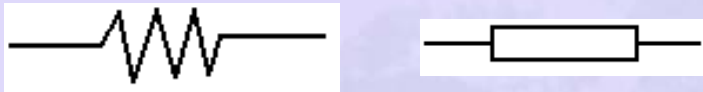


PASSIVE COMPONENTS

RESISTORS

To oppose the flow of electrons (current). The symbols are shown below.



Resistance is measured in units called “Ohm”. 1000 ohms is shown as 1k ohm (10^3 ohm) and 1000 k ohm is shown as M.ohms (10^6 ohm).

Resistors can be broadly of two types.

- *Fixed* Resistors and *Variable* Resistors.

Fixed Resistors:

Carbon Film (5%, 10% tolerance) and Metal Film Resistors (1%,2% tolerances) and wire wound resistors. A fixed resistor is one for which the value of its resistance is specified and cannot be varied in general.

Resistance Value

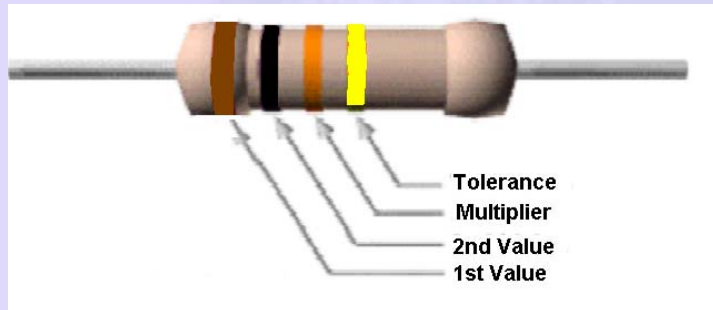
The resistance value is displayed using the color code (the colored bars/the colored stripes), because the average resistor is too small to have the value printed on it with numbers. The resistance value is a discrete value. For example, the values [1], [2.2], [4.7] and [10] are used in a typical situation.

COLOR CODING

Example 1:

(Brown=1),(Black=0),(Orange=3)

$10 \times 10^3 = 10\text{k ohm}$; Tolerance(Gold) = $\pm 5\%$



Resistor Color Codes

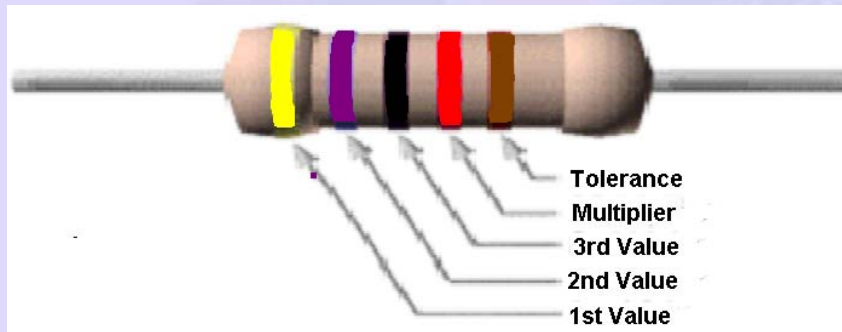
<i>Color</i>	<i>Value</i>	<i>Multiplier</i>	<i>Tolerance (%)</i>
Black	0	0	-
Brown	1	1	<u>+1</u>
Red	2	2	<u>+2</u>
Orange	3	3	<u>+0.05</u>
Yellow	4	4	-
Green	5	5	<u>+0.5</u>
Blue	6	6	<u>+0.25</u>
violet	7	7	<u>+0.1</u>
Gray	8	8	-
White	9	9	-
Gold	-	-1	<u>+5</u>
Silver	-	-2	<u>+10</u>
None	-	-	<u>+20</u>

RESISTORS

Example 2:

(Yellow=4),(Violet=7),(Black=0),(Red=2)

$470 \times 10^2 = 47\text{k ohm}$; Tolerance(Brown) = $\pm 1\%$



Tolerance of the resistor is also an important property to consider. A 100Ω resistor with 10% tolerance, means that its value can be any fixed value between 90 to 110 ohms. A 120Ω resistor with 10% tolerance, means that its value can be any fixed value between 108 to 132 ohms. Thus the upper tolerance limit (110) of the lower value (100) and the lower tolerance limit (108) of the upper value (120) overlap.

Hence a resistor with value between 100 to 120 ohms can be obtained from either of the two sets of 100 or 120 ohms. Similarly a resistor with value between 120 to 150 ohms can be obtained from either

of the two sets of 120 or 150 ohms. Resistor values for manufacturing under 10% tolerance are chosen such that the upper limit of the lower value and the lower limit of the upper value overlap.

This leads to the preferred set of values shown in the table (E12).

<i>E12 series</i>	<i>E24 series</i>
10% tolerance 10	5% tolerance 10
	11
12	12
	13
15	15
	16
18	18
	20
22	22
	24
	27
	30
33	33
	36
	39
39	43
	47
47	47
	51
	56
56	56
	62
68	58
	75
82	82
	91

Resistors are made in multiples of these values, for example, 1.2, 12, 120, 1.2k, 12k, 120k and so on.

CARBON FILM RESISTORS

This is the most general purpose, cheap resistor. Usually the tolerance of the resistance value is $\pm 5\%$. Power ratings of 1/8W, 1/4W and 1/2W are frequently used. The disadvantage of using carbon film resistors is that they tend to be electrically noisy.

RESISTORS



METAL FILM RESISTORS

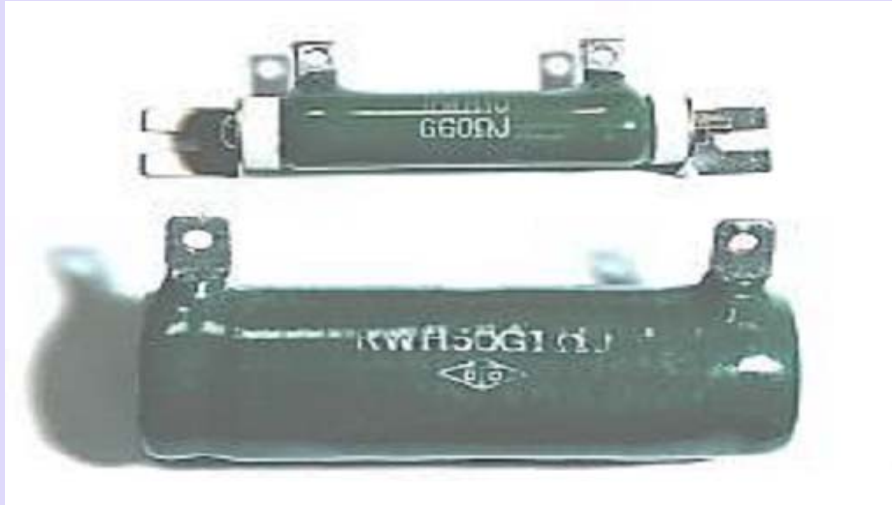
Metal film resistors are used when a higher tolerance (more accurate value) is needed. Nichrome (Ni-Cr) is generally used for the material of resistor. They are much more accurate in value than carbon film resistors. They have about $\pm 0.05\%$ tolerance.

RESISTORS



OTHER RESISTORS

There is another type of resistor called the wire wound resistor. A wire wound resistor is made of metal resistance wire, and because of this, they can be manufactured to precise values. Also, high-wattage resistors can be made by using a thick wire material. Wire wound resistors cannot be used for high-frequency circuits.



Ceramic Resistor

Another type of resistor is the Ceramic resistor. These are wire wound resistors in a ceramic case, strengthened with a special cement. They have very high power ratings, from 1 or 2 watts to dozens of watts. These resistors can become extremely hot when used for high power applications, and this must be taken into account when designing the circuit.

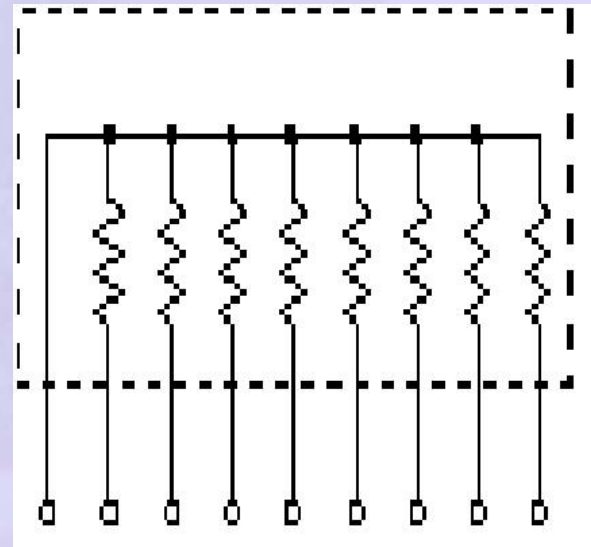
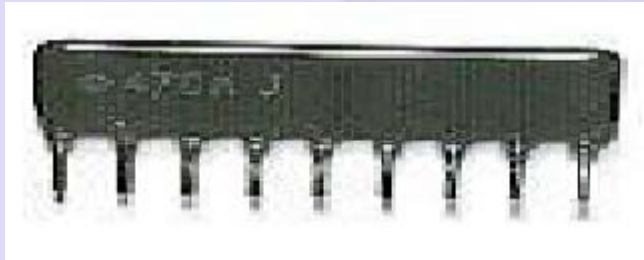
RESISTORS



SINGLE-IN LINE NETWORK RESISTORS

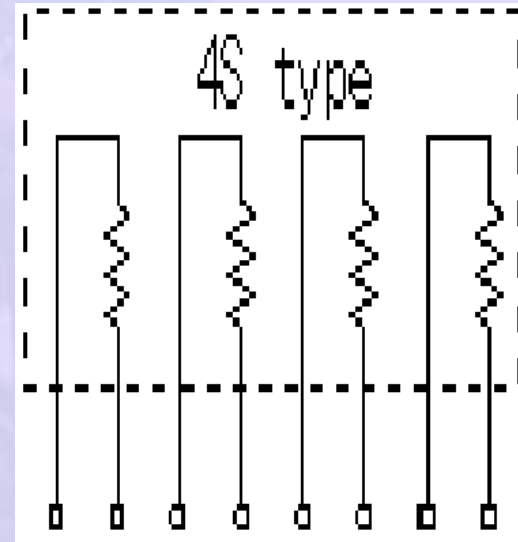
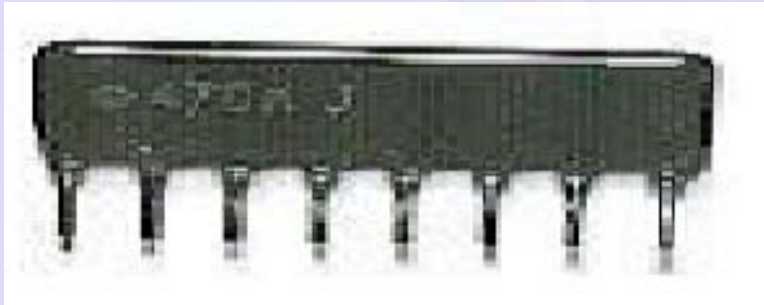
It is made with many resistors of the same value, all in one package. One side of each resistor is connected with one side of all the other resistors inside. One example of its use would be to control the current in a circuit powering many light emitting diodes (LEDs). The face value of the resistance is printed.

In the photograph below, 8 resistors are housed in the package. Each of the leads on the package is one resistor. The ninth lead on the left side is the common lead.



4S-RESISTOR NETWORK

The 4S indicates that the package contains 4 independent resistors that are not wired together inside. The housing has eight leads instead of nine.



VARIABLE RESISTORS

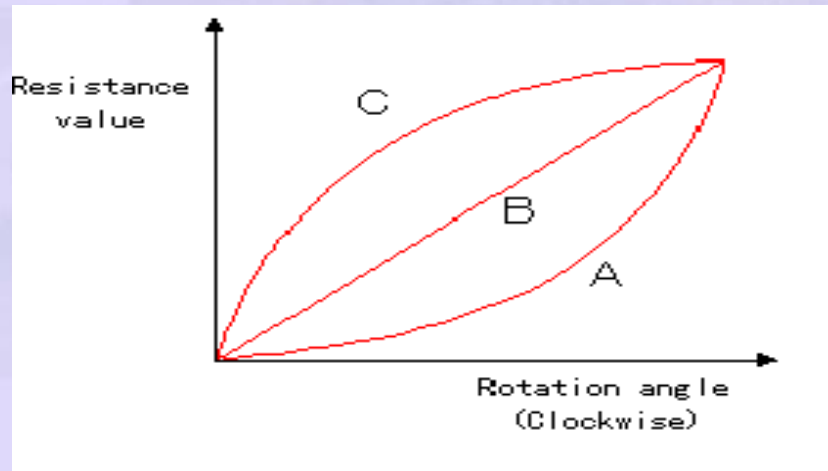
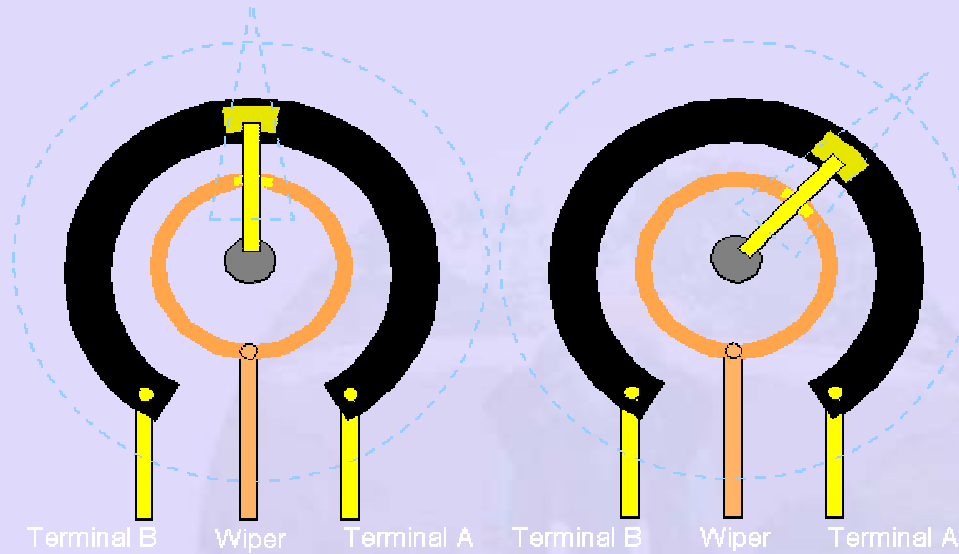
There are two general ways in which variable resistors are used. One is the variable resistor whose value is easily changed, like the volume adjustment of Radio. The other is semi-fixed resistor that is not meant to be adjusted by anyone but a technician. It is used to adjust the operating condition of the circuit by the technician.

Semi-fixed resistors are used to compensate for the inaccuracies of the resistors, and to fine-tune a circuit. The rotation angle of the variable resistor is usually about 300 degrees. Some variable resistors must be turned many times(multi-turn Pot) to use the whole range of resistance they offer. This allows for very precise adjustments of their value. These are called "Potentiometers" or "Trimmer Potentiometers" or "presets".

The four resistors at the center are the semi-fixed type. The two resistors on the left are the trimmer potentiometers



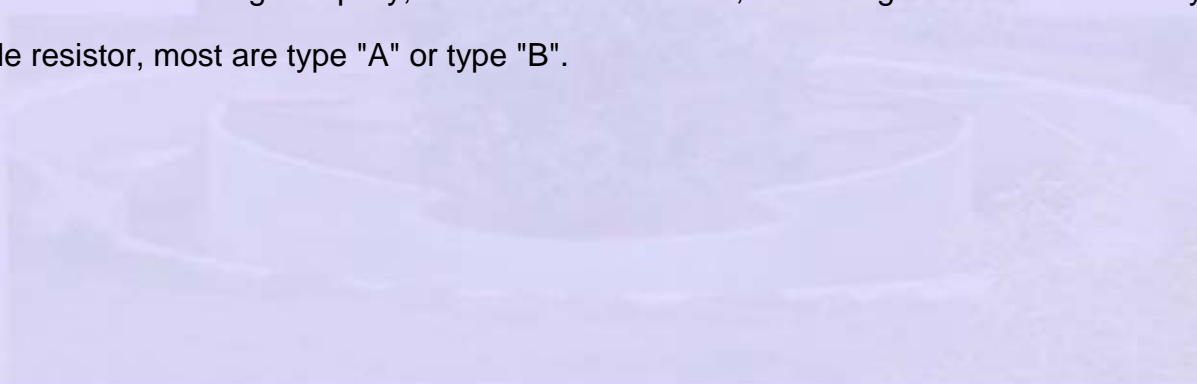
RESISTORS



There are three ways in which a variable resistor's value can change according to the rotation angle of its axis. When type "A" rotates clockwise, at first, the resistance value changes slowly and then in the second half of its axis, it changes very quickly. It is well suited to adjust a low sound subtly. They are sometimes called "audio taper" potentiometers.

Type "B" the rotation of the axis and the change of the resistance value are directly related. The rate of change is the same, or linear, throughout the sweep of the axis. This type suits a resistance value adjustment in a circuit, a balance circuit and so on. They are sometimes called "linear taper" potentiometers.

Type "C" changes exactly the opposite way to type "A". In the early stages of the rotation of the axis, the resistance value changes rapidly, and in the second half, the change occurs more slowly. As for the variable resistor, most are type "A" or type "B".

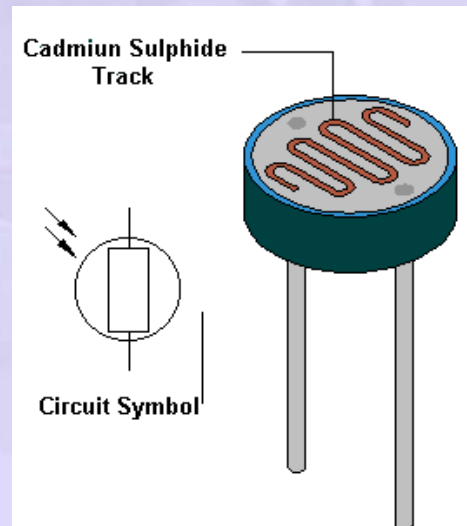


TYPES OF RESISTORS

LIGHT DEPENDENT RESISTANCE (LDR)

Some components can change resistance value by changes in the amount of light falling on them. One type is the Cadmium Sulfide Photocell. It is a kind of resistor, whose value depends on the amount of light falling on it. When in darkness its resistance is very large and as more and more light falls on it its resistance becomes smaller and smaller.

There are many types of these devices. They vary according to light sensitivity, size, resistance value etc.



Its diameter in a typical case is 8 mm, 4 mm high, with a cylinder form. When bright light is hitting it, the value is about 200 ohms, and when in the dark, the resistance value is about 2M ohms.



THERMISTOR

They are thermally sensitive resistor. The resistance value of the thermistor changes according to temperature. They are used as a temperature sensor. There are generally two types of thermistors, with

→ Negative Temperature Coefficient (NTC)

→ Positive Temperature Coefficient (PTC)

The resistance of NTC thermistors decreases on heating while that of PTC thermistors increases.



The relation between the temperature and the resistance value of the NTC type can be calculated using the following formula.

$$R = R_0 \cdot e^{\beta \left(\frac{1}{T} - \frac{1}{T_0} \right)}$$

R is The resistance value at the temperature T[K]; R_0 is the resistance value at the reference temperature T_0 [K]; and B is a coefficient. When current flows through R heat is produced (Joule's heat). This heat, when in excess, can damage the resistor. Hence there is a maximum power rating for resistors. The power rating indicates how much power the resistor can safely tolerate. The maximum rated power of the resistor is specified in Watts. Power is calculated using the square of the current (I^2) x the resistance value (R) of the resistor. Resistors in electronic circuits are typically rated as 1/8W, 1/4W, and 1/2W. When powering a LED, for example, a comparatively large current flows through the resistor, so we need to consider the power rating of the resistor we choose.

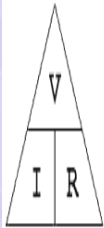
ELECTRIC POWER RATING

For example, to power a 5V circuit using a 12V supply, using only a resistor, then we need to calculate the power rating of the resistor as well as the resistance value. The current consumed by the 5V circuit needs to be known.

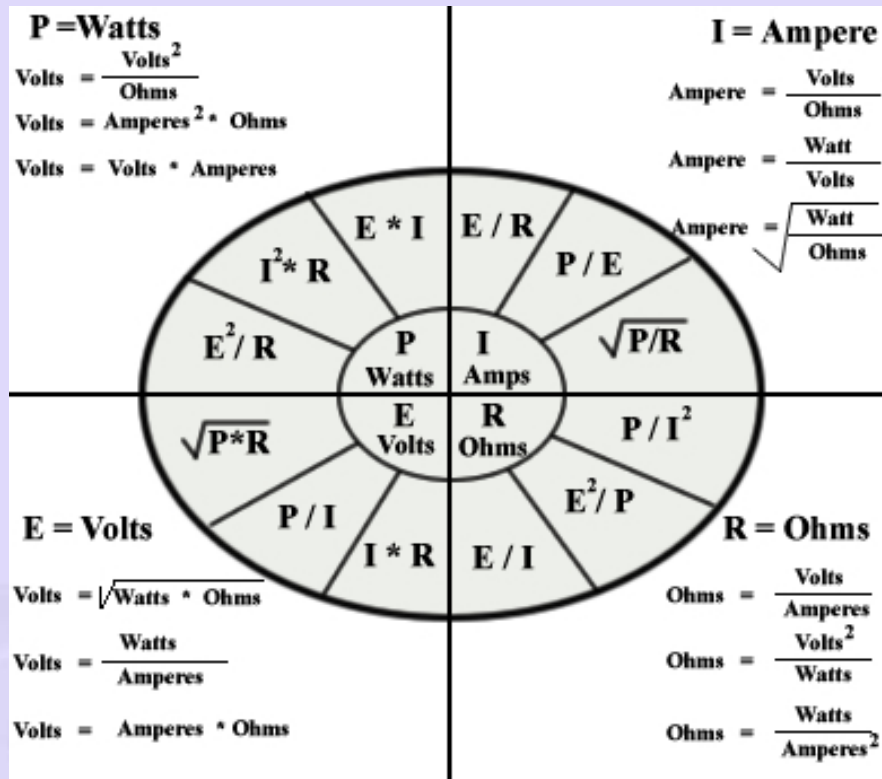
Assume the current consumed is 100 mA (milliamps) in the above example. That means 7V (=12-5 V) must be dropped with the resistor. The resistance value of the resistor becomes $7V / 0.1A = 70(\text{ohm})$. The consumption of electric power for this resistor becomes $0.1A \times 0.1A \times 70 \text{ ohm} = 0.7W$. Thus the selection of resistors depends on two factors namely tolerance and electric power ratings.

OHM'S LAW

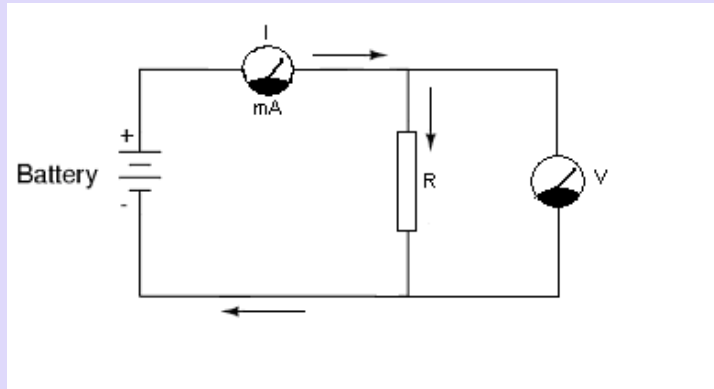
Important and useful law. The current (I) flowing through a conductor is proportional to the voltage (V) applied across its ends. This can be written in algebraic form as $V \propto I$ Or $V = IR$ where R is the proportionality constant. R is called Resistance and is measured in 'Ohms' (Ω) after the scientist George Simon Ohm. Usually resistors are also specified in circuits in kilo Ohms($k\Omega$) and Mega Ohms($M\Omega$). The other useful relationships are $V = RI$, and $R=V/I$.


$$V = I \times R \quad I = \frac{V}{R} \quad R = \frac{V}{I}$$

USEFUL RELATIONSHIPS



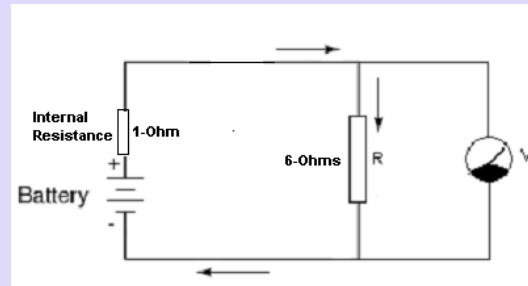
OHM'S LAW CIRCUIT



IDEAL VOLTAGE SOURCE

Every voltage source (power supply, battery, etc.) has its own resistance due to its internal construction. Of course this will generally be small of the order of few Ohms only. Still this internal resistance can cause difficulty in circuits as we shall see now.

Assume a 6V battery connected to a resistance of (a) 6Ω and (b) 1Ω . What would be the current according to Ohm's law? It will be $[6V/6\Omega] = 1A$ in the first case and $[6V/1\Omega] = 6A$ in the second case. OK? However, if you actually measured the current you would find the currents would not be these values.



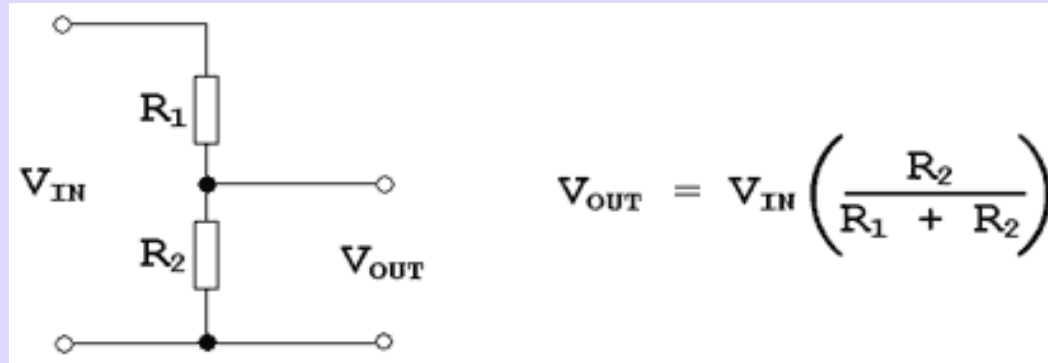
In a typical case, these currents were 0.86 and 3A only instead of 1A and 6A! The reason is, the battery had an internal resistance of 1Ω . Hence the currents in the two cases are $[6V/(6+1)\Omega] = 0.86A$ and $[6V/(1+1)\Omega] = 3A$. The voltages across the internal resistance are 0.86V and 3V and the voltages across the load resistance are 5.14V and 3V in the two cases respectively. So when you draw more current from the battery, the drop in the internal resistance is also more and hence only less voltage is available across the load. But ideally we wish the voltage applied across the load must always be 5V. This will happen when the internal resistance of the battery or any voltage source becomes ZERO!

IDEAL VOLTAGE SOURCE

Hence an ideal voltage source is characterised by ZERO INTERNAL RESISTANCE! When we say we want to regulate a power supply we really mean to reduce its effective internal resistance to as small a value as possible. Of course, there are no ideal voltage sources. But one can get sources which are very close to ideal behaviour.

Voltage Dividers

Resistors can also be used to determine voltages, in a configuration called a voltage divider.



The ratio of R_1 to R_2 determines V_{OUT} , allowing any voltage within V_{IN} to be obtained. Logically, if R_1 and R_2 are equal V_{OUT} will be exactly half of V_{IN} . Although the ratio between the two resistors is what determines the output, some thought should be given to actual values chosen.

If we look at the circuit we will see that current must pass through R_1 in order to reach V_{OUT} , thus R_1 determines the current available at V_{OUT} . (use ohms law to determine this current) . Because the desired ratio must be maintained to obtain the correct V_{OUT} , reducing R_1 to increase available current means we must also reduce R_2 .

In the above circuit R_1 and R_2 will allow a certain amount of current to flow across V_{IN} to no useful purpose. (ie. it is wasted). Furthermore, if the current flowing through the voltage divider is too large it will lower V_{OUT} . (just like fast current flow in a water pipe results in low static pressure) In short, we

cannot draw large amounts of current through a voltage divider and should therefore use resistors greater than say, 1Kohm. (larger at higher voltages)

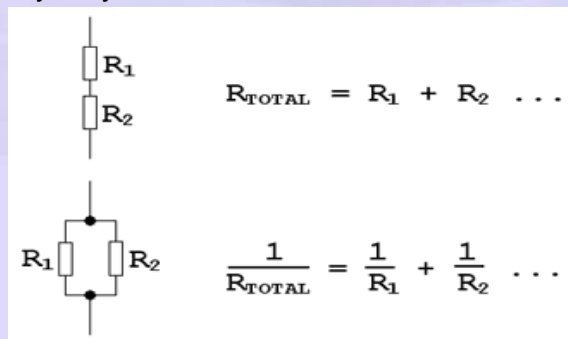
Voltage Divider Application:

More interesting results can be achieved if one (or both) of the resistors are replaced with a variable resistor. The circuit shown net is a very basic light activated switch which makes use of variable resistors in voltage dividers.

Other Resistor Configurations:

Some resistors are not available in any value we might happen to calculate, and those values which are available are often not close enough. In such cases we have two options; use a trim-pot (a small adjustable resistor) or combine two or more resistors to get the required value.

Trim-pots are too expensive to use for every case, but resistor combinations can cost as little as 15c but require some time with a calculator, rather than a precision screwdriver. Below are the two basic combinations of resistors, or any passive component for that matter. Series or parallel. These simple circuits can be combined in many ways to achieve the desired results.



Calculating values for two or more resistors in series is simple, add all the values up. This is because all current must flow through all resistors, thus both resistances are imposed on the same potential.

R_{TOTAL} will always be greater than any of the included resistors.

- Parallel resistances are a little more complicated.
- When an electrical potential (voltage) encounters two possible paths, it will divide.
- If the two resistances are equal the current will divide equally and the R_{TOTAL} will be exactly half of either resistor or exactly one third if there are three resistors.
- This is because the current flow will split and be limited (as by ohms law above) by each resistor individually, and then added together.
- So, if 0.5A was able to flow through each resistor then 1A would flow in total.
- This is the same as using a single resistor with half the value.
- Now if two different resistors are used the current will still split, but not evenly.
- More current will take the path of least resistance and less current will take the path of higher resistance.
- The total current is still always less than would be for either resistor alone, and can be precisely calculated from the formula above.
- Just remember that the result is also a reciprocal and must be reciprocated to obtain the correct result.

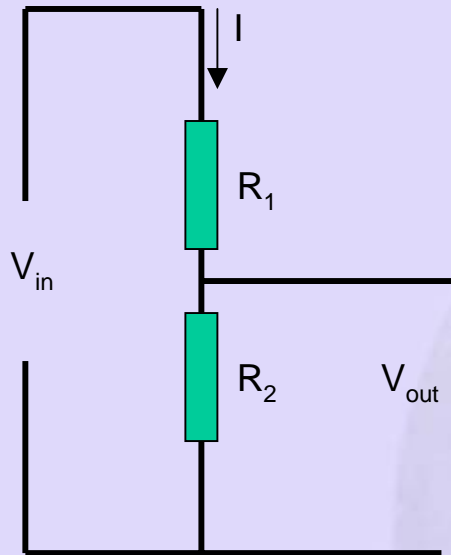
Power Dissipation:

- It is also worth noting that when two resistors are in parallel then their overall power rating is increased.
- If both resistors are the same value and same power rating, then the total power rating is doubled.
- If parallel resistances are not equal, then the resistors with smaller values will be required to handle more power.
- This is most useful when we require higher power handling, but don't want to go out and buy more expensive (and physically larger) resistors.
- Four identical 0.25W resistors can be wired in parallel to give a resistor with one fourth the value in ohms, but four times the power rating. (1.0W)

$$P = V \times I$$

- For the mathematically inclined, power (in watts) can be calculated by multiplying voltage by current. By using ohms law, the parallel or series resistor formulas and the above formula, a minimum power rating for a certain resistor can be calculated.
- If this is exceeded the resistor is likely to get hot and hopefully quietly breakdown. It could even start a fire.

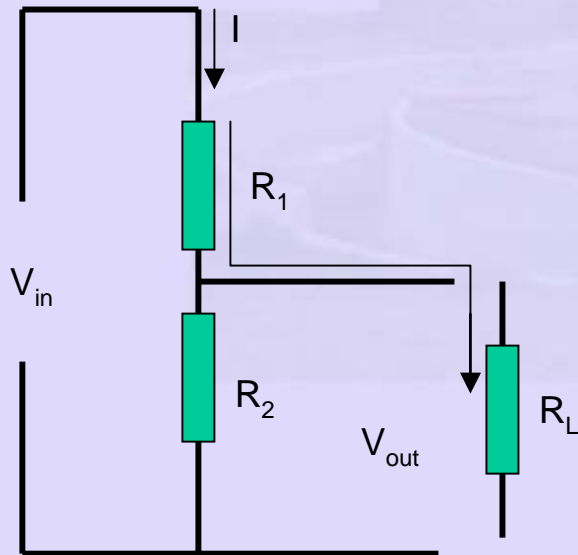
POTENTIAL DIVIDER



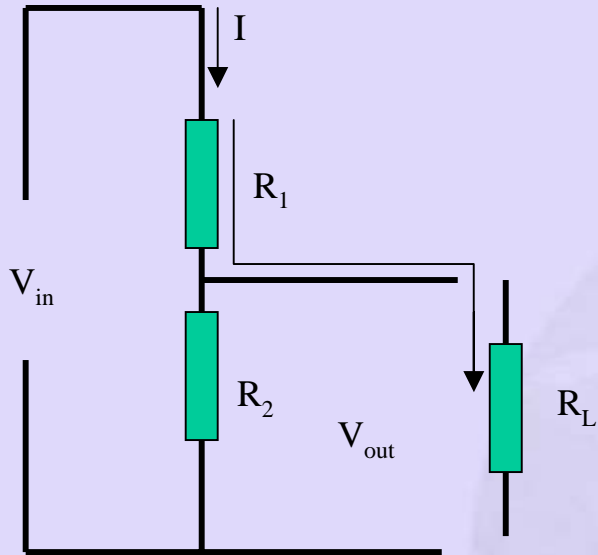
- The current $I = \frac{V_{in}}{R_1 + R_2}$
- Since the current I flows through R_2 , the voltage developed across it from Ohm's law is

$$V_0 = I \times R_2 = \frac{V_{in}}{R_1 + R_2} R_2$$

$$V_0 = \frac{R_2}{R_1 + R_2} V_{in}$$



- If $R_1 = R_2$ then $V_0 = V_{in}/2$
- But R_1 & R_2 can be $100\text{k}\Omega$ each or 100Ω Ohms each!
- Which is to be used?
- Observe, the current I flowing through the Load will also pass through R_1 .



- Hence R_1 will have to be chosen carefully. If we need more current through load R_L , then R_1 must be small.
- But too small a value will cause energy drain on the power supply.

