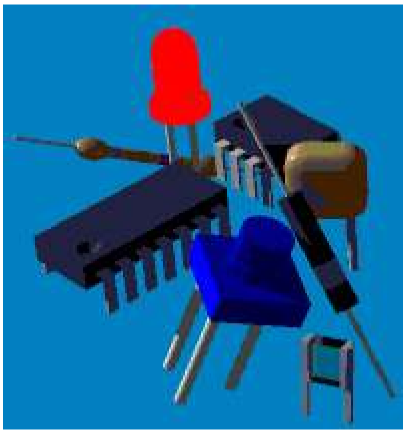
Basic Introduction To Electronic Components



The Resistor

Resistors come between conductors, which conduct easily and insulators which don't conduct. Resistance is measured in ohms after the discoverer of a law relating voltage to current (Ohms Law).

The main function of resistors in a circuit is to control the flow of current and voltage drops to other components. An LED (Light Emitting Diode) for example; if too much current flows through an LED it is destroyed but to little and in will not light, so a resistor is used to limit the current but not so big as it will limit all the current.

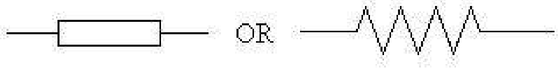
When a current flows through a resistor energy is wasted and the resistor heats up, you will only notice this if the resistor working at its maximum power rating. The greater the current flowing through the resistor hotter it gets. A battery or power supply has to do work to force electrons through the resistor and this work ends up as heat energy in the resistor.

An important property to know about resistors is how much heat energy it can withstand before it's damaged or causes a fire. Resistors can in this Lab dissipate about 0.25 Watts, so be careful when choosing your values.

It's difficult to make a resistor to an exact value, so resistances are given a tolerance. This is expressed as being plus or minus a percentage. A ±10% resistor with a stated value of 100 ohms could have a resistance anywhere between 90 ohms and 110 ohms.

In circuit diagrams you will often see an 'R' instead of omega to represent ohms. This is a convention that dates from before the days of computers and laser printers when Greek letters were rarely found on the keyboards.

The symbol and a few examples of this type is shown below:



Carbon Film

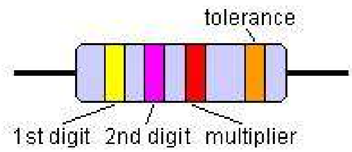
Metal Film

Thick Film Plate

Resistor Colour Code

The resistor colour code is a way of showing the value of a resistor. Instead of writing the resistance on its body, which would often be too small to read, a colour code is used. Different colours represent the numbers 0 to 9. The first two coloured bands on the body are the first two digits of the resistance, and the third band is the 'multiplier'. Multiplier just means the number of zeroes to add after the first two digits. Red represents the number 2, so a resistor with red, red, red bands has a resistance of 2 followed by 2 followed by 2 zeroes, which is 2200 ohms or 2.2 kilohms.

The final band is the tolerance (the accuracy ± x %). All resistors have a tolerance which is shown by the last band.



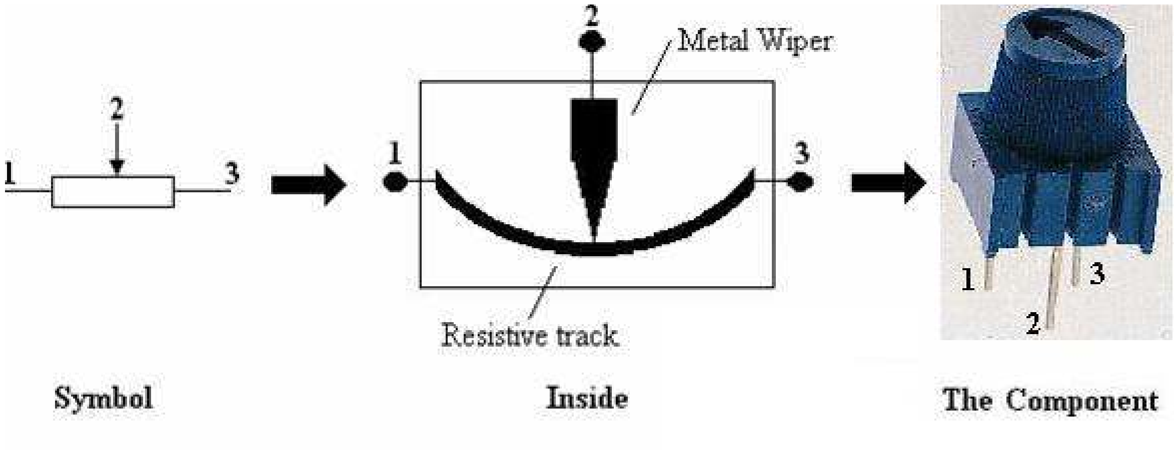
Colour	1st Band	2nd Band	3rd Band	4th Band
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1000	
Yellow	4	4	10000	
Green	5	5	100000	
Blue	6	6	1000000	
Purple	7	7		
Grey	8	8		
White	9	9		
Red				1%
Gold				5%
Silver				10%

Here are some examples:

Yellow, Purple, Red, Gold = 47 x 100 = 4 700 ohms = 4.7 kilohms + 5%
Brown, Black, Yellow, Gold = 10 x 10 000 = 100 kilohms + 5%
Yellow, Purple, Black, Silver = 47 x 1 = 47 ohms + 10%
Brown, Black, Red, Red = 10 x 100 = 1 000 ohms = 1 kilohms + 1%
Brown, Black, Green, Gold = 10 x 100 000 = 1 000 kilohms = 1 Megohms + 5%

Variable Resistors

Variable resistors are resistors whose resistance can be varied by moving a knob or slider. Variable resistors can also be called presets or pots, they have a metal wiper resting on a resistive track usually made from carbon. The wiper moves along the track as the preset is moved. The current flows through the wiper, then through part of the carbon track or through the carbon track then through the wiper. The more of the track it has to go through the greater the resistance.



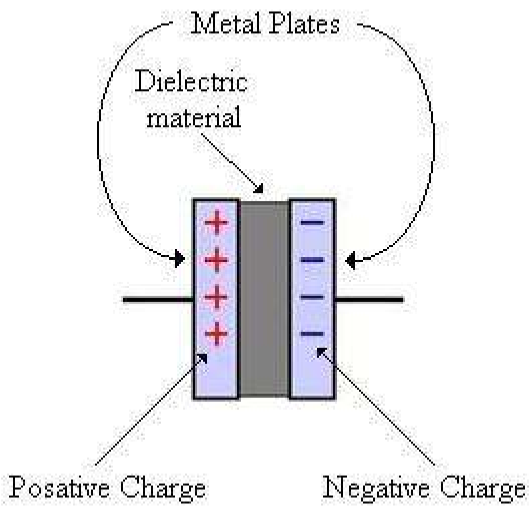
Pots have three legs. The top leg connects to the wiper (2) and the other two legs to the two ends of the track (1 and 3). Generally two of the legs are use if you wish it to act like a variable resistor or all three if it is to be a potential divider but this depends on the operation you want it to perform.

The Capacitor

Capacitors are components that store an electrical charge. Like tiny batteries they can cause a current to flow in a circuit. But they only do this for a short time, they cannot deliver a sustained current. They can be charged up with energy from a battery, then return that energy back later. The capacitance of a capacitor is a measure of how much energy/charge it can store.

In its simplest form a capacitor consists of two separated metal plates with air or another non-conductive material filling the gap, the bigger the plates the bigger the capacitance. To stop capacitors becoming impractically large they can be rolled up.

Another way of increasing the capacitance is to put some non-conducting material between the plates. This is called a dielectric material. When a capacitor charges up the protons and electrons in the dielectric separate out a little, this allows more charge to be stored on the plates than usual. Dielectrics are made of various materials Ceramic, paper, polyester, polystyrene, mica, e.t.c.

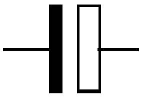
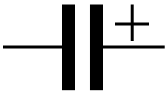


Capacitance is measured in Farads after the scientist Michael Faraday. One Farad is a very big unit and are usually found in the range of pico to micro farads.

Capacitors come in two flavours, electrolytic and non-electrolytic.

Electrolytic capacitors use special dielectrics sometimes a solid but the must common types are a liquid or paste which is formed into a very thin dielectric in the factory. Non-electrolytic capacitors have solid dielectrics.

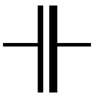
The symbol for electrolytic capacitors and a few examples of this type is shown below:

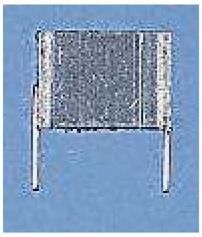
Electrolytic Tantalum

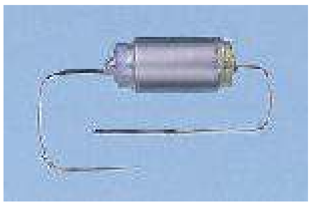
The symbol for non-electrolytic capacitors and a few examples of this type is shown below:



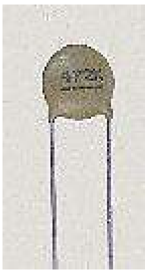
Polyester

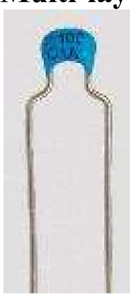
Polystyrene



Ceramic Disk

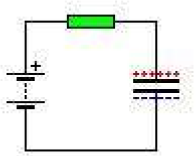


Multi-layer Ceramic

Electrolytic capacitors can store more charge but there are a couple of problems. They Have a polarity and must be connected the right way around in a circuit. They also slowly leak their charge, and they have quite large tolerances i.e 10% to 20%. Where as non-electrolytic capacitors still leak but not as fast as electolytics and do not have a polarity problem but store less charge.

When a capacitor is connected to a source it begins to charge. The current flows rapidly at first then more slowly as it gets to maximum its charge. Charge builds up on the two plates, negative charge on one plate and the same amount of positive charge on the other. The positive charge results from electrons leaving one of the plates and leaving positively-charged protons behind. But as the capacitor fills with charge it starts to oppose the current flowing in the circuit. It is as if another battery were working against the first. The current decreases and the capacitor charges more slowly. The plates become full of charge and it takes practically forever to squeeze the last drop in, until no current flows, and the circuit acts like an open.



charging a capacitor through a resistor

If a capacitor is shorted then it discharges. Charge flows out of the capacitor rapidly at first, then progressively more slowly. The last little drop just trickles out. The speed at which the capacitor empties or charges depends on the resistance. If a simple wire shorts out a capacitor then it empties in a flash, often with a spark if it's a big capacitor.

We've seen that when a capacitor is fully charged the current stops. In other words a continuous current cannot flow through a capacitor. A continuous current is called a direct current or D.C.

An alternating current (A.C.) however can flow through a capacitor. An alternating current is one which is continually changing its direction. Mains is an A.C. and changes its direction 50 times a second (50Hz). An alternating current continually charges and discharges a capacitor and hence is able to keep current flowing.

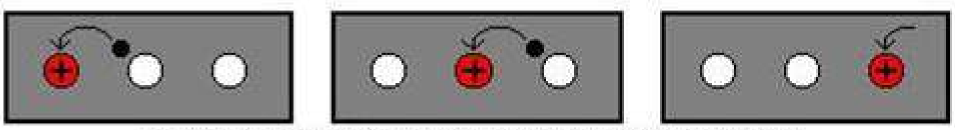
Semiconductor Introduction

Now we come to what is probably the most important discovery in electronics which happened last century. Without this discovery we wouldn't have televisions, computers, space rocket, CD players, etc. Unfortunately it's also one of the hardest areas to understand in electronics.

Recall that the reason what makes metals such good conductors, this is that they have lots of electrons which are so loosely held that they're easily able to move when a voltage is applied. Insulators have fixed electrons and so are not able to conduct. Certain materials, called semiconductors, are insulators that have a few loose electrons. They are partly able to conduct a current.

The free electrons in semiconductors leave behind a fixed positive charge when they move about (the protons in the atoms they come from). Charged atoms are called ions. The positive ions in semiconductors are able to capture electrons from nearby atoms. When an electron is captured another atom in the semiconductor becomes a positive ion. This behaviour can be thought of as a 'hole' moving about the material, moving in just the same way that electrons move. So now there are two ways of conducting a current through a semiconductor, electrons moving in one direction and holes in the other. There are two kinds of current carriers.

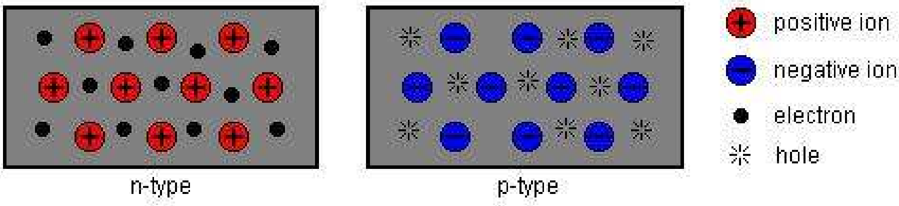
The holes don't really move of course. It is just fixed positive ions grabbing neighbouring electrons, but it appears as if holes are moving.



electrons moving to the left = 'holes' moving to the right

In a pure semiconductor there are not enough free electrons and holes to be of much use. Their number can be greatly increased however by adding an impurity, called a donor. If the donor gives up some extra free electrons we get an n-type semiconductor (n for negative). If the donor soaks up some of the free electrons we get a p-type semiconductor (p for positive). In both cases the impurity donates extra current carriers to the semiconductor. Adding impurities is called dopping.

In n-type semiconductors there are more electrons than holes and they are the main current carriers. In p-type semiconductors there are more holes than electrons and they are the main current carriers. The donor atoms become either positive ions (n-type) or negative ions (p-type).



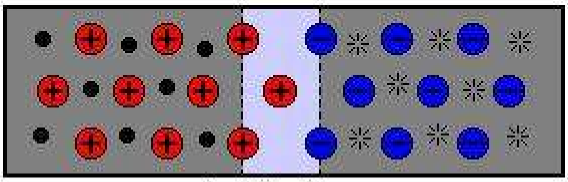
The most common semiconductors are silicon (basically sand) and germanium. Common donors are arsenic and phosphorus.

When we combine n-type and p-type semiconductors together we make useful devices, like transistors, diodes and chips.

The Diode

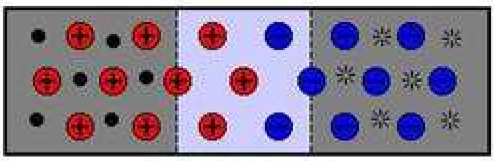
A diode consists of a piece of n-type and a piece of p-type semiconductor joined together to form a junction.

Electrons in the n-type half of the diode are repelled away from the junction by the negative ions in the p-type region, and holes in the p-type half are repelled by the positive ions in the n-type region. A space on either side of the junction is left without either kind of current carriers. This is known as the depletion layer because there are no current carriers in this layer, so current can flow. The depletion layer is, in effect, an insulator.

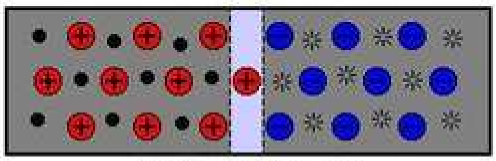


depletion layer

Now consider what would happen if we connected a small voltage to the diode. Connected one way it would attract the current carriers away from the junction and make the depletion layer wider. Connected the other way it would repel the carriers and drive them towards the junction, so reducing the depletion layer. In neither case would any current flow because there would always be some of the depletion layer left.

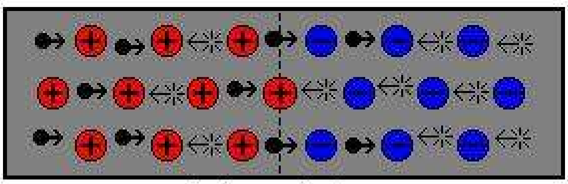


depletion layer wider



depletion layer narrower

Now consider increasing the voltage. In one direction there is still no current because the depletion layer is even wider (reverse biased), but in the other direction the layer disappears completely and current can flow (forward biased). Above a certain voltage the diode acts like a conductor. As electrons and holes meet each other at the junction they combine and disappear.

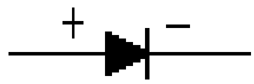


diode conducting

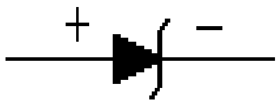
Thus a diode is a device which is an insulator in one direction and a conductor in the other. Diodes are extremely useful components. We can stop currents going where we don't want them to go. For example we can protect a circuit against the battery being connected backwards which might otherwise damage it.

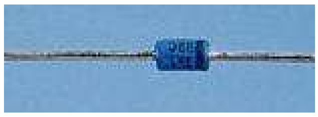
The symbol and a few examples of this type is shown below (Note the cathode on the component is shown by a ring at one end):

Small Signal



Zenner



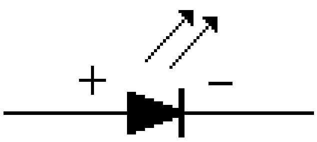


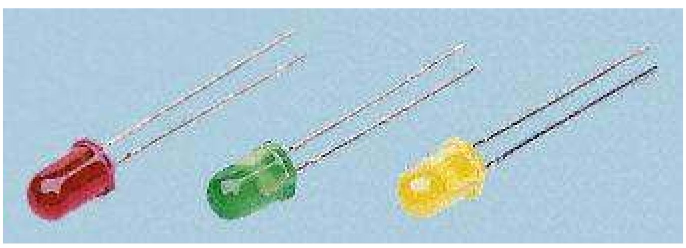
LEDs (Light Emitting Diode)

Light emitting diodes (LEDs) are special diodes that give out light when they conduct. The fact that they only conduct in one direction is often incidental to their use in a circuit. They are usually just being used as lights. They are small and cheap and they last practically forever, unlike traditional light bulbs which can burn out.

The light comes from the energy given up when electrons combine with holes at the junction. The colour of the light depends on the impurity in the semiconductor. It is easy to make bright red, green and yellow LEDs but technology cant make cheap LEDs of other colours like white or blue.

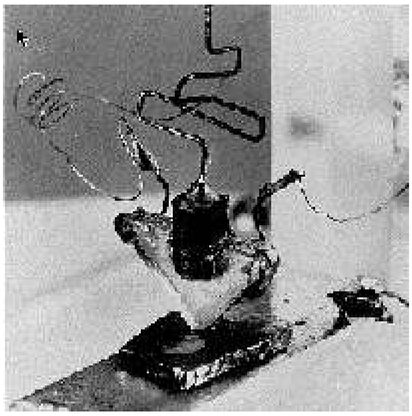
The symbol and a few examples of this type is shown below(Note the cathode on the component is shown as a flat edge or the short leg):





The Transistor

Transistors underpin the whole of modern day electronics. They are found everywhere - in watches, calculators, microwaves, hi-fi's. A Pentium(tm) computer chip contains over a million transistors!



This is a picture of the first transistor ever created

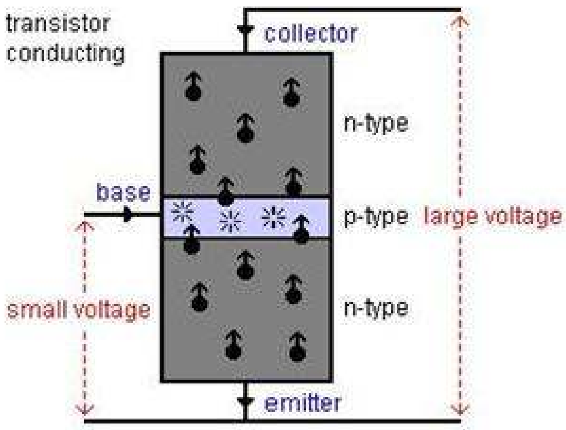
Transistors work in two ways. They can work as switches (turning currents on and off) and as amplifiers (making currents bigger). We'll be looking at them as switches here. To understand them as amplifiers would involve a little mathematics your lectures should cover both these actions. When acting as an amplifier they operate in the linear mode and as a switch they are forced into saturation (on) or cut off (off).

Transistors are sandwiches of three pieces of semiconductor material. A thin slice of n-type or p-type semiconductor is sandwiched between two layers of the opposite type. This gives two junctions rather than the one found in a diode. If the thin slice is n-type the transistor is called a p-n-p transistor, and if the thin slice is p-type it is called a n-p-n transistor. The middle layer is always called the base, and the outer two layers are called the collector and the emitter.

We will consider the (more common) n-p-n transistor. In a n-p-n transistor electrons are the main current carriers (because n-type material predominates).

When no voltage is connected to the base then the transistor is equivalent to two diodes connected back to back. Recall that current can only flow one way through a diode. A pair of back-to-back diodes can't conduct at all.

If a small voltage is applied to the base (enough to remove the depletion layer in the lower junction), current flows from emitter to base like a normal diode. Once current is flowing however it is able to sweep straight through the very thin base region and into the collector, only a small part of the current flows out of the base. The transistor is now conducting through both junctions. A few of the electrons are consumed by the holes in the p-type region of the base, but most of them go straight through.



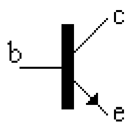
Electrons enter the emitter from the battery and come out of the collector. (Isn't that rather illogical you might say, electrons emitted from the collector? Yes it is, but the parts of a transistor are named with respect to conventional current, an imaginary current which flows in the opposite direction to real electron current.)

Now you can see how a transistor acts as a switch. A small voltage applied to the base switches the transistor on, allowing a current to flow in the rest of the transistor.

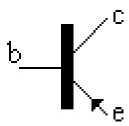
NPN and PNP Transistor components look identical to each other the only way to tell the difference is by the component number.

The symbol and a few examples of this type is shown below (on transistors you need a data sheet to tell you which pin is which, but some you can make a guess i.e. the collector lead on a metal can transistor is connected to the case and the metal tag is next to the emitter lead):

N-P-N Transistor

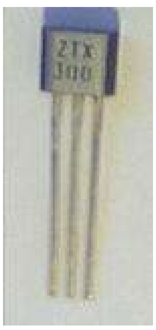


P-N-P Transistor



There are many different packages a transistor can come in these are but a few

E-Line Package



TO-18 Package

SOT-32 Package