to be constructed by wrapping wire around brass nails hammered into wooden boards such as those used for kneading dough to make bread. Hence the term “breadboarding” to indicate a prototype layout for an electronic circuit.

Of course you can make your own by hammering brass nails into a wooden board and soldering or wrapping the component wires around the nails. The modern equivalent of the “breadboard” takes several forms. The most common employs springs fixed vertically to a board. You can push the component wires between the spring coils which will grip the wires and make good electrical contact.

This is OK for larger components but not so convenient for I.C.s.
So a further development is called by various names like “S-Dec, “µDec” and “BredBord” which consists of a moulded plastic block containing strips of springy metal – usually phosphor-bronze or berillium-copper alloy. The top surface of the plastic box is perforated with rows of holes to allow component leads to be positioned easily.
(I’ve painted the wires red on the breadboard, below, so they can be seen).





The circuit is powered by two 1.5 volt AA cells in a twin battery holder (order EH73S from SatCure).

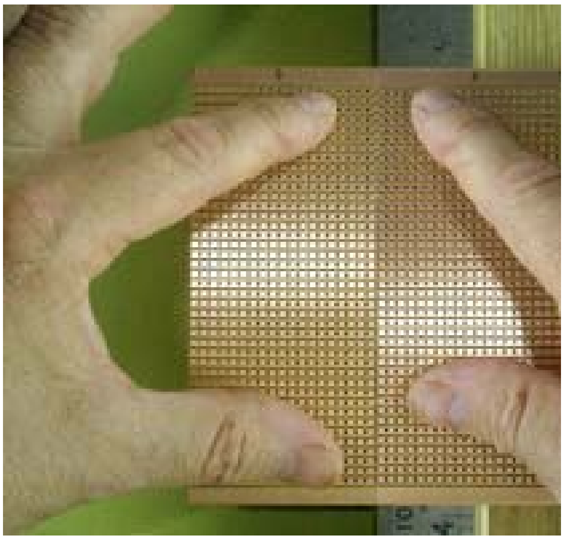
IC1 = TLC555
D1 = LED
D2 = 1N4148
BAT1 = 3 volt
C1 = 2µ2F tar
R1 = 4k7
R2 = 1MΩ

Compare the physical layout with the circuit diagram. Notice that the I.C. is pushed into eight holes, straddling the central channel. Each of the eight holes is one of a group of 5 which are all connected together horizontally inside the plastic. In fact there are two colums, each with 29 rows of 5 interconnected holes. A further four columns, at each side, are connected together internally in vertical sets of 25 holes. (These vertically connected holes were not used in our layout). This type of “breadboard” layout requires no soldering and can be assembled for testing in less than two minutes (with practice).
(BredBord, and this kit as illustrated, is available from http://www.SatCure.co.uk).

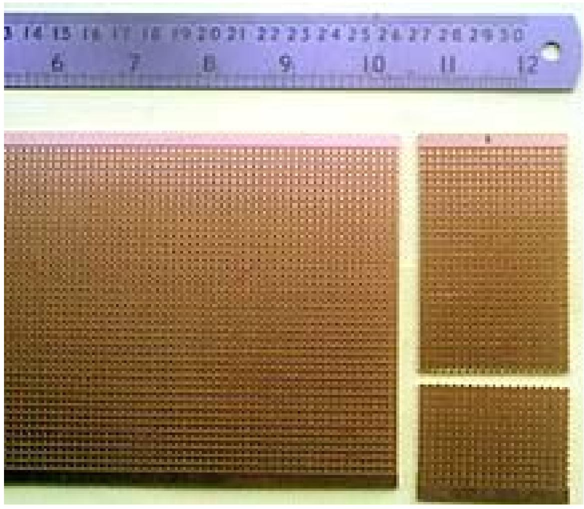
Building the LED Flasher

Once the circuit is proven you can build it up. This project is easy to build on perforated stripboard. We'll call it by a well known manufacturer's trademark "**Veroboard®**".

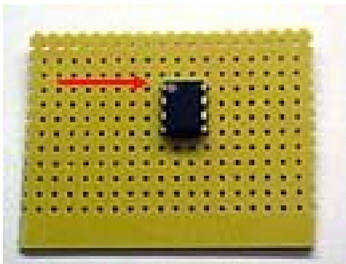
If you start off with a large piece of Veroboard, it needs to be cut down to size. Use a sharp blade to score across the board, following a line of holes. Be sure to make an extra deep notch at each edge.



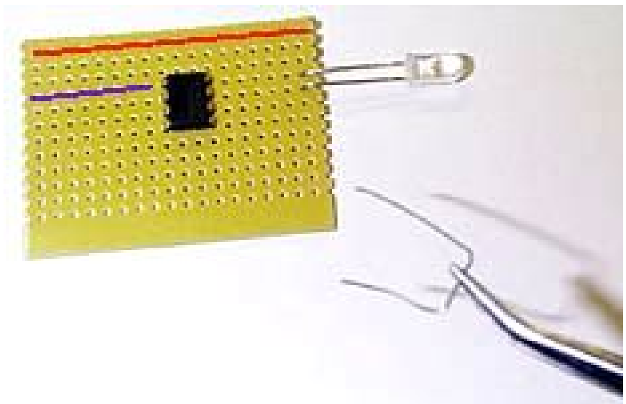
Now rest the board over the edge of a table or bench, with a steel ruler or similar sharp edge immediately below the score mark. Apply downward pressure and the end piece should snap off cleanly.



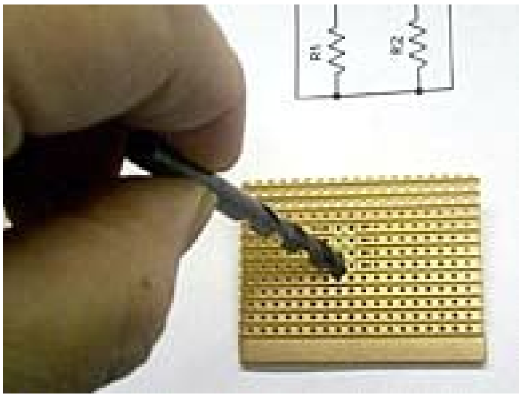
Repeat this process to make a smaller piece for this project.



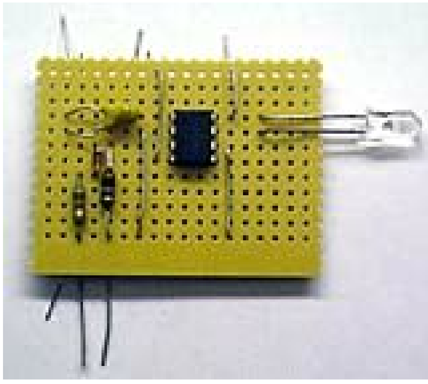
Fit the I.C. in a roughly central position and bend its pins to retain it. Pin 1 is indicated by the arrow. Pin 1 normally has a dot or notch just to the right of it. The other pins are numbered clockwise from 1.



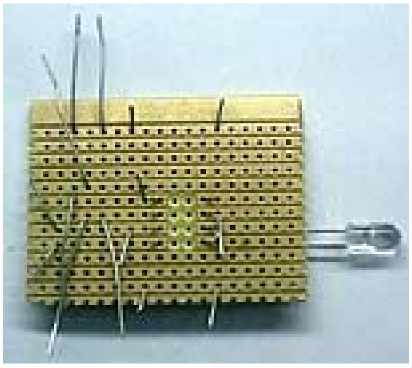
Look at the circuit diagram and decide where the parts can fit. The LED connects between pins 7 and 8 so that's easy to do. Wire links are used to connect pins to other tracks. At this stage you should choose where the positive and zero voltage tracks can be. I've marked my choice with red and blue lines, respectively. Needle-nose pliers or tweezers are handy for bending and fitting the wires.



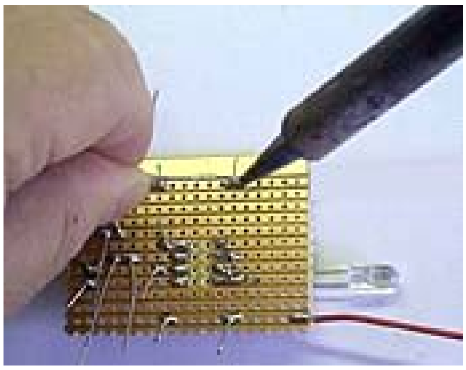
Once you are happy that the I.C. is in a convenient position, you can cut the copper tracks between its two rows of pins, otherwise they will be connected together. This operation is carried out simply by using a twist drill of 3.5 - 4.0 millimetres in diameter. Make sure each track is cut completely. If you are unsure of the I.C. position, leave this operation till later, but do it before you solder the I.C. pins.

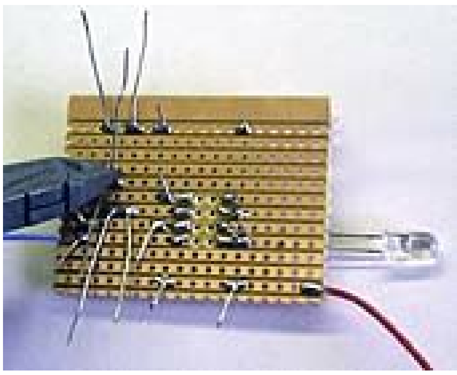


Carry on fitting the components. The actual physical positions of the parts are unimportant. Just make sure that they will be connected to each other and to the I.C. pins in accordance with the circuit diagram. The physical layout of parts on the board doesn’t have to look exactly like the circuit diagram, although it may help you if it is reasonably close. For a more complex project, you may find it easier to sketch a provisional component layout on squared paper.

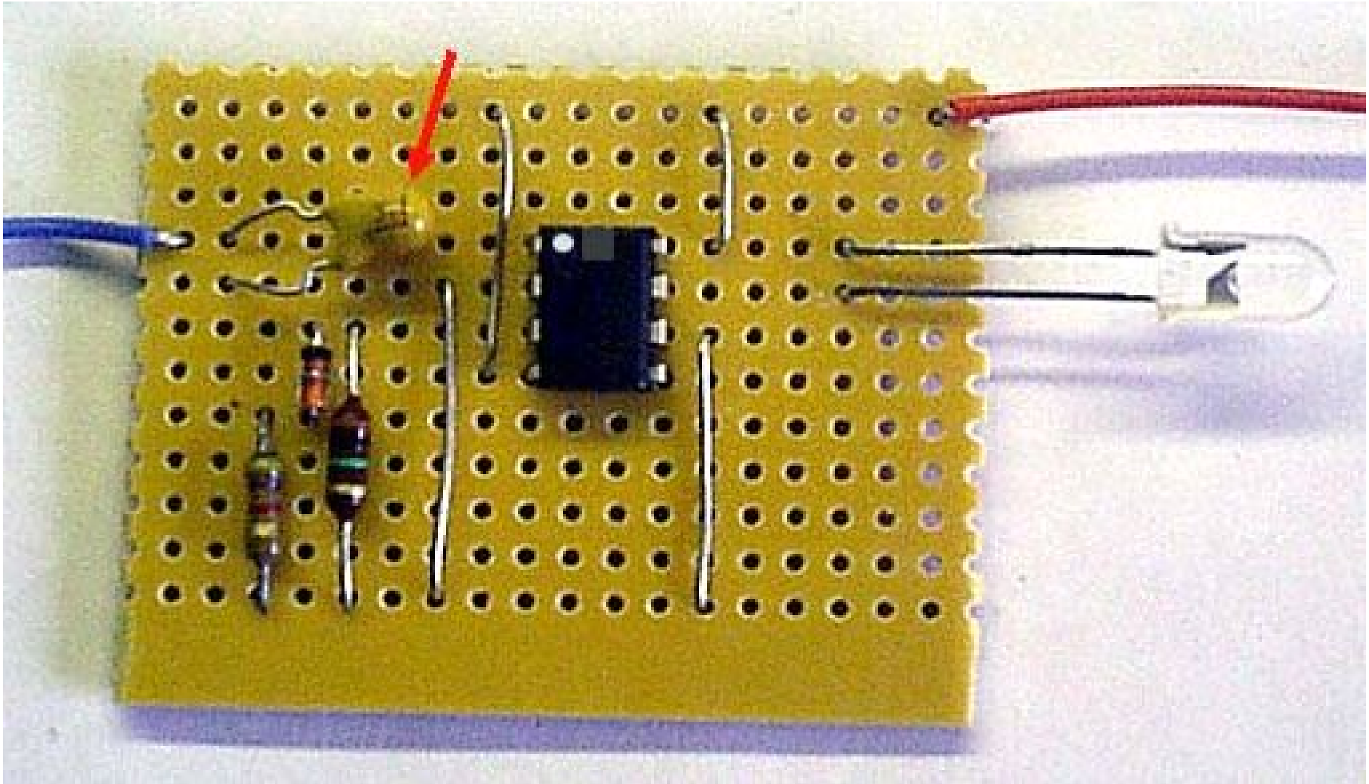


Bend the component wires underneath the board as you fit each part. This will prevent them from falling out as you fit subsequent parts to the board. At this stage it is easy to pull out parts and reposition them if you don’t like the initial result.





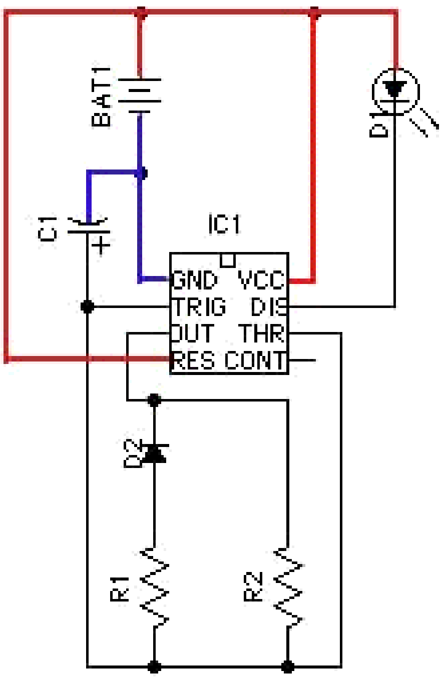
When you are happy that you have positioned the components and link wires correctly, solder the wires to the copper tracks. First, be sure to apply fresh solder to the iron tip then wipe off excess on a damp sponge. (The sponge must be a cellulose type as sold for the purpose. Household “sponges” are made of plastic and will melt!) Be sure to press the hot tip against the wire and track, rotating it back and forth in your fingers as you apply the solder to the joint. The rotating motion helps to scrape off oxidised copper to make a good electrical connection. Be sure to apply the solder to the copper track *after* the tip of the iron has been pressed onto the joint. Applying solder to the iron tip at this stage will result in the solder running *up* the tip away from the joint! Note that this project can be made on a smaller piece of board. I’ve spread it out to make the layout clearer for you. See the big picture on the next page.

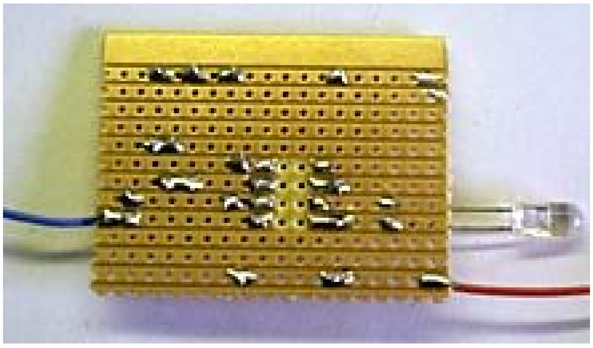


Here is a big photograph of the finished item. Compare it with the circuit diagram.

Remember that the links and components are connected by the copper tracks beneath.

The capacitor is polarised and its positive wire is marked with a “+” symbol (red arrow on the board above).



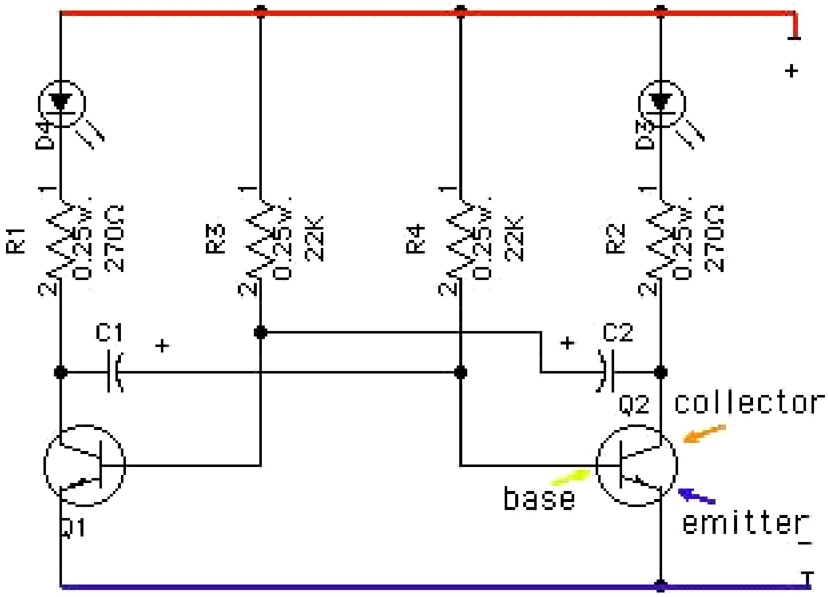


IC1 = TLC555CP
D1 = LED
D2 = 1N4148
BAT1 = 3 volt
C1 = 2µ2F tant
R1 = 4k7
R2 = 1MΩ

The LED is polarised. Its “cathode” is usually a large anvil shape inside. The diode is also polarised and its “cathode” end is marked by a black band. Resistors are not polarised and can go either way round. Notice that the 4700 Ohm (4k7) resistor is marked yellow-violet-red and has a gold band to indicate that it is within 5 percent of the correct value. The 1,000,000 Ohm (1M) resistor is marked brown-black-green and has a silver band to indicate that it is within 10 percent of its correct value. The accuracy or “tolerance” of the parts is not important for this circuit unless the flashing time is critical. I’ve used red for positive and blue for negative (zero volt) battery connections.

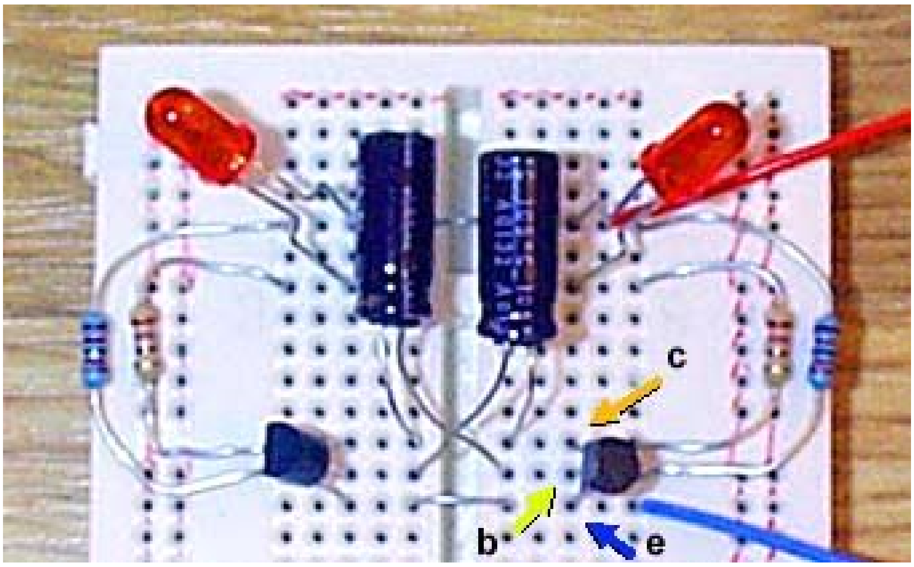
Astable Multivibrator using two transistors

Another LED flasher



Back to basics. You can build lots of interesting and useful circuits without using I.C.s. After all, an I.C. is simply a handy container for a bunch of miniature components! Here is an extremely common circuit with a multitude of uses - eg. a slow alternating flash for a model railway crossing or a fast rate of flash for a flickering flame.

First we can plug the components into a "breadboard" to make sure that the circuit works. The transistors, Q1 and Q2, can be any general purpose NPN silicon bipolar type such as BC547B (as used here) or 2N3404. Transistors have three wires which we call the "collector", the "base" and the "emitter". I've marked these with arrows. (Please note that all BC transistors are configured like this but 2N devices may have the collector and base transposed). Resistors R1 and R4 protect the LEDs from excessive current. The actual value is dependent on the characteristics of the LEDs but 270 Ohms should be fine for supply voltages of between 3 volts and 12 volts.

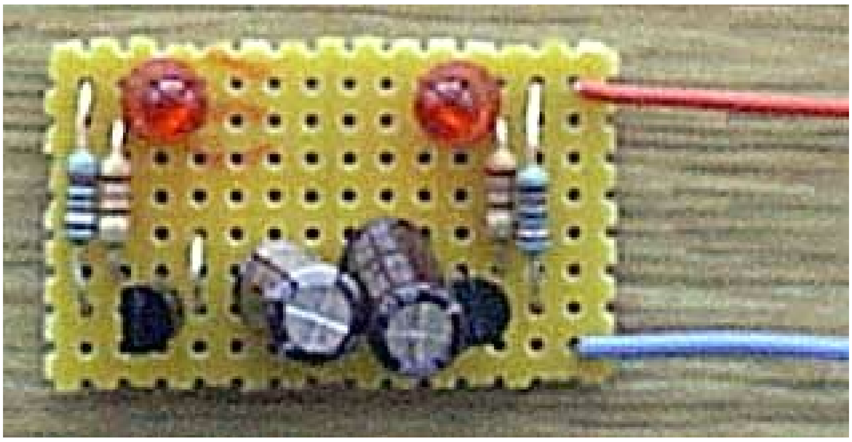


R3 and R4 determine the speed at which the LEDs flash alternately (the frequency of oscillation). Capacitors C1 and C2 also have a big influence on the frequency. For a slow flash of about one Hertz (one flash per second) you can use 100 microFarad (100µF) electrolytics. For a rapid flash use 4.7 microFarad (4µ7F) capacitors. For other speeds try different values. (it's OK to experiment. That's what design is all about!) Notice that the negative end of each capacitor is connected to a transistor "collector".

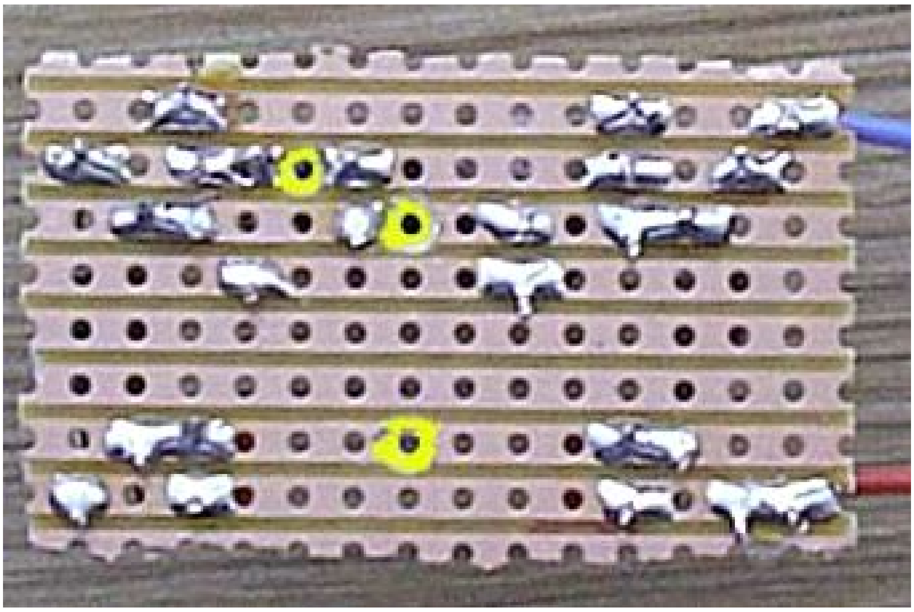
(BredBord, and this kit as illustrated, is available from http://www.SatCure.co.uk).

Now let's put the final circuit onto Veroboard ...

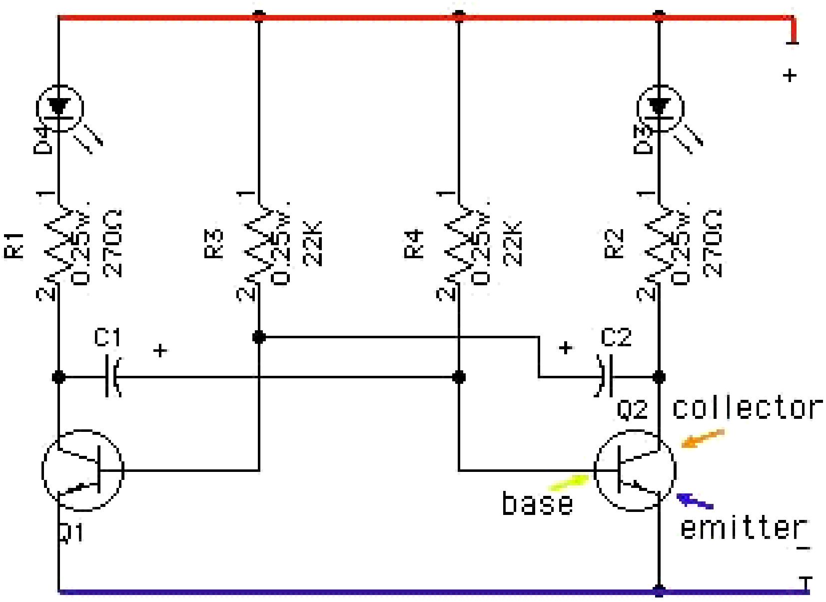
Astable Multivibrator on Veroboard



Here are the components soldered onto Veroboard, The layout follows the circuit diagram fairly closely but the crossed-over capacitors are dealt with by adding a wire link. Three tracks have to be cut (highlighted in yellow).



I have pushed the LEDs down onto the board but you might prefer to leave them "on stalks". This leaves them prone to vibration-fracture so it's a good idea to squirt some hot-melt adhesive around the wires to secure them to the board. If you leave the LED wires long, it's easier to fit the unit into, say, a robot with "flashing eyes".



Here is the circuit diagram again so you can compare it with the physical layout of the components. It took me about ten minutes to do the whole job but I've been playing with this stuff since I was ten years old!

So take your time when you design your own projects. Soon you'll be able to do this just from a circuit diagram. It simply takes practice.

Order kits at http://www.satcure.co.uk/accs/kits.htm