

## TOPIC 4

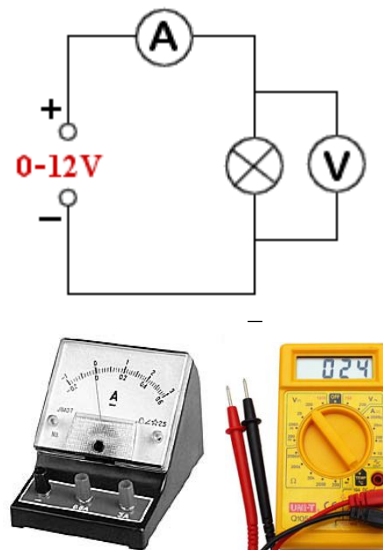
### ELECTRIC CIRCUITS

#### ELECTRIC CURRENT (I):

Current (I) is defined as the rate of flow of electric charge ( $Q$ ) in an electric conductor. The unit of current is **ampere (A)**. It is measured by devices called ammeter or multimeter.

$$I = \frac{Q}{t}$$

Electric charge ( $Q$ ) in a conductor is carried by subatomic particles electrons and ions. Electrons carry negative charge and ions could be positive or negative charge. Unit of electric charge is coulomb (C). It is a charge passing through any point in a circuit when a steady current of 1ampere maintained for 1 second, that is 1Coulomb = 1Ampere -second.



#### Charge and current:

There is a link between charge and current – the current is the flow of charges in a conductor in one second. For example if one coulomb of charge is passed in a copper wire in one second then it means that the current is one ampere. This link between charge and current can be expressed by equation:

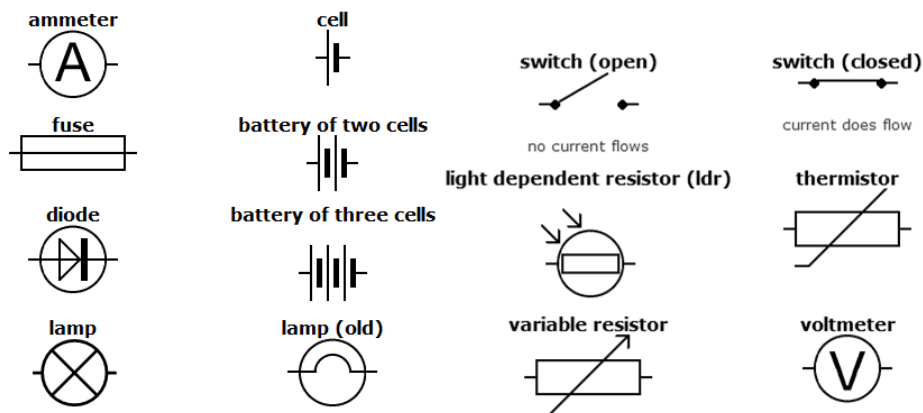
$$Q = I \times t$$

$$\text{charge} = \text{current} \times \text{time}$$

$$(\text{Coulombs}) = (\text{ampere}) \times (\text{seconds})$$

#### ELECTRIC CIRCUITS:

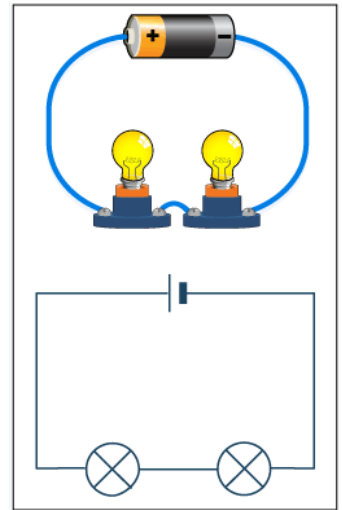
For the current to flow it must have a complete path of conductors. This complete path is called circuit. For example copper wires, which are conductors, are used to connect lamps in a circuit to complete the path for the flow of electrons. The battery is also attached to the circuit to push the electrons around. To draw the complete path of flow of electrons on a paper, we use circuit diagrams with symbol for every part of the circuit. Following are some common circuit symbols.



### *Series and Parallel Circuits:*

- There are two different ways of circuits, of connecting resistors (e.g. lamps) to the same battery. These circuits are called series and parallel circuits.
- A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take.
- The current is same through each resistor in series circuit.
- The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors. Equivalent resistance ( $R$ ) of resistors in series circuit can be expressed by.

$$R = R_1 + R_2 + \dots$$



- In series circuit the total potential difference ( $V$ ) of individual resistor is the sum of individual potential differences. That is

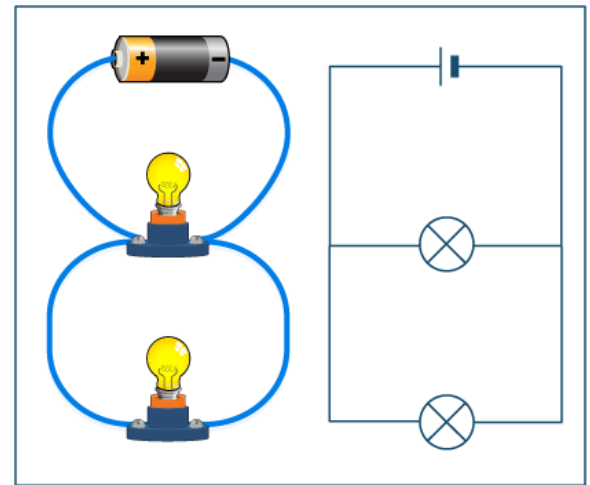
$$V = V_1 + V_2 + \dots$$

- The current ( $I$ ) remains the same in each resistance therefore the ammeter is connected in series with the other resistances.
- A parallel circuit is a circuit in which the resistors are arranged with one end of each resistor connected together, and other end of each resistor connected together and then each end connected directly to the battery.
- The current in a parallel circuit breaks up and take the easiest path first, with some flowing along each parallel branch and re-combining when the branches meet again.
- The voltage across each resistor in parallel circuit is same. Equivalent resistance of resistors in parallel circuit can be expressed by:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

or

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$



- In parallel circuit the total current is the sum of individual currents in each resistance.

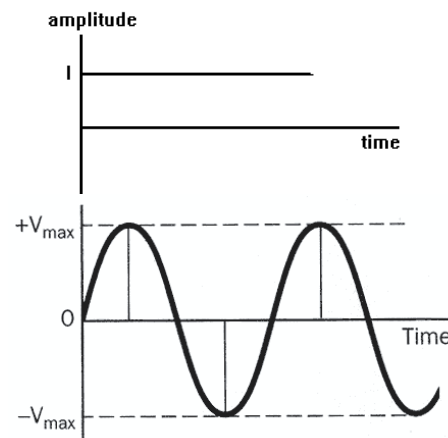
$$I = I_1 + I_2 + \dots$$

- Voltage in each resistor remains the same across each resistor; therefore the voltmeter in parallel circuit is always connected in parallel with other resistances.
- The combine resistance of all the resistances is less than the individual resistance.

### *Direct and alternating currents (d.c. and a.c. currents):*

The electrons constantly flowing around the circuit, from the negative terminal of the battery to the positive terminal, produce direct current (d.c.). All batteries produce direct current.

In the mains electricity at homes, the electrons in the circuit move backwards and forwards 50 to 60 times in one second. This kind of current is called alternating current (a.c.). The main advantage of using alternating current over direct current is it can be transmitted from power stations to our homes at very high voltage which reduces the amount energy that is lost during the transmission.



### *Action and use of various circuit components:<sup>1</sup>*

#### **Variable resistor or rheostats:**



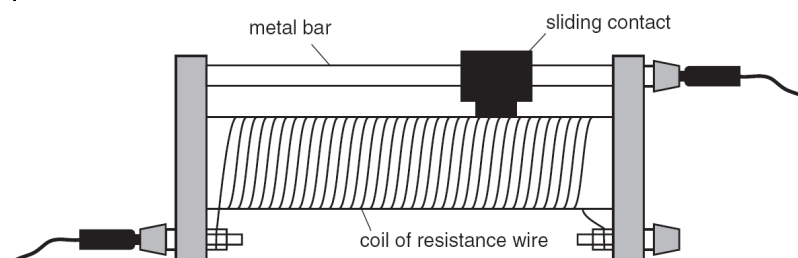
Resistors are specially made to provide resistance. In simple circuit, they reduce the amount of current. Hence if the voltage  $V$  is constant in the circuit then

$$R \propto \frac{1}{I}$$

Unit of resistance is ohms ( $\Omega$ ).

Resistors can have values from few hundred ohms to several million ohms.

In variable resistor the value of the resistance can be adjusted from zero to its maximum value by sliding the bar so that the current pass through whole resistance wire. The diagram above is a simple variable resistor used in school laboratory. In light dimmers they use to control the brightness of the light and in hi-fi equipment, circular variable resistors are used as volume control. The resistance equation can be written as



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

Consider the example of use of variable resistor to control the speed of an electric motor. If the motor is 24V; 12 $\Omega$ , battery with voltage of 24V, the variable resistor is set at 0  $\Omega$  then the potential difference across the motor will be 24V and the motor will run at full speed. The resistance of whole circuit is 12 $\Omega$  (0 $\Omega$ +12 $\Omega$ =12 $\Omega$ ) and the current through the motor is 2.0A.

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

$$I = \frac{24}{12} = 2.0A$$

Now if the resistance of variable resistor is set at 12 $\Omega$ , then the total resistance of the circuit will be 24 $\Omega$  (12 $\Omega$ +12 $\Omega$ =24 $\Omega$ ) and the current will

$$I = \frac{24}{24} = 1.0A$$

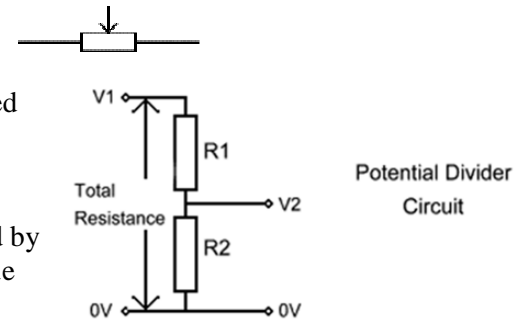
The current through the motor will have halved and the motor will run slower.

<sup>1</sup>Refer to this web link for more reading <http://www.kpsec.freeuk.com/components/vres.htm>

### Potentiometer or potential divider:

Potential divider is simply a variable resistors used as potential divider in which all **three terminals** are connected. This arrangement is normally used to **change voltage**, for example to change the brightness of the lamp, or control the volume (loudness) in a hi-fi amplifier circuit. A potential (or voltage) divider is made up of two resistors. The output voltage from a potential divider will be a proportion of the input voltage and is determined by the resistor values. In the arrangement of the circuit in the diagram the value of  $V_2$  can be determined by the formula:

$$V_2 = \frac{R_2}{R_1 + R_2} V_1$$



### Thermistor:

A thermistor is a heat sensor (resistor) which changes its resistance with the change of temperature (heat) around it. Its resistance decreases as the temperature increases which is reverse to the normal conductor. For example:

- Icy water  $0^\circ\text{C}$  has high resistance, about  $12\text{k}\Omega$ .
- Room temperature  $25^\circ\text{C}$  has medium resistance, about  $5\text{k}\Omega$ .
- Boiling water  $100^\circ\text{C}$  has low resistance, about  $400\Omega$ .

Thermistor is called input transducer. It means it changes resistance with the change in environment.

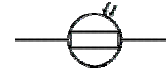


### LDR (Light Dependent Resistor):

An LDR is a light sensor (resistor) which changes its resistance with the brightness of light around it. It is made from cadmium sulphide compound (CdS) and its resistance decreases as the brightness of light falling on the LDR increases.

- Darkness: maximum resistance, about  $10^6\Omega$ .
- Very bright light: minimum resistance, about  $100\Omega$ .

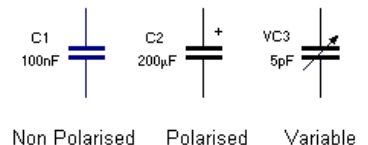
LDR is called input transducer. It means it changes resistance with the change in environment.



### Capacitor:

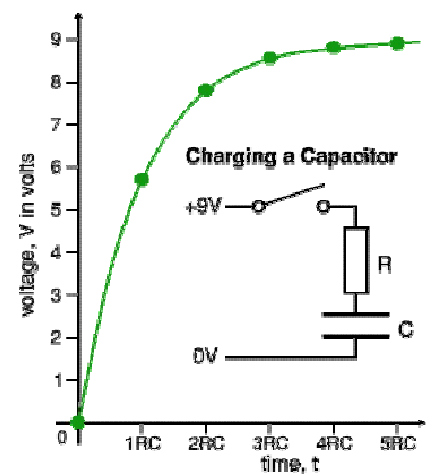
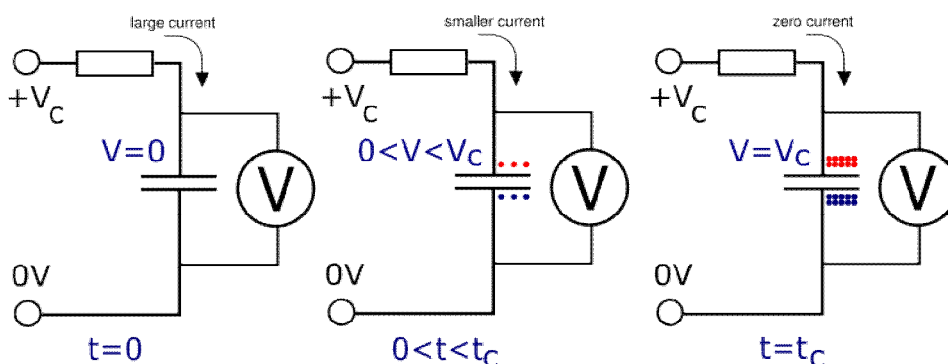
The capacitor is used to store electric charge (or that means electrical energy).

A basic capacitor is made up of two conductors separated by an insulator, or *dielectric material*. The dielectric can be made of paper, plastic, mica, ceramic, glass, a vacuum or nearly any other nonconductive material. When the terminals of a capacitor are connected with the battery the capacitor becomes charged and stored energy. Similarly when the two terminals short circuited, the capacitor discharged.



### Charging of capacitor:

When the battery is connected with positive and negative terminals of the capacitor, the positive terminal of the battery attracts electrons from the one plate and negative terminal repel electrons from other plate. The positive ions build up on the plate where negative terminal of the battery is connected and same as the negative ions at the



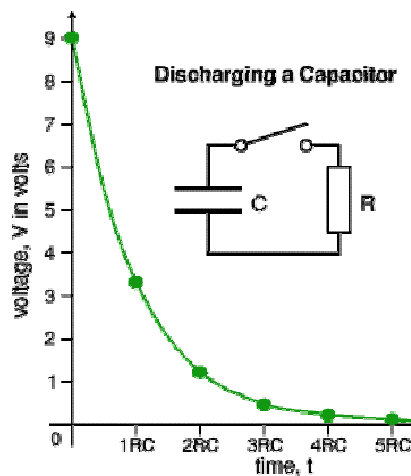
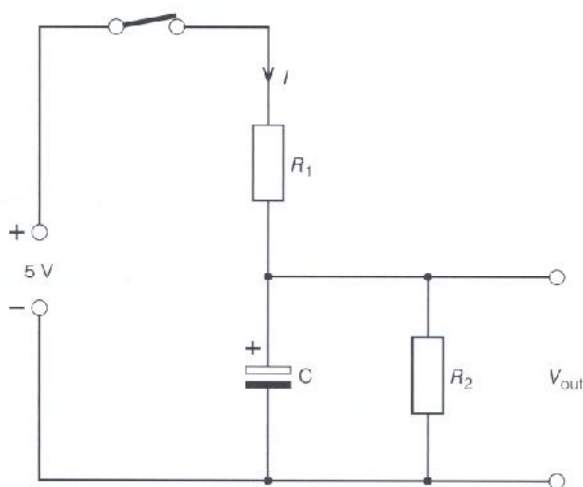
positive terminal. When the switch is closed, current will flow into the capacitor as shown. The resistor is fitted in series with the capacitor to prevent too much current pass through the circuit. Initially the potential difference (V) across the capacitor is 0 V and the full 9V is across the resistor. As the capacitor stores charges, the potential difference across the resistor increase and reached the maximum value of 9V. When the capacitor is fully charged, p.d. across the capacitor will be 9V and p.d. across the resistor will be 0V, and the current will stop flowing through the circuit.

### Discharging:

When the charged capacitor is connected to a resistor or a lamp and switch is closed, the resistor or lamp will have 9V of p.d. across it and it will be at maximum brightness as the current flows out of the capacitor. Since the capacitor is discharging, the voltage across the capacitor will gradually drop and the lamp will get dimmer and dimmer until the current stops completely.

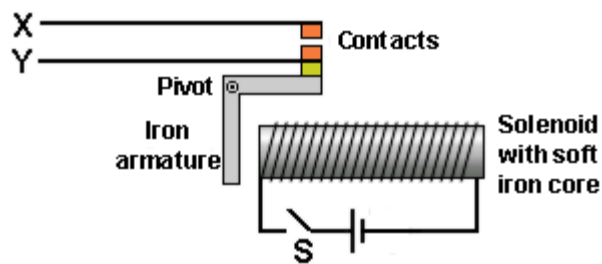
### Time Delay Circuit:

The capacitor can be used in time delay circuit. In this circuit, when the switch is closed, p.d. across the capacitor C will increase from zero to its maximum value during charging. If the output is connected to a relay or any other device that operates when the output voltage reaches say at 3V, then there will be a time delay between the switch closing and device operating. This delay could be fraction of second or many minutes, depending on the resistance of R1 and value of capacitor C.



### Relay:

A relay is a switch operated by an electromagnet. With a relay, a small switch with thin wires, low voltage battery and an electromagnet can be used to turn on or off the current in a much more powerful circuit. In the diagram, when the switch S is closed, the current flows through the solenoid. This pulls the iron armature towards it, which closes the contacts. As a result, a current flows through the circuit X-Y. There are two types of relays; normally open relay and normally closed relay.

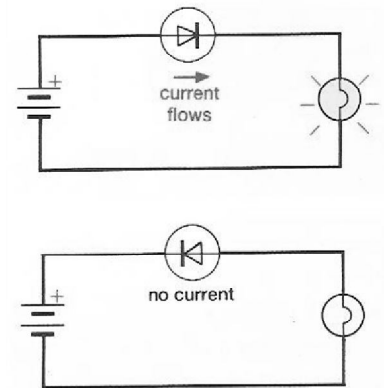
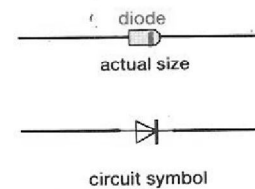
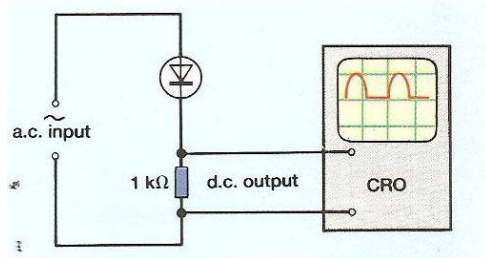


## Diodes:

The diode is a special device that allows the current to pass only in one direction. The symbol for diode is:

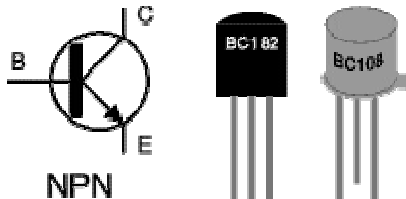
### Diode as Rectifier:

Diodes can be used to change alternating current (a.c.) to direct current (d.c.). This process is called rectification and diodes that do that is called rectifier. As simple rectifier circuit is shown in the figure. The diode lets the positive part of alternating current to pass through, but blocks the negative part. So the current in the circuit only flows in one direction.



## Transistor:

Transistors are used for very fast switching and amplifying signals. Most are made from specially treated crystals of silicon. Most of the electronic circuits and processor of a computer contains millions of them. It is the building block of electronics. Normally transistors have three wires coming out of it. They called **emitter**, **base** and **collector**.



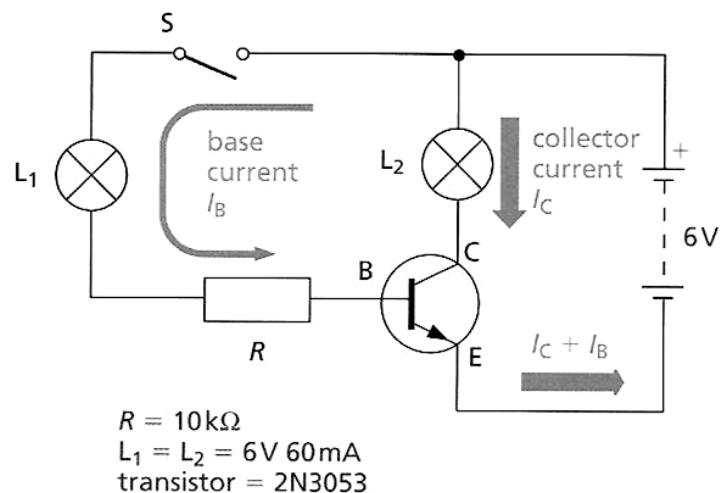
### Transistor as a switch:

In transistor there are really two circuits;

1. one is the collector-emitter circuit which is the main circuit and
2. other is the base-emitter circuit which is use for switching the transistor on and off.

In transistor the small base current controls much larger current collector current. When the circuit is connected using collector-emitter, no current will pass through the circuit since base will work as a barrier in passing the current when no p.d. applied to the base-emitter. However when the small p.d. across base-emitter increases (say about +0.6V) it changes the way transistor behaves. The blocking effect or barrier vanishes and transistor starts conducting the current from collector to emitter through base.

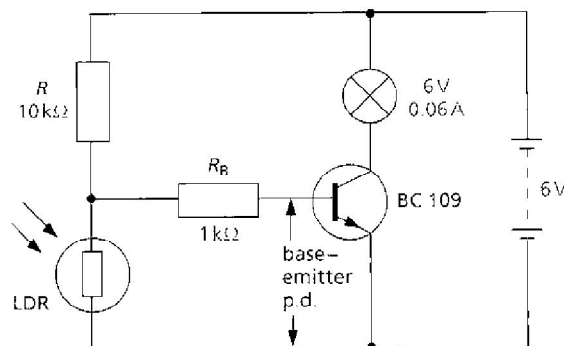
Transistors have many advantages over other electrically operated switches such as relays. They are small, cheap, reliable, have not moving parts, their life is almost indefinite in a well-designed circuit and they can switch on and off millions times a second.



### LDR- light Dependent Switch using transistor:

(light  $\uparrow$ , Resistance  $\downarrow$ , Current  $\uparrow$ )

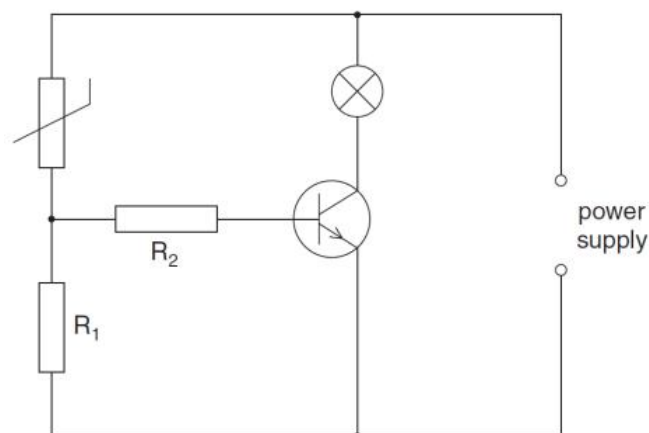
In light operated circuit the LDR is the part of a potential divider. The lamp comes ON when the LDR is in dark. At this time the current through B-E circuit is less than the current through Resistance  $R$ , due more of the battery p.d.



### Thermistor – Temperature control switch using transistor:

(Temperature  $\uparrow$ , Resistance  $\downarrow$ , Current  $\uparrow$ )

When the temperature of the thermistor rises, its resistance decreases and a larger fraction of the 6V supply is dropped across  $R$ , i.e. the base-emitter p.d. increases which allows the current through collector-emitter. This small amount of current drive the relay which completes the electrical buzzer and buzzer rings.



### Electricity at home:

- There are three main wires running parallel in home in every electrical circuit. That is:
  - Line (L) → Red or brown – has current**
  - Neutral (N) → Black or blue – no current**
  - Earth (E) → Green or green and yellow – no current**
- The earth wire is for safety precaution to prevent electric shock should an appliance develop a fault.
- Each circuit is connected in parallel with the supply, received the full potential difference of 230V.
- All switches and fuses are connected in the line wire.
- In staircase circuit a single light is connected with two two-way switches.
- The ordinary socket in home wiring is rated at maximum of 13A current.
- The modern form of fuse is called circuit breaker. It contains an electromagnet which breaks the circuit when the current exceeds the rated value of the circuit breaker, to prevent further increase of current in the circuit. They operate much faster and can be reset by pressing a button.
- Kilowatt-hour (kWh) is the unit we use to measure the amount of electrical energy used in home appliances.



Instead of using ammeter and voltmeter to measure electrical energy transferred by an appliance a **joulemeter** can be used to obtained it directly in joules.





### *Dangers of Electricity:*

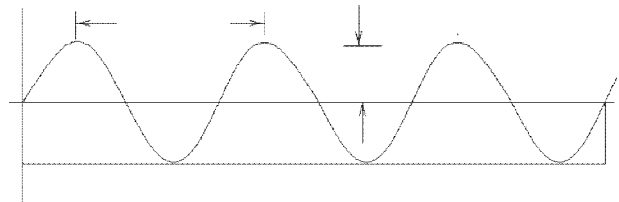
**Electric shock:** Electric shock happens if current flows from an electric circuit through a person's body to earth. This happens if there is a damaged insulation on the wire. The resistance of dry human body is  $10,000\Omega/m$  and when it is wet it is  $1000\Omega/m$ . Lower the resistance of a body, higher the current through the body. The damp conditions also increase the severity of electric shock

**Fire risks:** It happens if the heating appliances placed close to the electrical wiring or too much current pass through the electrical wires which causing overheating. To reduce the risk of fire due to overheating of electrical wires, the maximum current in the cables should be below or under the maximum rating of the wire.

### *Digital electronics*

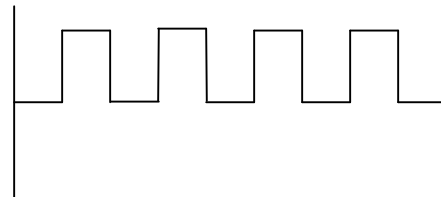
#### **Analogue signals:**

- These are usually older electronic gadgets (before 1990's).
- Analog systems handle information which is represented by continuous change and flow, such as voltage or current.
- Analog devices have dials and sliding mechanisms.
- Analog signals itself loses the strength of signal while making copies or after long time.
- A good example of an analogue signal is the loud-speaker of a stereo system. When the volume is turned up the sound increases slowly and constantly.
- Other examples of analogue systems include; Old radios, megaphones and the volume control on old telephone handsets.



#### **Digital Signals:**


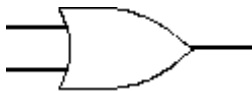

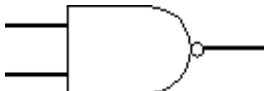
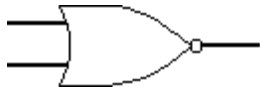
- The digital signal represents the data in discrete units (the binary digits 1 and 0).
- Modern electronic products such as computers and mobile phones depend on digital signals
- Digital circuits are the most common mechanical representation of [Boolean algebra](#) and are the basis of all digital computers.
- In most cases the number of states is two, and these states are represented by two [voltage](#) levels: one near to zero volts and one at a higher level depending on the supply voltage in use. These two levels are often represented as "Low" and "High."
- A good example of a digital signal is Morse code. The signal is sent as a series of 'on' and 'off' pulses. The signal is either present or it is not.





**Logic Gates:**

A logic gates are an elementary building block of a [digital circuit](#). They are the complex circuitry of number of transistors and resistors. Most logic gates have two inputs and one output. At any given moment, every terminal is in one of the two [binary](#) conditions *low* means 0(zero) or *high* 1(one), represented by different voltage levels. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

| AND Gate:<br>               | <table><tr><th>Input 1</th><th>Input 2</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table> | Input 1 | Input 2 | Output | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
|--|---|---------|---------|--------|---|---|---|---|---|---|---|---|---|---|---|---|
| Input 1  | Input 2   | Output  |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 0   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 1   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 1   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| OR Gate:<br>                | <table><tr><th>Input 1</th><th>Input 2</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table> | Input 1 | Input 2 | Output | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| Input 1  | Input 2   | Output  |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 0   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 1   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 1   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| NOT Gate or Inverter:<br> | <table><tr><th>Input</th><th>Output</th></tr><tr><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td></tr></table>   | Input   | Output  | 1      | 0 | 0 | 1 |   |   |   |   |   |   |   |   |   |
| Input  | Output  |         |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0   |         |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 1   |         |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| NAND Gate:<br>            | <table><tr><th>Input 1</th><th>Input 2</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table> | Input 1 | Input 2 | Output | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| Input 1  | Input 2   | Output  |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 0   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 1   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 1   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| NOR Gate<br>              | <table><tr><th>Input 1</th><th>Input 2</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table> | Input 1 | Input 2 | Output | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| Input 1  | Input 2   | Output  |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 0   | 1       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 0  | 1   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 0   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |
| 1  | 1   | 0       |         |        |   |   |   |   |   |   |   |   |   |   |   |   |