Chapter 12: Basic Electronics

Introduction
This document is not an in-depth presentation of the subject of electronics. Instead, it is intended to give you sufficient (empirical) knowledge of the subject to be able to understand, design and build simple circuits such as the control circuits used with the 'Free Energy' devices described in the later parts of this eBook.

Disclaimer
This material is provided for information purposes only. Should you decide to attempt construction of some device based on information presented here and injure yourself or any other person, I am not liable in any way. To clarify this; should you construct something in a heavy box and drop it on your toe, I am not liable for any injury you may sustain (you should learn to be more careful). If you attempt to construct some electronic circuit and burn yourself with the soldering iron, I am not liable. Also, I strongly recommend that unless you are expert in electronics, you do not construct any device using, or producing more than 30 Volts - high voltage circuits are extremely dangerous and should be avoided until you gain experience or can obtain the help and supervision of a person experienced in constructing high voltage circuits.

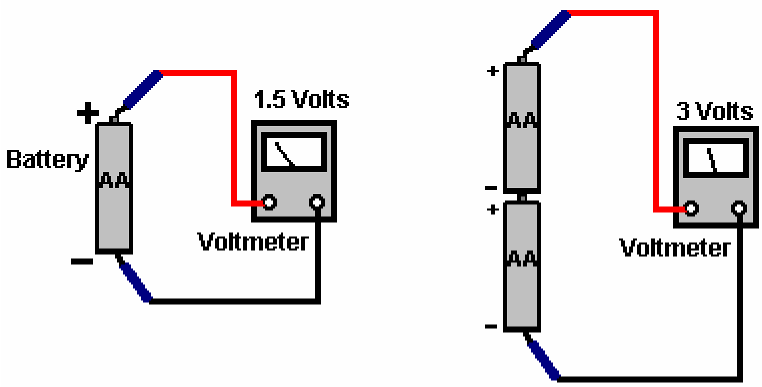
Voltage.
Voltage is the key to understanding electronics. Without voltage, nothing happens in electronics. What is it? Nobody knows. We know how to generate it. We know what it does. We know how to measure it, but nobody knows what it actually is.

It is also called "Electro Motive Force" or "EMF" which is no help whatsoever in knowing ***what*** it is. That, is roughly equivalent to saying "the thing that pushes is the thing that pushes" - very true but absolutely no help whatsoever. OK, having admitted that we really don't know *what* it is, we can start to say the things we do know about it:

A new battery has a voltage between its terminals. This voltage is said to cause a current to flow through any complete electrical circuit placed across it. The current flowing through the circuit can cause various things to happen such as creating light, creating sound, creating heat, creating magnetism, creating movement, creating sparks, etc., etc.

By using the current caused by a voltage, a device called a 'Voltmeter' can indicate how big the voltage is. The bigger the voltage, the bigger the current and the bigger the display on the voltmeter. The voltmeter can have a numerical display where you read the voltage directly from the display, or it can be an 'analogue' voltmeter where the voltage is shown by the position of a needle on a scale. The size of the voltage is stated in 'Volts' which is a unit of measurement named after the man Volta who introduced voltage to the world (it was always there, we just did not know about it).

Voltages add up if they are connected the same way round, i.e. with the + terminals all facing the same way:



The physical size of the battery usually determines the length of time it can supply any given current - the bigger the battery, the longer it can provide any given current. A battery is constructed from a number of 'cells'. The number of cells in the battery controls the voltage of the battery. For example, an 'AA' size battery (what used to be called a 'penlight' battery) has a single 'cell' and so produces 1.5 Volts when new. The very much larger and heavier 'D' battery also has just one cell and so it also produces 1.5 Volts when new. The difference (apart from the higher cost of the 'D' cell) is that the larger cell can provide a much higher current if both batteries are discharged over the same period of time.

There are several different types of battery construction. A rechargeable NiCad battery has a single cell but its construction method means that it produces about 1.35 Volts when fully charged. In passing, NiCad batteries have a ‘memory’ characteristic which means that if they are recharged before they are fully discharged, then the next time they are discharged they run out of power at the voltage level it had when the last charging was started. Consequently, it is a good idea to fully discharge a NiCad battery before charging it again.

Car and motorcycle batteries are described as Lead/Acid batteries. This type of construction is not very convenient being large, heavy and potentially corrosive. The big advantages are the ability to provide very high currents and giving 2.0 Volts per cell. These batteries are normally produced as 6 Volt or 12 Volt units. The Amp-Hours for lead/acid car batteries is usually quoted for a 20 hour discharge period, so a fully charged, new, 20 AHr battery can provide 1 Amp for 20 hours of continuous use. That battery loaded to give 5 Amps, will **not** provide that current for 4 hours but might only last 2 hours, or perhaps a little better. The manufacturers literature should give an indication of the performance, but if it is important, run your own test to see how the battery actually works in practice.

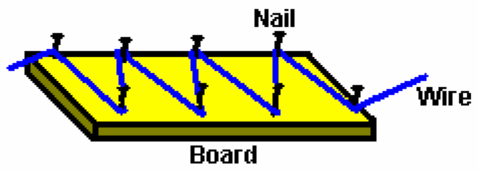
“Mains units” are known in the electronics world as “Power Supply Units” or “PSUs” for short. These convert the mains voltage (220 Volts in UK, 110 Volts in USA) to some convenient low voltage; 12 Volts, 9 Volts, 6 Volts, or whatever is needed. A mains unit can provide several different voltages simultaneously.

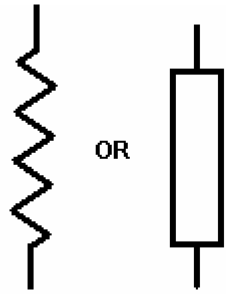
Resistance.

Being familiar with Voltage and Resistance is the key to understanding electronic circuitry. Resistance is a measure of how difficult it is for current to flow through something. Some materials such as glass, ceramics, wood and most plastics do not easily carry a current and so are considered to be ‘insulators’. That is why you will see power lines hung from their pylons by a series of ceramic discs. Current flows easily through metals, especially along the surface of the metal, so cables are made from metal wires surrounded by a layer of plastic insulation. The higher grade cables have wire cores made up of many small-diameter strands as this increases the surface area of the metal for any given cross-sectional area of the metal core (it also makes the cable more flexible, and generally, more expensive).

There is a very important, third group of materials, silicon and germanium in particular, which fall between conductors and insulators. Not surprisingly, these are called ‘semi-conductors’ and the amount of current they can carry depends on the electrical conditions in which they are placed. Much, much more about this later on.

While a metal wire carries current very well, it is not perfect at the job and so has some ‘resistance’ to current flowing through it. The thicker the wire, the lower the resistance. The shorter the wire, the lower the resistance. The first researchers used this characteristic to control the way circuits operated. Sometimes, as higher resistances were needed, the researcher used to need long lengths of wire which would get tangled up. To control the wire, a board with nails along each side was used and the wire wound backwards and forwards across the board like this:

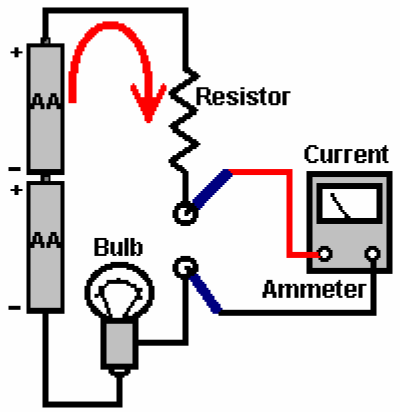


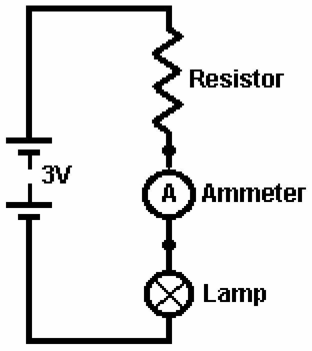


Resistor symbols

When drawing a circuit diagram, the researcher would sketch the wire on the board giving a zig-zag line which is still used today to represent a ‘resistor’ although different methods of construction are now used. An alternative symbol for a resistor is a plain rectangle as shown above.

If a resistor is connected across a battery, a circuit is formed and a current flows around the circuit. The current cannot be seen but that does not mean that it is not there. Current is measured in ‘Amps’ and the instrument used to display it is an ‘ammeter’. If we place an ammeter in the circuit, it will show the current flowing around the circuit. In passing, the ammeter itself, has a small resistance and so putting it in the circuit does reduce the current flow around the circuit very slightly. Also shown is a bulb. If the current flowing around the circuit is sufficiently high and the bulb chosen correctly, then the bulb will light up, showing that current is flowing, while the ammeter will indicate exactly how much current is flowing:





Circuit Diagram

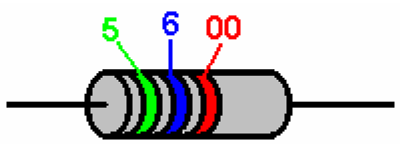
Shown on the right, is the way that this circuit would be shown by an electronics expert (the ‘Resistor’, ‘Ammeter’ and ‘Lamp’ labels would almost certainly not be shown). There are several different styles of drawing circuit diagrams, but they are the same in the basic essentials. One important common feature is that unless there is some very unusual and powerful reason not to do so, every standard style circuit diagram will have the positive voltage line horizontally at the top of the diagram and the negative as a horizontal line at the bottom. These are often referred to as the positive and negative ‘rails’. Where possible, the circuit is drawn so that its operation takes place from left to right, i.e. the first action taken by the circuit is on the left and the last action is placed on the right.

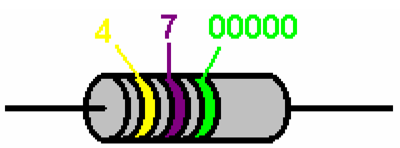
Resistors are manufactured in several sizes and varieties. They come in ‘fixed’ and ‘variable’ versions. The most commonly used are the ‘fixed’ carbon ‘E12’ range. This is a range of values which has 12 resistor values which repeat: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and then: 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820 and then: 1000, 1200, 1500, 1800, 2200, 2700, 3300, 3900, 4700, 5600, 6800, 8200, etc. etc. Nowadays, circuits often carry very little power and so the resistors can, and are, made in very small physical sizes. The higher the resistance value of a resistor, the less current will flow through it when a voltage is placed across it. As it can be difficult to see printing on small resistors clustered together on a circuit board and surrounded by other larger components, the resistor values are not written on the resistors, instead, the resistors are colour-coded. The unit of measurement for resistors is the ‘ohm’ which has a very small size. Most resistors which you encounter will be in the range 100 ohms to 1,000,000 ohms. The higher the resistance of any resistor, the smaller the current which will flow through it.

The colour code used on resistors is:

0 Black
1 Brown
2 Red
3 Orange
4 Yellow
5 Green
6 Blue
7 Purple (Violet if your colour vision is very good)
8 Grey
9 White

Each resistor has typically, three colour bands to indicate its value. The first two bands are the numbers and the third band is the number of noughts:





Green: 5
Blue: 6
Red: 2 noughts
Value: 5,600 ohms or 5.6K or 5K6

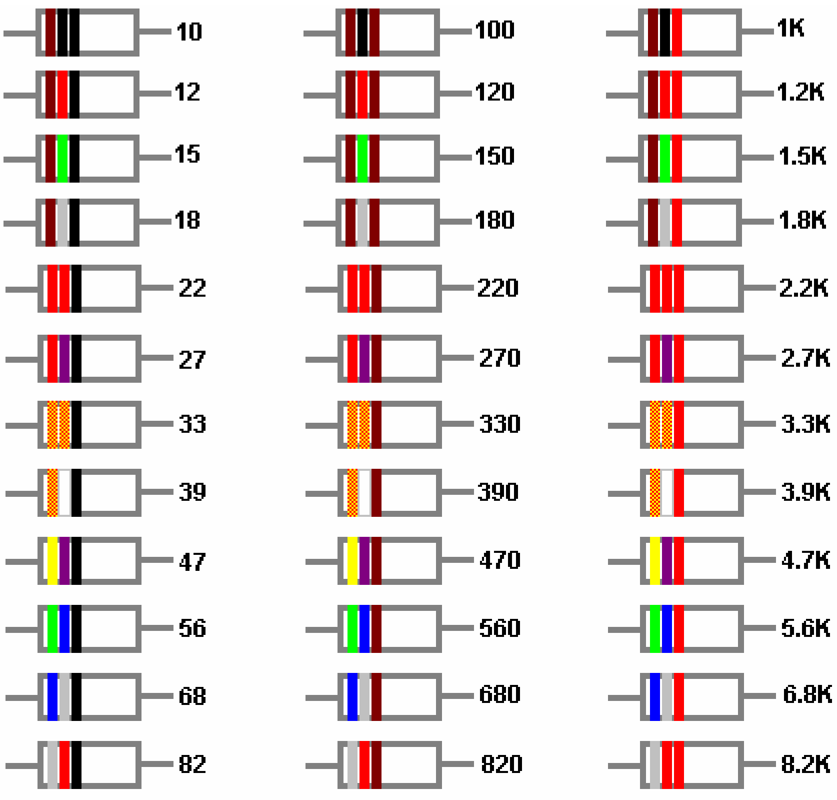
Yellow: 4
Purple: 7
Green: 5 noughts
Value: 4,700,000 ohms or 4.7M or 4M7

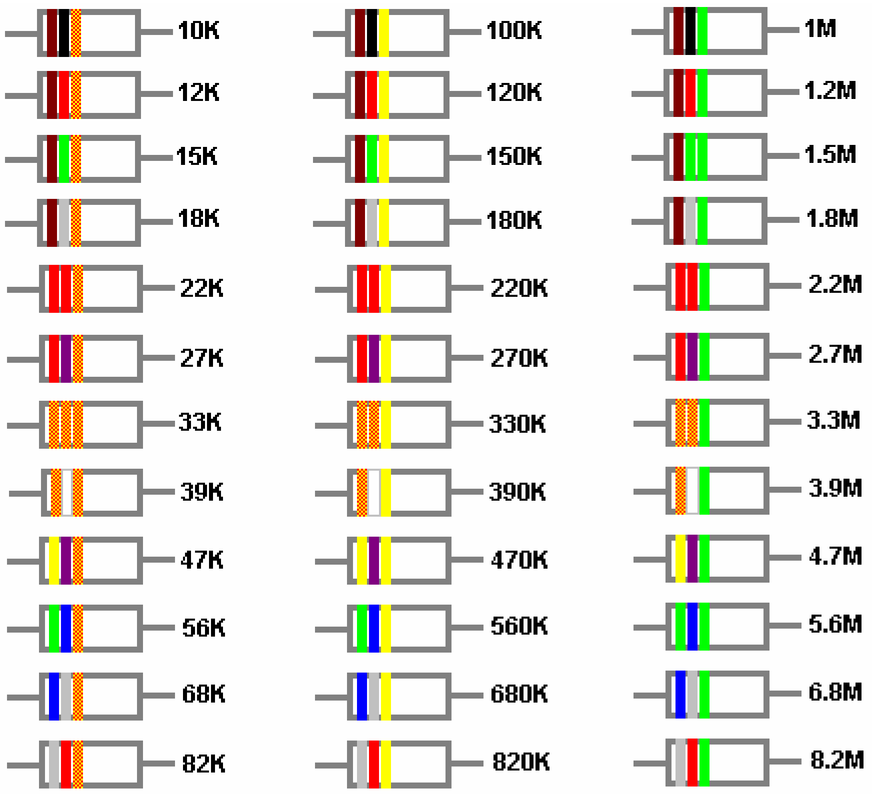
The colour bands are read from left to right and the first band is close to one end of the body of the resistor. There is often a fourth band which indicates the manufacturing tolerance: you can ignore that band.

Examples:

Red, Red, Red: 2 2 00 ohms or 2K2
Yellow, Purple, Orange: 4 7 000 ohms or 47K
Brown, Black, Brown: 1 0 0 ohms or 100R
Orange, Orange, Orange: 3 3 000 ohms or 33K
Brown, Green, Red: 1 5 00 ohms or 1K5
Brown, Green, Black: 1 5 no noughts, or 15 ohms
Blue, Grey, Orange: 6 8 000 ohms or 68K
Brown, Green, Green: 1 5 00000 ohms or 1,500,000 ohms or 1M5
Yellow, Purple, Brown: 4 7 0 ohms

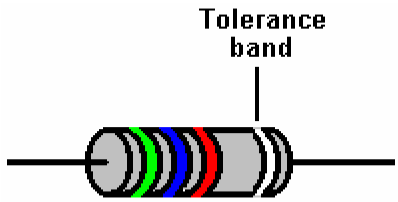
As there are only 12 standard resistor values per decade, there are only 12 sets of the first two colour bands:
10: Brown/Black,
12: Brown/Red,
15: Brown/Green,
18: Brown/Grey
22: Red/Red,
27: Red/Purple
33: Orange/Orange,
39: Orange/White
47: Yellow/Purple
56: Green/Blue
68: Blue/Grey
82: Grey/Red





Black = 0 or None, Brown = 1, Red = 2, Orange = 3, Yellow = 4,
Green = 5, Blue = 6, Purple = 7, Grey = 8, White = 9

The details above give you all the basic information on resistor colour codes but there are a few additional refinements. There is an extra colour band further down the body of the resistor as shown here:

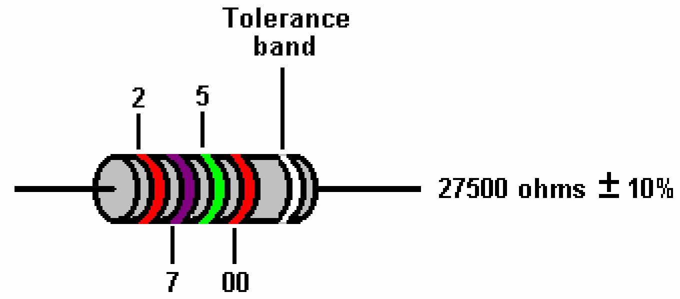


This extra band is used to indicate the manufacturing tolerance of the construction of the resistor. Resistor values are never exact and this rarely has any significant effect on their use in circuits. If some circuit needs very accurate resistor values in it, then buy several resistors of the same nominal value and use an ohm-meter to measure that actual value of each particular resistor and if none are perfect, then use two or more resistors to give the exact value wanted.

The tolerance band has the following codes:

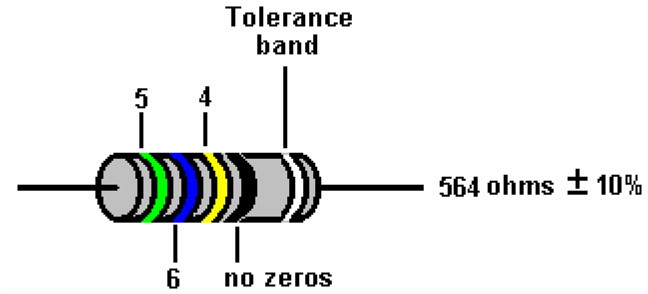
Silver is ± 10% (i.e. a 10K resistor of this type should be between 9K and 11K)
Gold ± 5% (i.e. a 10K resistor of this type should be between 9.5K and 10.5K)
Red ± 2% (i.e. a 10K resistor of this type should be between 9.8K and 10.2K)
Brown ± 1% (i.e. a 10K resistor of this type should be between 9.9K and 10.1K)
Green ± 0.5% (i.e. a 10K resistor of this type should be between 9.95K and 10.05K)
Blue ± 0.25% (i.e. a 10K resistor of this type should be between 9.975K and 10.025K)
Purple ± 0.1% (i.e. a 10K resistor of this type should be between 9.99K and 10.01K)

This type of resistor in the 10% and 5% ranges are the most common as they are the cheapest to buy and so tend to be the most popular. Recently, however, two additions to the coding have been introduced in order to allow for very high specification resistors which the average constructor may never come across. Each of these additions involves one additional colour band. The first additional colour band allows an extra digit in the resistor value, and looks like this:



As before, the colour coding is exactly the same, with the fourth colour band specifying the number of zeros after the digits indicated by the colour bands in front of it. So, in the example shown above, the first band being Red indicates a "2". The second colour band being Purple indicates a "7". The third colour band being Green indicates a "5" and the fourth colour band being Red indicates "2 zeros", so putting those together it produces the value of 27,500 ohms, which can also be written as 27.5 K or more briefly as 27K5.

Another example of this is:

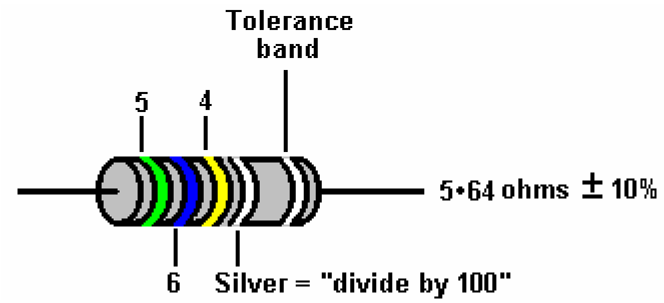


The fourth colour band coding has also been extended to include two other colours:

Gold: meaning "no zeros and divided by 10" so if the band in the example above had been gold, then the value would be 56.4 ohms.

Silver: meaning "no zeros and divided by 100" and if the example band had been silver then the value would have been 5.64 ohms.

So, for example, if the resistor had a fourth colour band which was silver, then the value would be:

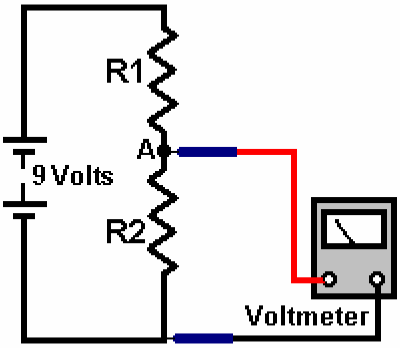


Finally, for very high-quality applications (typically military applications), there can be a sixth colour band positioned outside the tolerance band, and that final colour band states how much the resistance value can be expected to alter with changes in temperature. This is not something which is likely to be of any interest to you, but the codes for that final colour band are:

Brown: 0.01% of the resistor value for each degree Centigrade change in temperature.
Red: 0.005% of the resistor value for each degree Centigrade change in temperature.
Yellow: 0.0025% of the resistor value for each degree Centigrade change in temperature.
Orange: 0.0015% of the resistor value for each degree Centigrade change in temperature.

To put this in context, the worst of these represents a change of 1% in the resistor value when moving from the temperature of ice to the temperature of boiling water. Is this something which you really care about? I don't.

Leaving the details of identifying individual resistors, we now come to the interesting part: what happens when there are several resistors in a circuit. The important thing is to keep track of the voltages generated within the circuit. These define the currents flowing, the power used and the way in which the circuit will respond to external events. Take this circuit:



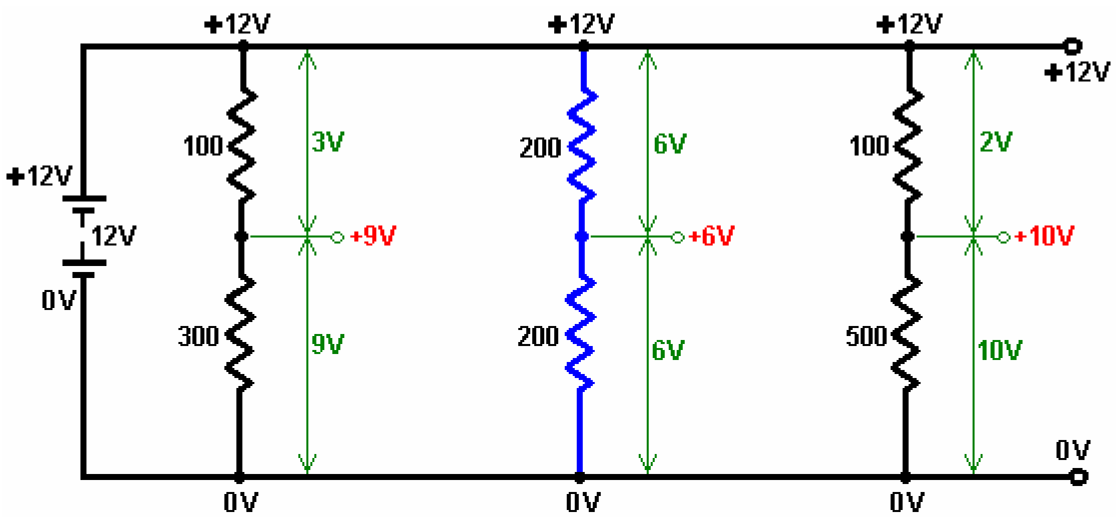
What is the voltage at point ‘A’? If you feel like saying “Who cares?” then the answer is “you” if you want to understand how circuits work, because the voltage at point ‘A’ is vital. For the moment, ignore the effect of the voltmeter used to measure the voltage.

If R1 has the same resistance as R2, then the voltage at ‘A’ is half the battery voltage, i.e. 4.5 Volts. Half the battery voltage is dropped across R1 and half across R2. It does not matter what the actual resistance of R1 or R2 is, as long as they have exactly the same resistance. The higher the resistance, the less current flows, the longer the battery lasts and the more difficult it is to measure the voltage accurately.

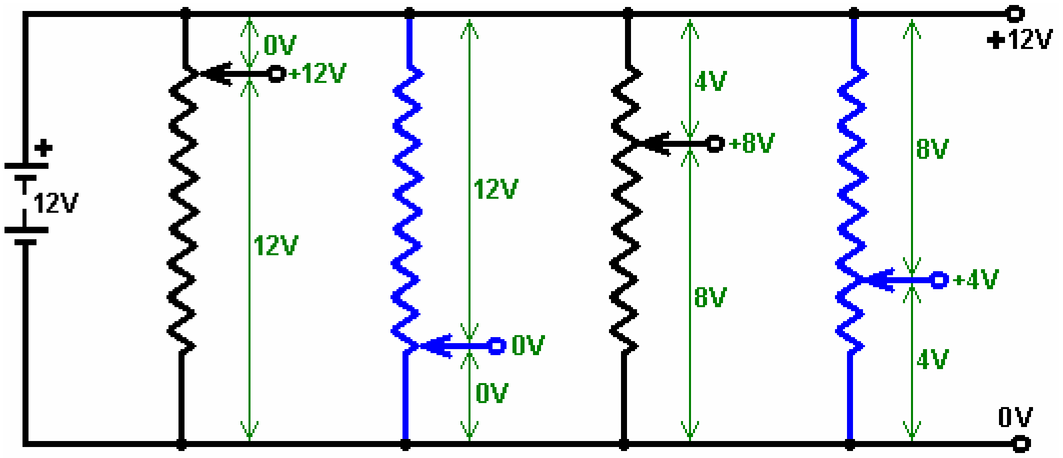
There is no need to do any calculations to determine the voltage at point “A” as it is the ratio of the resistor values which determines the voltage. If you really want to, you can calculate the voltage although it is not necessary. The method for doing this will be shown you shortly. For example, if R1 and R2 each have a value of 50 ohms, then the current flowing through them will be 9 volts / 100 ohms = 0.09 Amps (or 90 milliamps). The voltage drop across R1 will be 50 ohms = Volts / 0.09 amps or Volts = 4.5 volts. Exactly the same calculation shows that the voltage across R2 is exactly 4.5 volts as well. However, the point to be stressed here is that it is the **ratio** of R1 to R2 which controls the voltage at point “A”.

If R1 has half as much resistance as R2, then half as much voltage is dropped across it as is dropped across R2, i.e. 3 Volts is dropped across R1, giving point ‘A’ a voltage of 6 Volts and that is what the voltmeter will show. Again, it does not matter what the actual value of R1 is in ohms, so long as R2 has exactly twice the resistance (shown by a higher number on the resistor).

If R1 has twice as much resistance as R2, then twice as much voltage is dropped across it as is dropped across R2, i.e. 6 Volts is dropped across R1, giving point ‘A’ a voltage of 3 Volts. Here are some examples with different resistors:

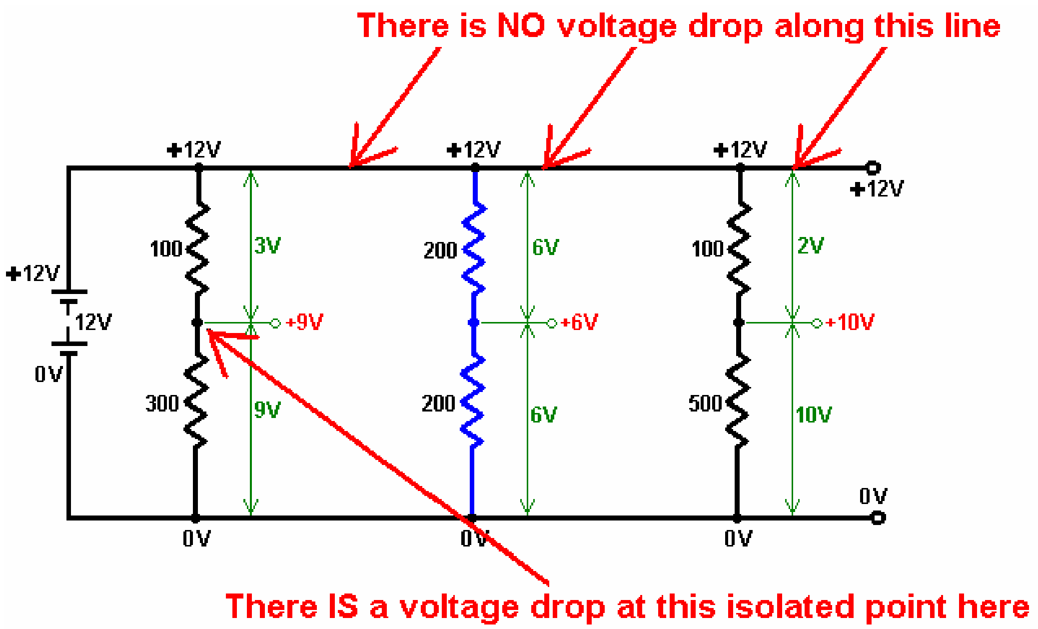


The same division of the supply voltage can be produced by positioning the slider of a variable resistor at different points by rotating the shaft of the device:



This determination of the voltage levels is the key factor to understanding electronic circuitry. The voltage levels control what currents flow and how every circuit will perform, so it is essential to understand what is happening. Stick with this section until you understand it, and if necessary, ask questions about what you find difficult.

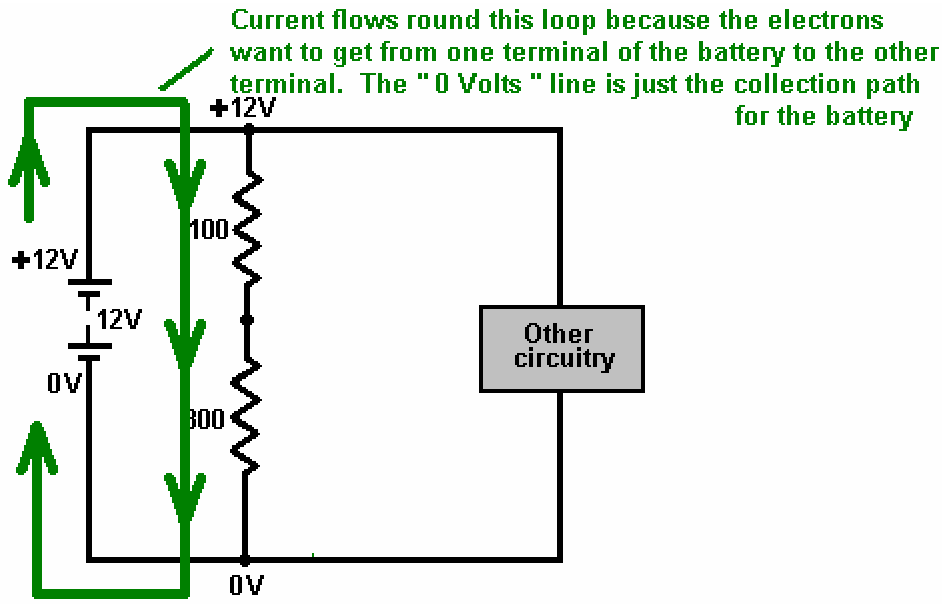
First, please understand that a good battery is an unlimited source of voltage and that voltage does not get "used up" when a resistor or whatever is connected across it:



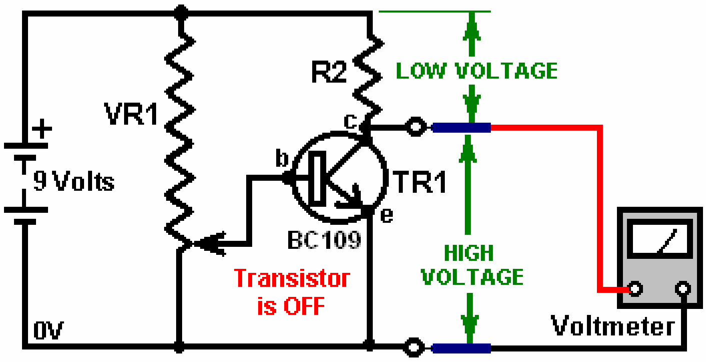
There can be some difficulty in understanding the "0-volt" connection in a circuit. All this means is that it is the return line for current flowing from the battery. Most conventional circuits are connected to both sides of the battery and that allows a current to flow around a closed "circuit" from one terminal of the battery to the other terminal.

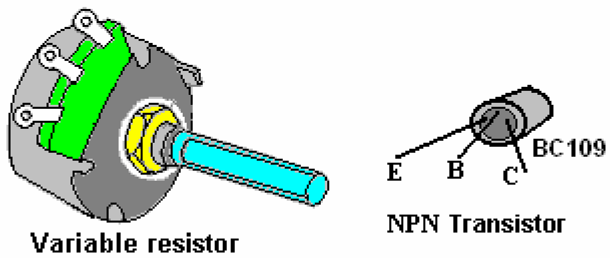
It is normal practice to draw a circuit diagram so that the Plus terminal of the battery is at the top and the minus terminal is at the bottom. Many circuit diagrams show the negative line at the bottom connected to the ground or an "earth" connection, which is literally a metal rod driven into the ground to make a good electrical connection to the ground. This is done because the Earth is literally a vast reservoir of negative electricity. However, in reality, most circuits are not connected directly to the Earth in any way. The standard circuit diagram can be visualised as being like a graph of voltage, the higher up the diagram, the higher the voltage.

Anyway, when there is a circuit connected across the battery, the negative or "0V" line just indicates the return path to the battery for the current flow:



This principle applies immediately to the following circuit:

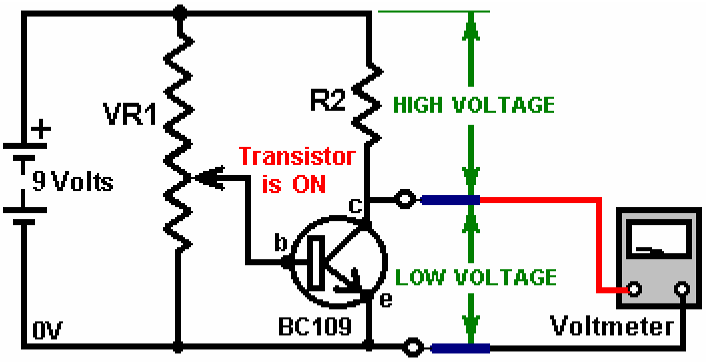




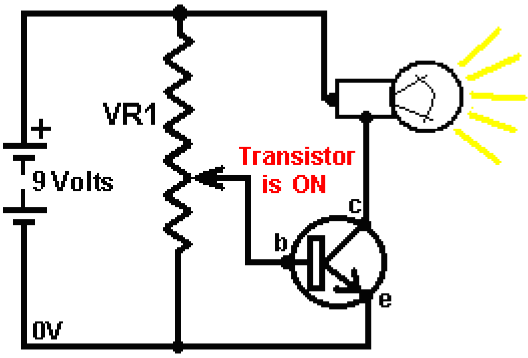
Here we encounter two new components. The first is 'VR1' which is a variable resistor. This device is a resistor which has a slider which can be moved from one end of the resistor to the other. In the circuit above, the variable resistor is connected across the 9 Volt battery so the top of the resistor is at +9 Volts (relative to the battery Minus terminal) and the bottom is at 0 Volts. The voltage on the slider can be adjusted from 0 Volts to 9 Volts by moving it along the resistor by turning the shaft of the component (which normally has a knob attached to it).

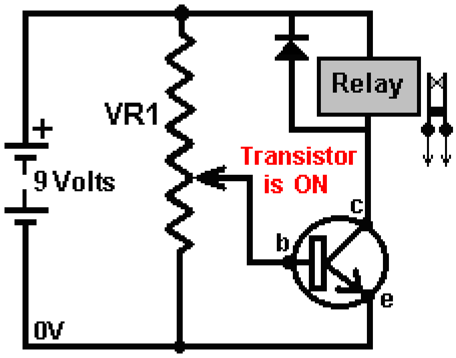
The second new device is 'TR1' a transistor. This semiconductor has three connections: a **C**ollector, a **B**ase and an **E**mitter. If the voltage on the base is below 0.7 volts, then the transistor is said to be "OFF" and in that state it has a very high resistance between the collector and the emitter, much higher than the resistance of resistor "R2". The voltage dividing mechanism just discussed means that the voltage at the collector will therefore, be very near to 9 Volts - caused by the **ratio** of the transistor's **C**ollector/**E**mitter resistance compared to the resistor "R2".

If the voltage on the base of the transistor is raised to 0.7 volts by moving the slider of the variable resistor slowly upwards, then this will feed a small current to the base which then flows out through the emitter, switching the transistor ON causing the resistance between the collector and the emitter to drop instantly to a very low value, much, much lower than the resistance of resistor 'R2'. This means that the voltage at the collector will be very close to 0 Volts. The transistor can therefore be switched on and off just by rotating the shaft of the variable resistor:



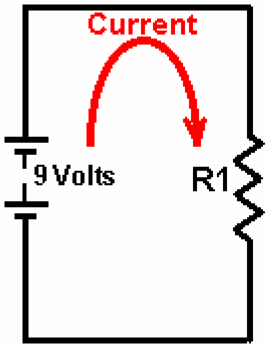
If a bulb is used instead of R2, then it will light when the transistor switches on. If a relay or opto-isolator is used, then a second circuit can be operated:





If a buzzer is substituted for R2, then an audible warning will be sounded when the transistor switches on. If a light-dependent resistor is substituted for VR1, then the transistor will switch on when the light level increases or decreases, depending on how the sensor is connected. If a thermistor is used instead of VR1, then the transistor can be switched on by a rise or fall in temperature. The same goes for sound, wind speed, water speed, vibration level, etc. etc. - more of this later.

We need to examine the resistor circuit in more detail:



We need to be able to calculate what current is flowing around the circuit. If the circuit contains only resistors, then this can be done using "Ohms Law" which states that "Resistance equals Voltage divided by Current" or, if you prefer:

Ohm's Law (resistive Circuits only).

"**Ohms = Volts / Amps**" which indicates the units of measurement.

In the circuit above, if the voltage is 9 Volts and the resistor is 100 ohms, then by using Ohm's Law we can calculate the current flowing around the circuit as 100 Ohms = 9 Volts / Amps, or Amps = 9 / 100 which equals 0.09 Amps. To avoid decimal places, the unit of 1 milliamp is used. There are 1000 milliamps in 1 Amp. The