Basic Electronics Concepts

Volts – (the symbol – V)

Units of electrical pressure, meaning the difference in potential between the positive and negative terminals of the power source.

Amp (the symbol - A)

This is the unit of current, meaning the rate that electricity flows around a circuit

Ohm – (the symbol Ω)

This is the unit of resistance within a circuit.

Materials that have a high resistance are called insulators, those with low are called conductors, and if a material has no resistance it is called a superconductor.

Watt (the symbol – W)

This is the unit of power this is worked out by Voltage (V) X Current (A)

Farad (the symbol – F)

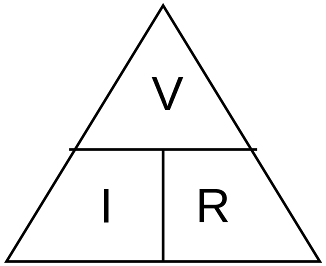
This is the unit of capacitance, which is the amount of electrical charge that can be stored in a capacitor

Coulomb (the symbol - C)
1 coulomb is the amount of electric charge carried by a current of 1 ampere flowing for 1 second.

It can also be defined in terms of capacitance and voltage, where one coulomb is defined as one farad of capacitance times one volt of electric potential difference:

Key concept

Ohms law defines the relationship between Voltage (V), Current (I) and Resistance (R) as:



Time constant can be calculated with:

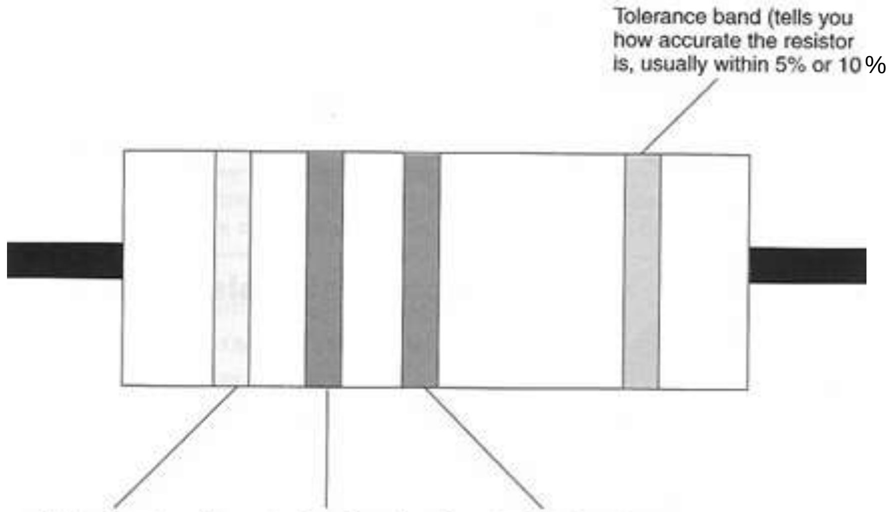
T (seconds) = C (farads) X R (ohms)

The following symbols and prefixes are used throughout electronics:

Symbol	Prefix	Multiplier	
G	giga	one thousand million	10^9
M	mega	one million	10^6
k	kilo	one thousand	10^3
m	milli	one thousandth	10^{-3}
μ	micro	one millionth	10^{-6}
n	nano	one thousand millionth	10^{-9}

Components

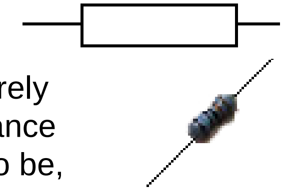
Resistor colour code



1st colour band		2nd colour band		3rd colour band		
Black	0	Black	0	Silver	divide by	100
Brown	1	Brown	1	Gold	divide by	10
Red	2	Red	2	Black	multiply by	1
Orange	3	Orange	3	Brown	multiply by	10
Yellow	4	Yellow	4	Red	multiply by	100
Green	5	Green	5	Orange	multiply by	1000
Blue	6	Blue	6	Yellow	multiply by	10000
Violet	7	Violet	7	Green	multiply by	100000
Grey	8	Grey	8	Blue	multiply by	1000000
White	9	White	9			

I.e. Yellow-Violet-Brown = 4:7: X 10 = 470 Ω

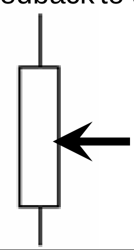
Resistor

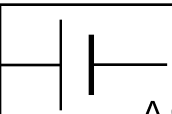


Resistors are rarely the exact resistance they are made to be, this is due to the large scale that they are manufactured in. however it is possible to use a variable resistor to achieve a required resistance

Variable resistor –

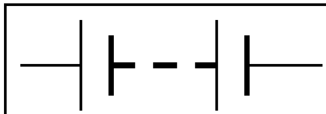
Their resistance is varied by the use of a knob or slider, often used for changing the sensitivity of a sensing device or reducing feedback to an amplifier





A Cell

The standard voltage of a dry battery is 1.5V. By connecting them together in series you can achieve a higher voltage.

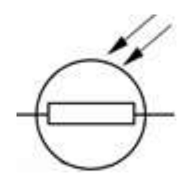


Battery of cells

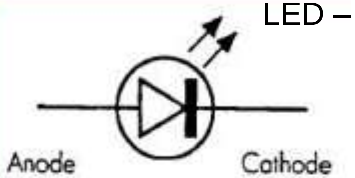
Light bulb

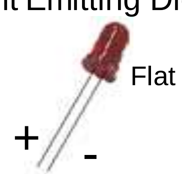
LDR – Light Dependant ~Resistor

These are special resistors that have a high resistance but their resistance falls when light falls on their surface.

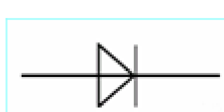


LED – Light Emitting Diode





Diode



Switches

These are some of the most common switches however there are many more types for a full list visit:
http://www.ibiblio.org/kuphaldt/electricCircuits/Digital/DIGI_4.html

Tilt Switch

Tilt switches contain a conductive liquid and when tilted this bridges the contacts inside, closing the switch. They can be used as a sensor to detect the position of an object.

DIP Switch

This is a set of miniature SPST on-off switches, the example shown has 8 switches. The package is the same size as a standard DIL (Dual In-Line) integrated circuit

Multi-pole

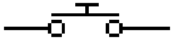
The picture shows a 6-pole double throw switch, also known as a 6-pole changeover switch. It can be set to have momentary or latching action. Latching action means it behaves as a push-push switch, push once for the first position, push again for the second position etc.

Single pole single throw

A simple on-off switch

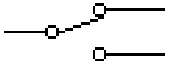
Push to break

A push-to-break switch returns to its normally closed (on) position when you release the button



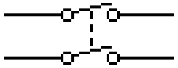
Push to make

A push-to-make switch returns to its normally open (off) position when you release the button



Single pole double throw

This switch can be on in both positions, switching on a separate device in each case. It is often called a **changeover switch.** For example, a SPDT switch can be used to switch on a red lamp in one position and a green lamp in the other position.



Double pole double throw

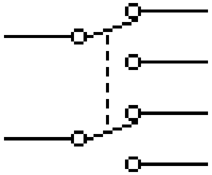
A pair of on-off switches which operate together

Microswitch

Microswitches are designed to switch fully open or closed in response to small movements. They are available with levers and rollers attached.

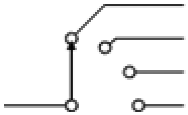
Reed

The reed switch contains two magnetic & electrically conductive metal reeds which are separated by a small gap. The reeds are sealed in a tubular glass envelope.



Double pole double throw

A pair of on-on switches which operate together (shown by the dotted line in the circuit symbol).



Rotary

Multi-way switches have 3 or more conducting positions. They may have several poles (contact sets). A popular type has a rotary action.

Transistors + The Darlington Pair

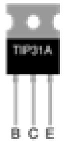
A **transistor** is a semiconductor device that uses a small amount of voltage or electrical current to control a larger change in voltage or current. The transistor is the fundamental building block of the circuitry that governs the operation of computers, cellular phones, and all other modern electronics.
Because of its fast response and accuracy, the transistor may be used in a wide variety of digital and analogue functions, including amplification, switching, voltage regulation, signal modulation, and oscillators.

A transistor has a minimum voltage (in the case of the NPN this is between 0.6V – 0.8V) that is needed before the transistor will allow the current to pass through it, this is known as the threshold voltage, this threshold allows the transistor to act as a switch in a circuit.

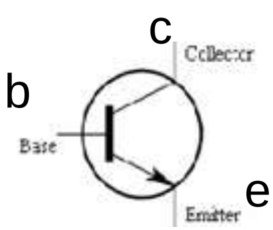
Transistors amplify current, for example they can be used to amplify the small output current from a logic chip so that it can operate a lamp, relay or other high current device. In many circuits a resistor is used to convert the changing current to a changing voltage, so the transistor is being used to amplify voltage.
The amount of current amplification caused by a transistor is called the current gain, symbol hFE.

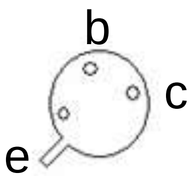
NPN Transistor

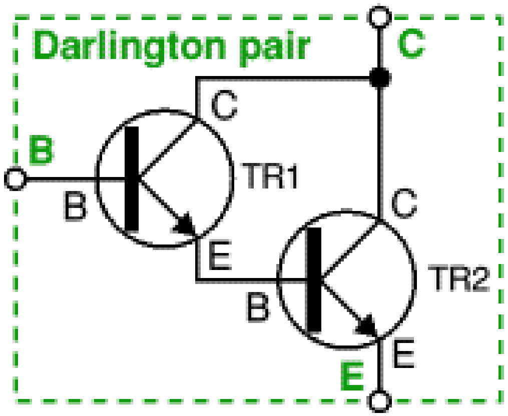
There are three leads called Base (b), Collector (c) and emitter (e).



The underneath







To the left is two transistors connected together so that the amplified current from the first is amplified further by the second transistor, this arrangement is know as a 'Darlington pair'. This gives the Darlington pair a very high current gain.
Darlington pairs can be sold as complete packages containing the two transistors. They have three leads (**B**, **C** and **E**) which are equivalent to the leads of a standard individual transistor.
Although you can make up your own Darlington pair from two transistors.
For example:
For TR1 use BC548B with hFE1 = 220.
For TR2 use BC639 with hFE2 = 40.
The overall gain of this pair is hFE1 × hFE2 = 220 × 40 = 8800.
The pair's maximum collector current IC(max) is the same as TR2.

It is not possible to connect more than two transistors in this way.

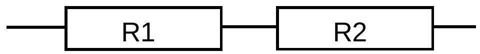
Resistors

In Serial and Parallel

Resistance

Resistance is the property of a component which restricts the flow of electric current. Energy is used up as the voltage across the component drives the current through it and this energy appears as heat in the component.

Resistors connected in Series

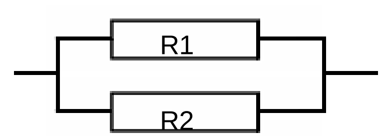


When resistors are connected in series their combined resistance is equal to the individual resistances added together. For example if resistors R1 and R2 are connected in series their combined resistance, R, is given by:

Combined resistance in series: **R = R1 + R2**

This can be extended for more resistors: **R = R1 + R2 + R3 + R4 + ...**

Resistors connected in Parallel



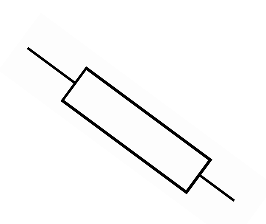
When resistors are connected in parallel their combined resistance is less than any of the individual resistances. There is a special equation for the combined resistance of **two** resistors R1 and R2:

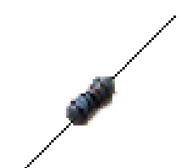
Combined resistance of **two resistors in parallel**:

$$R = \frac{R1 \times R2}{R1 + R2}$$

For more than two resistors connected in parallel a more difficult equation must be used. This adds up the reciprocal ("one over") of each resistance to give the reciprocal of the combined resistance, R:

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots$$





Relays

A relay is an electrically operated switch.

Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions, they are double throw (changeover) switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.
The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (Integrated Circuits) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.
Relays are usually SPDT (Single Pole Double Throw) or DPDT (Double Pole Double Throw) but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available.

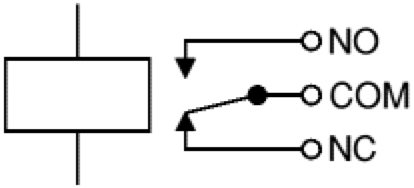
Most relays are designed for PCB mounting but you can solder wires directly to the pins providing you take care to avoid melting the plastic case of the relay. The supplier's catalogue should show you the relay's connections. The coil will be obvious and it may be connected either way round. Relay coils produce brief high voltage 'spikes' when they are switched off and this can destroy transistors and ICs in the circuit. To prevent damage you **must connect a protection diode across the relay coil.**

The animated picture (bottom right) shows a working relay with its coil and switch contacts. You can see a lever on the left being attracted by magnetism when the coil is switched on. This lever moves the switch contacts. There is one set of contacts (SPDT) in the foreground and another behind them, making the relay DPDT.

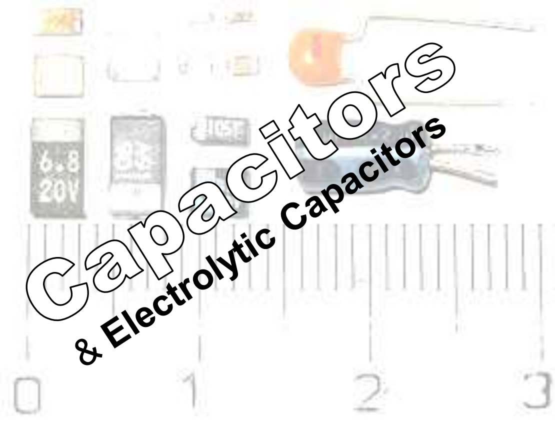
Reed relays

Reed relays consist of a coil surrounding a reed switch. Reed switches are normally operated with a magnet, but in a reed relay current flows through the coil to create a magnetic field and close the reed switch.
Reed relays generally have higher coil resistances than standard relays (1000 for example) and a wide range of supply voltages (9-20V for example).
They are capable of switching much more rapidly than standard relays, up to several hundred times per second; but they can only switch low currents (500mA maximum for example).

The relay's switch connections are usually labelled COM, NC and NO:
COM = Common, always connect to this, it is the moving part of the switch.
NC = Normally Closed, COM is connected to this when the relay coil is **off**.
NO = Normally Open, COM is connected to this when the relay coil is **on**.



Capacitors
& Electrolytic Capacitors



A capacitor has two terminals Inside, are two metal plates separated by a dielectric. The dielectric can be anything that does not conduct electricity and keeps the plates from touching each other.

A capacitor is an electrical device that can store energy in the electric field between a pair of closely-spaced conductors (called 'plates'). When voltage is applied to the capacitor, electric charges of equal magnitude, but opposite polarity, build up on each plate.

- The plate on the capacitor that attaches to the negative terminal of the battery accepts electrons that the battery is producing.
- The plate on the capacitor that attaches to the positive terminal of the battery loses electrons to the battery.
- Capacitors only need to be 63% charged to discharge, the time taken to discharge will be equal to the time taken to charge.

Capacitors store electric charge. They are used with resistors in timing circuits because it takes time for a capacitor to fill with charge. They are used to smooth varying DC supplies by acting as a reservoir of charge. They are also used in filter circuits because capacitors easily pass AC (changing) signals but they block DC (constant) signals.

There are many types of capacitor but they can be split into two groups, polarised and unpolarised. Each group has its own circuit symbol.

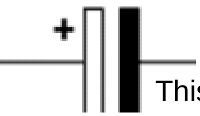
Electrolytic Capacitors

(these have large values above 1µF)

Electrolytic capacitors are polarised and they must be connected the correct way round, at least one of their leads will be marked + or -. They are not damaged by heat when soldering.
There are two designs of electrolytic capacitors; axial where the leads are attached to each end (220µF in picture) and radial where both leads are at the same end (10µF in picture). Radial capacitors tend to be a little smaller and they stand upright on the circuit board.

The Construction

Aluminium electrolytic capacitors are made from two conducting aluminium foils, one of which is coated with an insulating oxide layer, and a paper spacer soaked in electrolyte. The foil insulated by the oxide layer is the anode while the liquid electrolyte and the second foil act as cathode. This stack is then rolled up, and placed in a cylindrical aluminium casing.



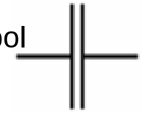
This is the circuit symbol for an **electrolytic capacitor**

Unpolarised capacitors

(small values, up to 1µF)

Small value capacitors are unpolarised and may be connected either way round. They are not damaged by heat when soldering, except for one unusual type (polystyrene). They have high voltage ratings of at least 50V, usually 250V or so. It can be difficult to find the values of these small capacitors because there are many types of them and several different labelling systems!
Many small value capacitors have their value printed but without a multiplier, For example **0.1** means 0.1µF = 100nF

This is the circuit symbol for a **capacitor**



Capacitance

This is a measure of a capacitor's ability to store charge. A large capacitance means that more charge can be stored. Capacitance is measured in farads, symbol F. However 1F is very large, so prefixes are used to show the smaller values. Common prefixes are; microfarads (µF), nanofarads (nF), and picofarads (pF).

A 1-farad capacitor can store one coulomb of charge at 1 volt.

Variable Capacitors

Variable Capacitor Symbol

Variable capacitors are mostly used in radio tuning circuits and they are sometimes called 'tuning capacitors'. They have very small capacitance values, typically between 100pF and 500pF (100pF = 0.0001µF). The type illustrated usually has trimmers built in (for making small adjustments - see below) as well as the main variable capacitor.

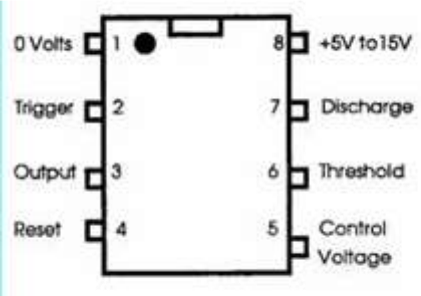
Variable capacitors are **not** normally used in timing circuits because their capacitance is too small to be practical and the range of values available is very limited. Instead timing circuits use a fixed capacitor and a variable resistor if it is necessary to vary the time period.

Trimmer capacitors (trimmers) are miniature variable capacitors. They are designed to be mounted directly onto the circuit board and adjusted only when the circuit is built.
A small screwdriver or similar tool is required to adjust trimmers. The process of adjusting them requires patience because the presence of your hand and the tool will slightly change the capacitance of the circuit in the region of the trimmer!
Trimmer capacitors are only available with very small capacitances, normally less than 100pF. It is impossible to reduce their capacitance to zero, so they are usually specified by their minimum and maximum values, for example 2-10pF.
Trimmers are the capacitor equivalent of presets which are miniature variable resistors.

Trimmer Capacitor Symbol

The MicroChip

Microchips are small electronic circuits that have many different components built onto a small piece of silicon (which is a semi-conductor) housed in a plastic case. These can be referred to as IC's (integrated circuits).



All IC's are usually set up in a DIL (Dual In Line) configuration, this is where there are two sets of parallel connections (the pins).

As you can be seen from the diagram to the left the I.C has a small circle, this normally identifies pin 1, and the remaining pins are numbered anticlockwise (as shown in the diagram).

The 555 Timer IC

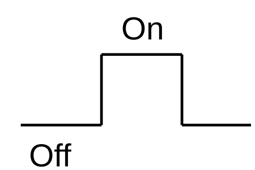
- These are cheap and come iin an 8-pin DIL pack.
- The main advantage of using this IC is that it can be used as both an astable and monostable timer.

It is possible to use discrete components such as resistors, capacitors, etc to achieve the same results as a 555 timer IC however it is more usual to use the 555 timer IC.

Monostable:

•This IC has only one stable state – this means that it remains off (logic 0) until triggered

•When a positive voltage is applied to the trigger, the output goes high (logic 1) for a time determined by the values of the resistor and capacitor – it then returns to its original state until triggered again.



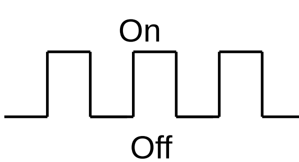
Possible use for this would be a burglar alarm, which once activated sounds for a set time.

Astable:

•This IC has no stable output – this means that it continually switched from low output (logic 0) to high output (logic 1).

•The astable generates a pulse, the time period of which is determined by the values of the resistors and capacitors used.

•The speed at which an astable switches on and off (or cycles) in one second is known as the frequency. The standard unit of frequency is Hertz (Hz). 1Hz = 1 Pulse per second. For example a computer processor may be 700 Mhz this means every second the processor switches from logic 0 to logic 1 700,000,000 times.



This IC would be ideal for a clock circuit.

Sinking Sourcing

Sinking and sourcing current

Chip outputs are often said to 'sink' or 'source' current. The terms refer to the direction of the current at the chip's output.

If the chip is sinking current it is flowing into the output. This means that a device connected between the positive supply (+Vs) and the chip output will be switched on when the output is low (0V).

If the chip is sourcing current it is flowing out of the output. This means that a device connec between the chips output and the negative supply (0V) will be switched on when the output high (+Vs).

It is possible to connect two devices to a chip output so that one is on when the output is low and the other is on when the output is high. This arrangement is used in the Level Crossing project to make the red LEDs flash alternately.
The maximum sinking and sourcing currents for a chips output are usually the same but there are some exceptions.