CHAPTER

1

Components and Wiring

1.1. INTRODUCTION

For construction of an electronic circuit, three most important factors to be taken under consideration are: (*i*) Selection of components like resistors, capacitors, inductors, relays, diodes, transistors and IC, (*ii*) Power sources and measuring instruments viz: power supplies, function generators, multimeters, DSO, CRO and (*iii*) Designing, simulation, fabrication, measurement and analysis of circuits. One can classify components into two main categories namely: active components and passive components. Active components are the ones which are essentially made up of p-n junctions of simple or compound semiconductors. Here the voltage biasing plays a major role in deciding the flow of charge carriers. These devices are capable of amplifying or modulating an input signal and can also direct the flow of current. Few examples of active components are diodes and transistors. On the other hand a passive component is the one which does not need an external source for biasing and often causes the power to be dissipated (lost) through it. These can neither generate nor amplify a signal. Capacitors, resistors and inductors are examples of passive components. The second aspect is the instruments and power supplies. The present chapter starts with familiarization of passive components, their construction, types, codes and tests. Next section deals with construction and testing of breadboard, different types of wires, followed by switches, resistance box and potentiometer. Also a few commonly used instruments like analog and digital voltmeter, ammeter, volt Ohmmeter, digital multimeter, audio oscillator and function generators have been explained in further sections. This is followed by explanation on circuit rules (current division and voltage division). The last section explains few experiments along with an advanced level project dealing with the control of a bicolor LED using switches.

1.1.1. Resistors

The resistor is a passive component that offers a known resistance to the flow of electricity in both ac and dc circuits. It is used in various applications such as controlling of current, adjustment of voltage for bias levels, frequency variation for timer circuits, impedance matching etc. One can express the resistance of any resistor as:

$$R = \rho l/A$$

Where ρ is resistivity, l is the length and A is the area of cross-section of the resistor and hence the value of resistance depends on length, area of cross section and material of the resistor. Its unit is ohm (Ω). Materials generally used for fabrication of resistors are Nichrome (80% Ni and 20% Cr), Constantan (55% Cu and 45% Ni) and Maganin (85% Cu and 10% Mn and < 5% Ni). Metals are not used as they have a very high temperature coefficient of resistance. Resistors are made in one of several ways i.e. a carbon rod, carbon or metal film on a ceramic rod, or wire-wound. Carbon rods are most common because they are less expensive and can be used for multiple purposes. When a carbon or metal film is used, parts of it are removed to give the resistor its resistance value. Wire wound resistors consist of wire wrapped around a ceramic rod in such a way that there are no inductance effects introduced. Again, the amount of wire used, depends on the required resistance level for the resistor. All resistors have a well defined current carrying capacity. Hence, a current more than the prescribed wattage may damage the resistor.

Color Code for Resistors: The value of the resistance on any resistor is usually coded in the first three colored bands appearing on the resistor as shown in Fig. 1.1. The fourth band tells us about the tolerance of the resistor. The numeric values assigned to the various colors are given in Table 1.1.

Table 1.1: Color code of resistors

Band color& its value		*Band color and its tolerance*	
Black	= 0	Gold	= $\pm$ 5%
Brown	= 1	Silver	= $\pm$ 10 %
Red	= 2	No color means 20 %	
Orange	= 3		
Yellow	= 4		
Green	= 5		
Blue	= 6		
Violet	= 7		
Grey	= 8		
White	= 9		

First band: the first digit of resistance

Second band: the second digit of resistance.

Third band: The Multiplier- a power of 10 or the number of zeroes to follow the two digits.

Fourth band: Tolerance

Reading from one end, as shown in Fig.1.1, the meaning of the bands are:

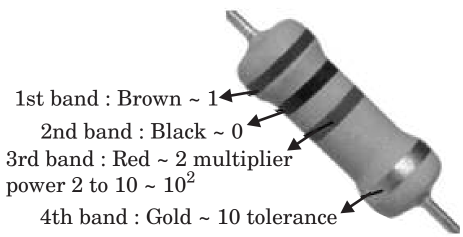


Fig. 1.1: Bands in Resistor

Therefore the value of resistance is: **$10 \times 10^2\ \Omega = 1\ k\ \Omega$ with a tolerance of 10%.**

Most commonly used resistors in the laboratory are fixed value resistors that exist for certain standard values normally in E12 range as given in table 1.2 Other ranges *i.e.* E24 and E48 also exist. In table 1.2, after the first twelve values as defined in the first row, the sequence repeats itself in multiples of 10, in the subsequent rows. The table cells which are left blank can similarly be filled.

Table 1.2: **Table for E12 range values of resistors in ohms.**

1.0 Ω	1.2 Ω	1.5Ω	1.8Ω	2.2Ω	2.7Ω	3.3Ω	3.9Ω	4.7Ω	5.6Ω	6.8Ω	8.2 Ω
10	12	15	18	22	—	—-	—	—	—	68	82
100	120	150	180	220	—	—	—	—	—	680	820
1k	1.2k	1.5K	1.8K	2.2K	—	—	—	—	—	6.8k	8.2k
10k	12 k	15K	18K	22K	—	—	—	—	—	6.8 k	82k
100k	120 k	150K	180K	220K	—	—	—	—	—	8.2 k	820k
1M	1.2M	1.5M	1.8M	2.2M	—	—	—	—	—	6.8M`	8.2M
10M	12M	15M	18M	22M	27M	33M	39M	47M	56M	68M	82M

Variable Resistors

Besides the fixed value resistors, there also exist variable resistors. The resistance of variable resistors can vary in steps or continuously. Potentiometer and rheostat are examples of a continuously varying resistor.

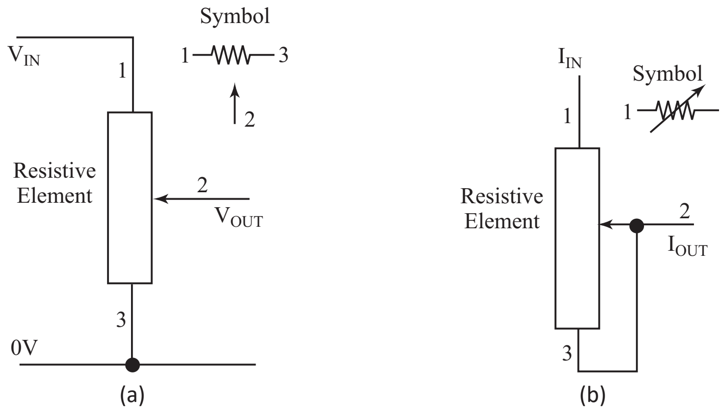


Fig. 1.2: (a) potentiometer (b) Rheostat

Principle construction of a rheostat and a potentiometer (pot) is same i.e. consisting of a track of wire of (cermets or carbon) having a wiper in between. Refer Fig. 1.2 (*a* and *b*). It has 3 connections namely 1, 2 and 3.

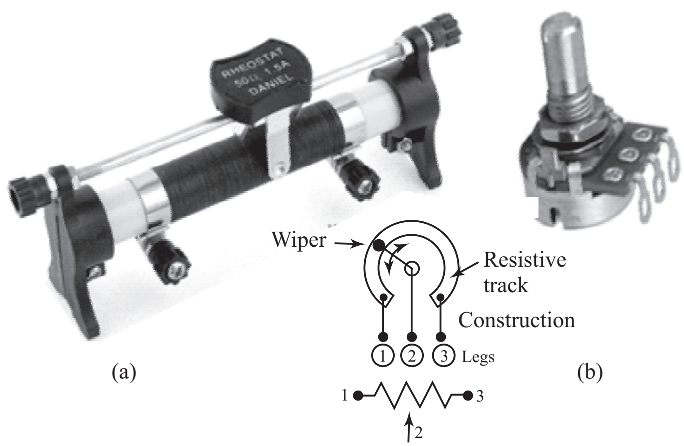


Fig. 1.3: (a) Rheostat (b) Potentiometer

If it is to be used as a variable resistance to control current then one end terminal and the in between wiper tap terminal is to be connected to the circuit as shown in 1.2b. The other end terminal may be shorted to terminal 2 or just left open. So the resistance in between terminals 1 and 2 will come in the circuit and which can be varied too. If it is to be used as a potential divider then terminals 1 and 3 is to be connected to circuit. (as in Fig. 1.2*a*) and the divided voltage appears at terminal 2.

There are two types of pots (linear and rotary) as shown in Fig. 1.3. and Fig. 1.4 is a picture of pots of different styles and packages. Presets or trimmers which are shown, are pots with an easy to adjust control, with a small screw driver. These are generally used on printed circuit board (pcb) where occasional small adjustments are to be made for example for calibration. These are generally set for once and mounted.

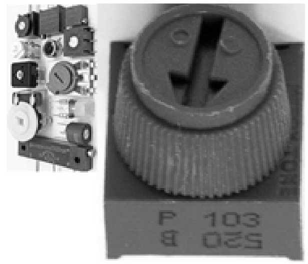


Fig. 1.4: Potentiometer.

Special Purpose Resistors

There are other types of resistors whose value depends on an external stimulus such as temperature or light.

Light dependent resistors (LDR) and thermistors are examples of special purpose resistors. Thermistor is a resistor made of a semiconductor whose value depends on its temperature. It is also called a heat sensor. LDR is a resistor whose resistance depends upon the amount of light falling on it. More details will follow in following chapters.

Capacitor

A Capacitor is a passive circuit element that is used to store charge temporarily and in general consists of two metallic plates separated and insulated from each other by a dielectric. Various applications of capacitors include tuning circuits, ignition systems and filter circuits etc. The capacitance of a capacitor is defined as:

$$C = \epsilon_o \epsilon_r \, A/d$$

where A is the area of plates, d is separation between the plates, ϵ_o is permittivity of free space and ϵ_r is relative permittivity. The unit of capacitance is Farad (F). The value of a capacitor depends upon the dielectric constant ($K = \epsilon_o \epsilon_r$) of the material. An important parameter of capacitors is its well defined voltage handling capacity beyond which the capacitor dielectric breaks down. Fig. 1.5 gives a view of variaus types of capacitors.

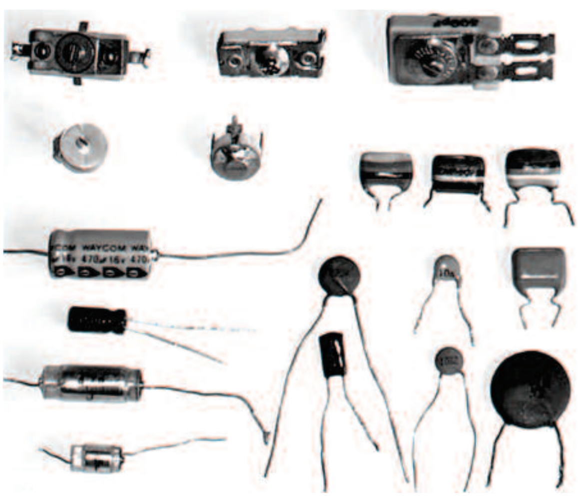


Fig. 1.5

There are three main classes of capacitors namely– (*i*) Non electrolytic or normal capacitors (*ii*) Electrolytic capacitors (*iii*) Variable capacitors

Normal capacitors are mostly of parallel plate type and can have mica, paper, ceramic or polymer as dielectric. In the paper capacitors two rectangular metal foils are interleaved between thin sheets of waxed paper and the whole system is rolled to form a compact structure. Each metal foil is connected to an electrode. In mica capacitors alternate layers of mica and metal are clamped tightly together. Refer Fig. 1.6(*a*) and 1.6(*b*) where cross-sectional views of a paper capacitor and a mica capacitor are shown respectively. In an electrolytic capacitor there are specific positive and negative terminals. Here mostly a thin metal-oxide film is deposited by means of electrolysis on an axial electrode and that is how it derives its name. During electrolysis the electrode acts as anode whose cathode is a concentric can. Since the dielectric layer is very thin hence these capacitors require special precaution for their use; ***i.e. they have to be connected in the right polarity failing which the dielectric breaks down.*** The variable capacitors are capable of providing different external capacitance values by changing the internal area of cross-section. They have a fixed set of plates and a movable set of plates that can be moved through a shaft. This movement changes the area of overlap of the two sets of plates which then changes its capacitance. A variable capacitor is illustrated in Fig. 1.7.

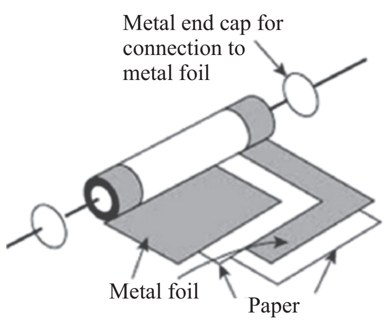


Fig. 1.6(a):

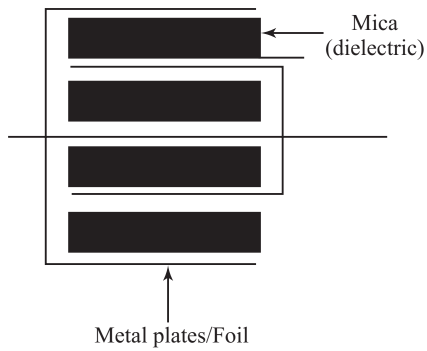


Fig. 1.6(b): Mica Capacitor

Color and Number Code of Capacitors

Different marking schemes are used for electrolytic and non-electrolytic capacitors.

***(i)* Electrolytic Capacitors:** There are two designs of electrolytic capacitors : (*i*) Axial where the leads are attached to each end (220 μF in picture) and (*ii*) Radial where both leads are at the same end (10 μF in) as shown in picture of Fig. 1.8.

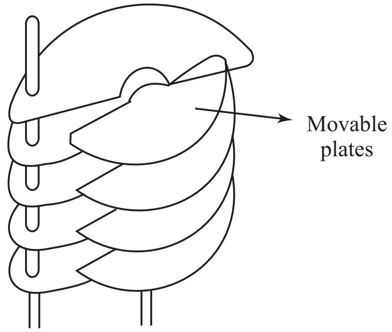


Fig. 1.7: Variable Capacitor

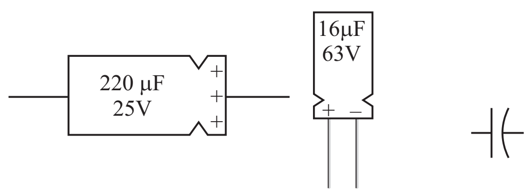


Fig. 1.8:

***(ii)* Non-polarized capacitors (< 1 μF):** These are small value capacitors which have their values printed but without a multiplier. For example 0.1 means 0.1 μF as shown in Fig. 1.9(*a*). Sometimes the unit is placed in between 2 digits indicating a decimal point. For example: 4 n7 means 4.7 nF.

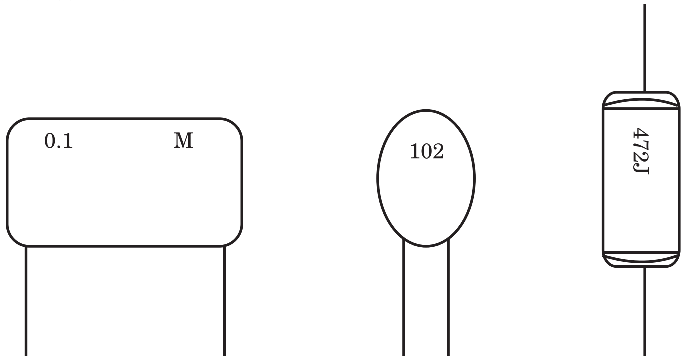


Fig. 1.9: (a) Examples of number coded capacitor.

Capacitor Number Code

A number code is also used sometimes on capacitors that are small and hence printing the value is difficult. The 1st number is the 1st digit, the 2nd number is the 2nd digit, and the 3rd number is the power of ten to be multiplied, to give the capacitance in pF. Any letters just indicate tolerance and voltage rating. For example: 102 on a capacitor in Fig. 1.9(*a*), means 10×10^2 pF and 472 J means 4700 pF (J means 5% tolerance). Table 1.3 gives details of the number code for capacitors.

Table 1.3: Multiplier and Tolerance Table for Capacitors

Third Digit	*Multiplier (multiply the first 2 digits by this number)*	*Letter*	*Tolerance*
0	1	B	+/– 0.10%
1	10	C	+/– 0.25%
2	100	D	+/– 0.5%
3	1000	E	+/– 0.5%
4	10000	F	+/– 1%
5	100000	G	+/– 2%
6 or 7	Not used	H	+/– 3%
8	.01	J	+/– 5%
9	.1	K	+/– 10%
		P	+100% ,–0%
		Z	+80%, –20%

Capacitor Color Code

Some capacitors are also color coded like the resistors. The colors have the same numeric value as that used for color coding in resistors. The top three color bands give the value of the capacitor in pF. The 4th band and 5th band are for tolerance and voltage rating respectively. For example: brown, black, orange means 10000 pF = 0.01 μF, as shown in Fig. 1.9(*b*).

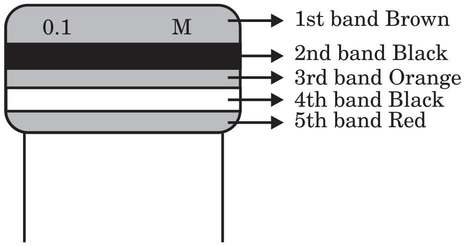


Fig. 1.9: (b) Color coded capacitor

Available Values of Capacitors: Like resistors, capacitors are also available for only particular values. Following are the 2 series defined for capacitors.

The E3 series (3 values for each multiple of ten) 10, 22, 47, then it continues as

100, 220, 470, 1000, 2200, 4700, 10000 etc.

The E6 series (6 values for each multiple of ten) 10, 15, 22, 33, 47, 68, .. then it continues 100, 150, 220, 330, 470, 680, 1000 etc.

1.1.3. Inductor

An inductor is a passive component that stores energy in a magnetic field. It is a component made by a coil of wire which is wound on a core. The inductance is defined as:

$L = \mu_o \mu_r N^2 A/I$, where μ_0 is the absolute permeability ($= 4\pi \cdot 10^{-7}$ H/m) and μ_r is the relative permeability of the material, N is number of turns, A is area of crossection and I is the current. Its unit is Henry (H).

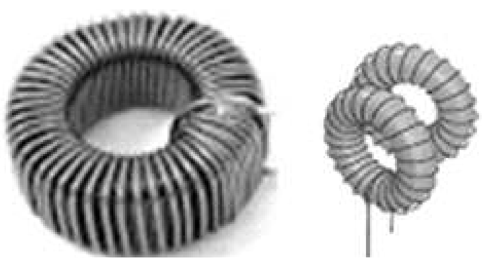


Fig. 1.10: Inductor

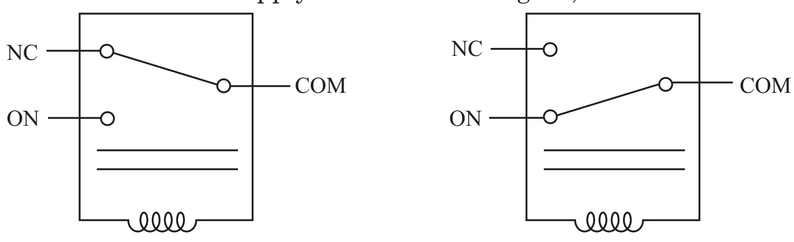
Quality factor (Q) is another important parameter of an inductor which is defined as the ratio of inductive reactance to resistance and is a measure of efficiency of the inductor. It is actually the ratio of 2π times the energy stored per cycle and energy dissipated per cycle. Quantitatively $Q = \omega L/R$ where ω is $2\pi f$, f being the frequency. Depending upon the type of application (example high frequency operation, current carrying requirement or requirement based on Q), the design of inductor varies. Construction wise, normally the coil of an inductor is made of copper wire. (Example: aluminum wire, or spiral pattern etched on circuit board). Its properties are also affected by the material used around and in the coil. The wire is insulated and the insulation type (*e.g.* enamel coated or silk) decides the number of turns per cm that can be safely wound without the insulation cracking for a given current. The current capacity depends upon the area of crossection of the wire. This insulated wire is wound on a cylindrical or torroidal core as shown in Fig. 1.10. For a straight solenoid, there are magnetic losses due to magnetic lines of flux leaking in the air whereas for a torroidal core, the magnetic field gets retained within the core, leading to higher efficiency. For core, few types of materials being used are Iron ($\mu_r = 1000$), ferrite ($\mu_r = 200000$), powdered iron and air. Between Iron and Ferrite cores, ferrite is more efficient because stray electricity cannot flow through it. Ferrite cores are more expensive but operate at much higher frequencies than iron cores. Some inductors have more than one core. Some are formed like transformers, using two E-shaped pieces facing each other, the wires wound about the central leg of the E's. The E's are made of laminated iron/steel or ferrite. Torroidal inductors are most efficient of all since they are wound around a donut shape which is made of ferrite. They are more difficult to make, because the formed coil cannot be placed on the torroid - it must be wound in situ.

Inductor (Coil) Color Code

Small coils or chokes do not generally have a code written on them. Even the larger coils don't show anything but a code. They have a 'color-code' painted on them much like resistors have but usually only three bands or three dots, unless they are made by 'Mil Spec' (Military Specification). The body itself may have a variety of colors depending on the dipped substance used.

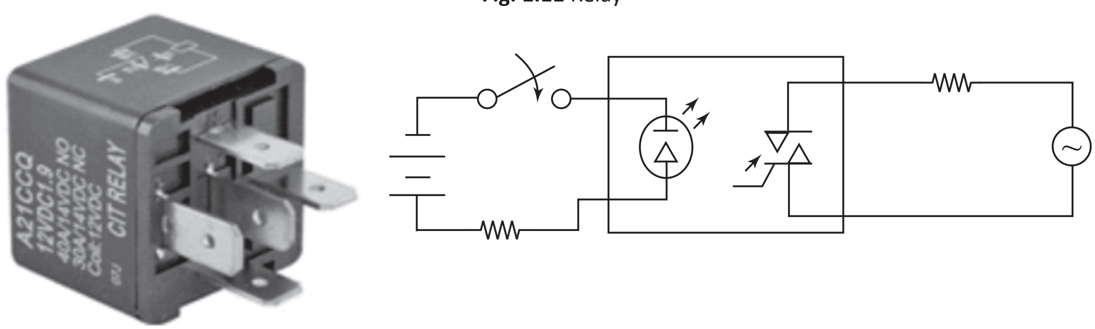
Relay

A relay is a device which is controlled by a small current to switch into ON and OFF conditions, to further control another high power circuit or in other words it acts as an electromagnetic switch. Construction wise it consists of an electromagnet, which gets energized with a very small amount of current as shown in Fig. 1.11(*a*) and (*b*). In these figures, when a small current flows through the electromagnet a, it pulls the switch to ON position thus energizing the motor in (*b*). When there is no current supply to the electromagnet, the switch is in OFF/NC state.



(*a*) (*b*)

Fig. 1.11 Relay



(*a*) (*b*)

Fig. 1.12: Electronic Relay

Main uses of relays are towards sensors, which themselves, produce a very small output voltage but they are needed to run high powered circuits. For example for the case of a fan or an AC to be switched on when the room temperature has shot to 35°C, the electronic thermal sensor, on sensing 35°C, would produce a small voltage, which would turn on the fan through the relay. There are various other types of relays depending upon the type of application and sensor or the input circuit involved. (*i*) *Electronic and semiconductor relays* : These involve electronic switching and have no moving parts, are faster but more expensive, (*ii*) *Thermal relays* : These switch on and switch off the devices to protect from overheating, (*iii*) *Over current relays*: These stop flow of current beyond a certain limit, (*iv*) *Frequency protection relays*: These protect the devices if the frequency overshoots a certain range. Fig. 1.12 gives a picture of an electronic of relay and its circuit.

1.1.4. Transformer

Transformer is a device used for transferring electrical energy from one ac circuit to another, by the principal of mutual induction and Faradays law. It can also be used for stepping up or stepping down of an ac voltage. Essential parts of a transformer are a coil (single or double) and a core. The core could be an air core or a solid core such as a ferrite core which helps to reduce magnetic losses which are otherwise present for the case of an air core. Transformer with a single coil is called an autotransformer and is usually used when not much voltage change is required. The other transformer having two coils (primary and secondary) can be of normal type or center tap type. Besides the above classifications, a transformer can also be single phase of multiphase types. In a single phase transformer, the primary and secondary windings are wound on a core of maximum permeability so that maximum lines of flux can pass through the core as shown in Fig. 1.13. The primary is connected to a voltage source and an alternating current passing through it, induces an alternating flux which also passes through the secondary. This changing flux induces a voltage in the secondary, by Faradays law and the direction of current in the secondary is such that it opposes the very cause producing it. The voltage induced in both primary and secondary is proportional to the number of turns in primary and secondary respectively.

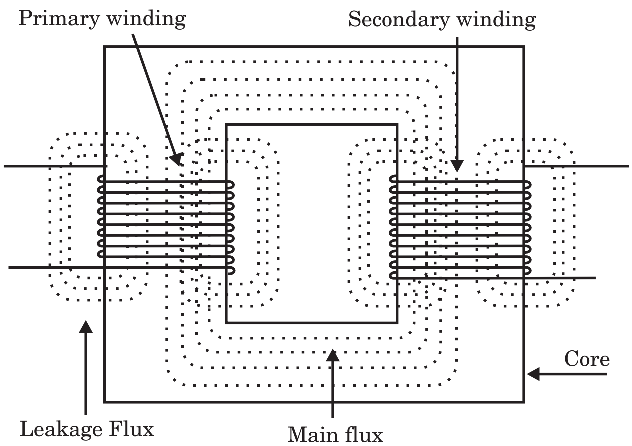


Fig. 1.13: Single phase Transformer

If V_p and N_p denote the primary voltage and number of turns in primary (V_s and N_s for secondary), then one can write

$$V_p = -N_p \frac{d\phi}{dt} \text{ and } V_s = -N_s \frac{d\phi}{dt} \Rightarrow \frac{V_p}{V_s} = \frac{N_p}{N_s} = n$$

where n is called the turns ratio. For a step up transformer, $n < 1$ ($V_s > V_p$) and for a step down transformer $n > 1$. By the law of conservation of energy (or power), $I_p \,.\, V_p = I_s \,.\, V_s$. This means that the primary power should be equal to secondary power provided no losses are present during the transfer and which is also the case of an ideal transformer. But practically there are core losses (hysteresis losses, eddy current losses), leakage losses and heat losses present due to which a practical transformer has an efficiency of much lesser than 100%.

Transformer EMF Equation. To develop a relation between the rms voltage value (E_{rms}) frequency f and number of turns for a transformer, one can start with a simple equation, for induced emf (E), where $\phi(= \phi_m \sin\omega t)$ is the sinusoidal flux, as follows:

$$E = N \cdot \frac{d\phi}{dt} = N \cdot \phi_m \cdot \omega \cdot \cos(\omega t) \Rightarrow E_m = N \cdot \phi_m \cdot \omega$$

$$\Rightarrow \qquad E_{rms} = \frac{N \cdot \phi_m \cdot \omega}{\sqrt{2}} = \frac{N \cdot \phi_m \cdot 2\pi f}{\sqrt{2}} = 4.44\, f \cdot N \cdot \phi_m$$

Center Tap Transformer

A center tap transformer is a normal transformer with a tap taken at the central point in the secondary winding as shown in Fig. 1.14. As one can see points A and C are at the ends and if load is connected the transformer acts as a normal transformer since the principle of operation is same. The point B in the figure, also known as the neutral point has a voltage in between the values at points A and point C. Suppose the points A and C are at 12 V and 0V respectively, then B will be at 6 V. Hence for a load connected between A and B, the output is 6V and if connected between C and B its again at 6V but with an opposite polarity. So one can say that for a center tap transformer one gets two outputs of exactly same voltages but with opposite polarities. So when it is connected with a full wave rectifier, one diode will be forward biased and the other will be reverse biased always as mentioned in chapter 4, section of rectifiers.

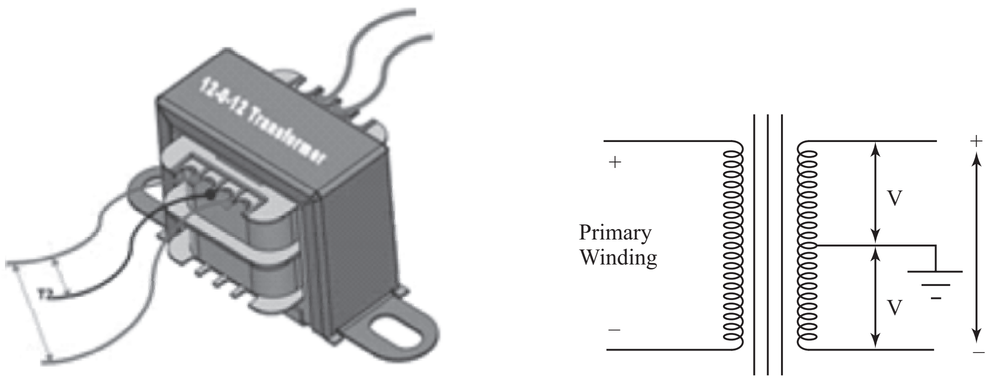


Fig. 1.14: Center Tap Transformer

Autotransformer

An autotransformer is a device consisting of a single coil only to which both primary and secondary get connected. Tapping is done from a predetermined point, to take the secondary tapping output, as shown in Fig. 1.15. In this figure, the part BC of the winding is common to both primary and secondary. The advantage of an autotransformer lies in the fact that it has a higher efficiency compared to a two winding transformer. This higher efficiency is because of lesser losses due to lesser copper being used, leading to lesser heat and reactance losses. It is mostly used for the cases where the Turn ratio is required as almost unity.

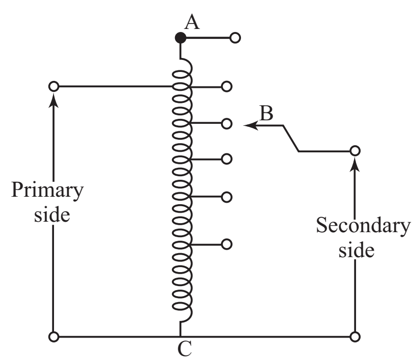


Fig. 1.15: Autotransformer

However unlike the two winding transformer, an autotransformer does not provide electrical isolation between two circuits.

1.1.5. Bread Board

A bread board is a board made up of white plastic, with holes which are connected at the back side by copper wires in a particular pattern, for the purpose of experimenting prototype circuits, without actually soldering the connections. This name is assigned because it was initially used for cutting of bread slices on a board. Fig. 1.16 and Fig. 1.17 illustrate a schematic representation of a bread board with pictures of front and back sides respectively. As shown in the figure the horizontal lines are connected in groups of five each and the side longitudinal holes are connected length wise Fig. 1.17, mainly for providing a bus of either ground or a higher voltage respectively. Usually the line of holes with blue wire indicates ground connection and line of holes with red wire indicates higher voltage bus. Hence a circuit having an IC and other components can be easily connected and tested without soldering and disordering as in a pcb.

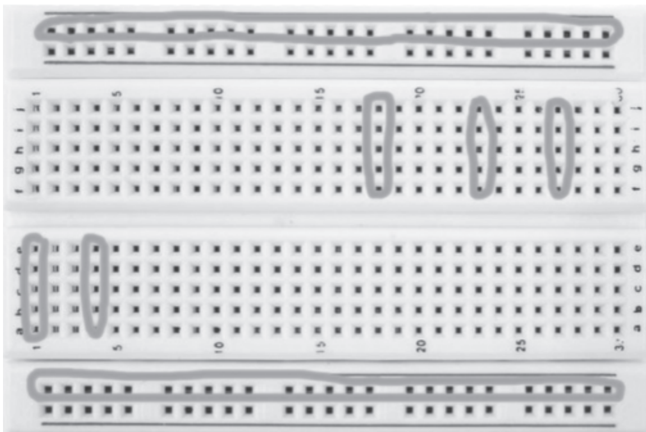


Fig. 1.16: Bread Board

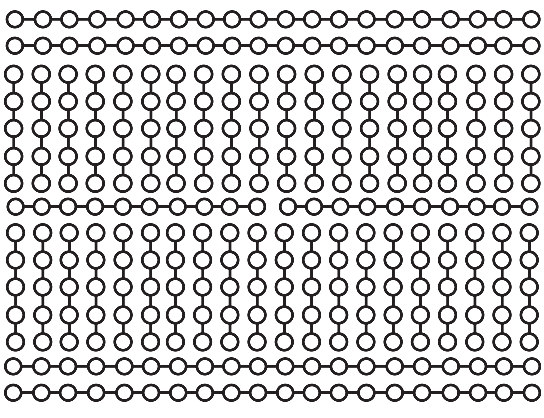


Fig. 1.17: Schematic representation of Bread board on the back

Testing of Bread Board: Before actually placing the components on the bread board, it is recommended that the breadboard be tested for any short circuit or open circuit connections. To do so, insert two wires across a horizontal row and test for continuity. Similarly insert two wires at the end of vertical rows and check for continuity. If two wires are inserted in two different horizontal rows they should not pass continuity test. Refer Fig. 1.18 and Fig. 1.19 for different testing different methods.

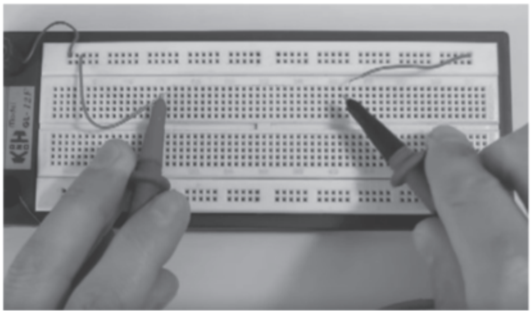


Fig. 1.18: Testing of Bread Board

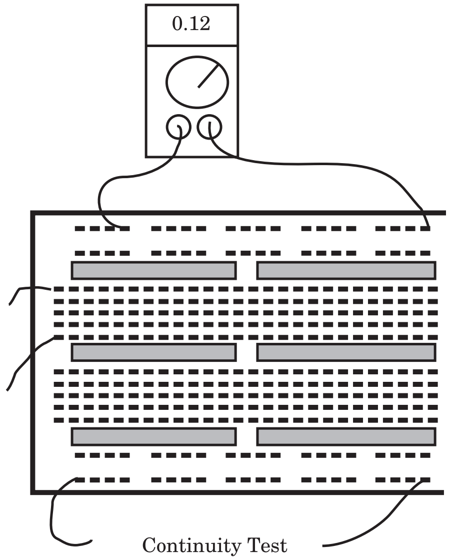


Fig. 1.19: Testing of Bread Board

How to do connections on the bread board: It is advised that the connections of a given circuit maybe done in the manner as mentioned below. Normally the positive end of the battery is connected to a hole in the vertical line and negative end on another vertical line as shown in Fig. 1.20. Then the lower most vertical line becomes the ground bus and the top most vertical holes have 5 V. A resistor is then connected from 5 V line till the anode of the LED, as shown and cathode of LED is connected to the ground line. In case of more connections, jumper wires could be used instead of directly connecting to supply lines. As shown in Fig. 1.21, a component connected across the four horizontal holes, gets shorted from the back side and hence is incorrect.

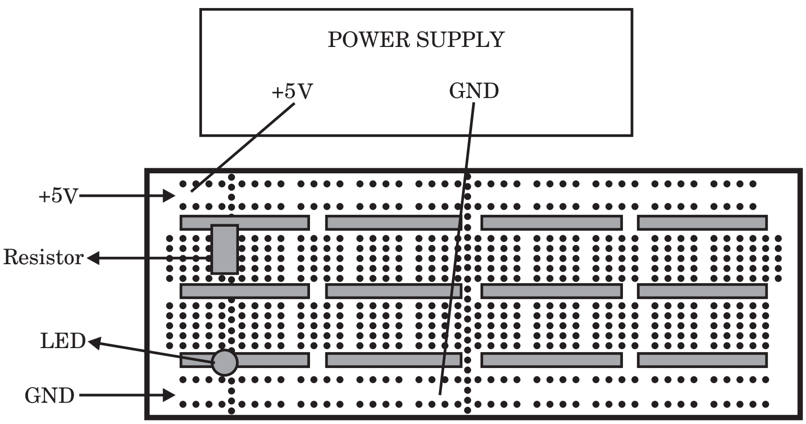


Fig. 1.20: Connections in Bread board

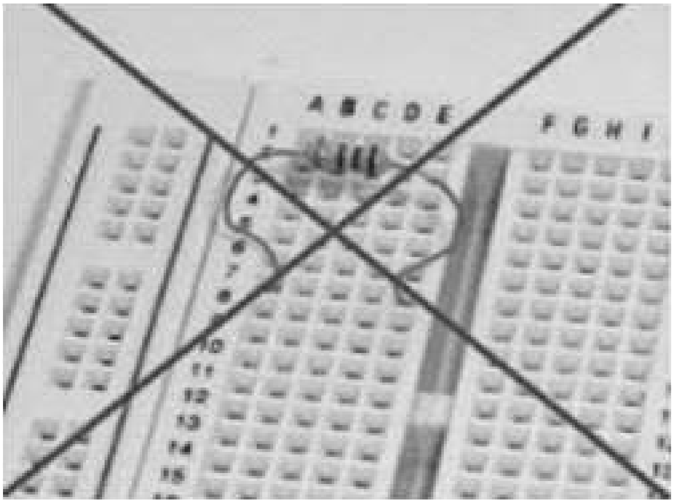


Fig. 1.21: Not allowed connections in Bread Board

Jumper Wire

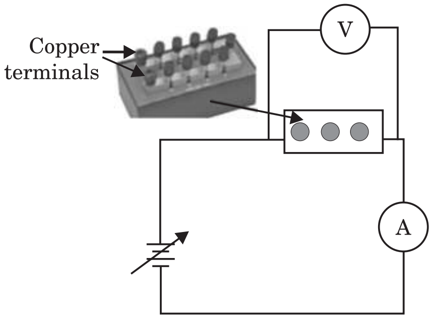
Jumper wire is a simple single strand wire ending in a special type of connector and is used for making connection on bread board or otherwise. If it ends in a pin then it can be used in bread boards. It can also have crocodile ends or banana type ends as shown in Fig. 1.22(*a*) and 1.22(*b*).

(a) (b)

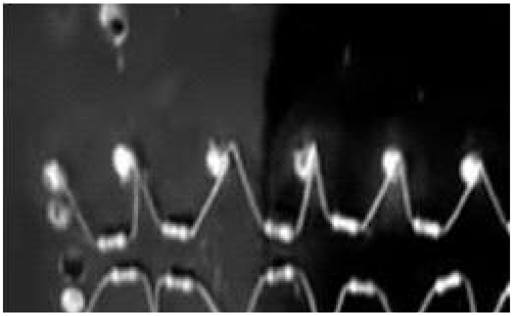
Fig. 1.22: Jumper wires

1.1.6. Resistance Box

A resistance box is used in circuits to enable a variation of resistances conveniently, without actually replacing them in the circuit. As shown in Fig. 1.23(*a*), it consists of two copper terminals to which the positive and negative ends of the circuit can be connected. The cover of the box is made up of ebonite or Bakelite material on which terminals and knobs are placed. To add any resistance value in the circuit, the corresponding knob marked with that resistance has to be removed. When all the knobs are placed there is no resistance, meaning it is a short. The knobs are of tapered brass with black handles. The holes have brass lugs which are embedded on the top sheet. The back surface of the top sheet has specified resistances connected in series as shown in 1.23(*b*), which is the inner view of the top sheet.



(a)



(b)

Fig. 1.23: Resistance Box

1.1.7. Switches

A switch is a component used for bringing a circuit into open and closed conditions respectively, by making or breaking of the contact. The contact material has to be of a suitable mechanical strength, resistive to corrosion and oxidative effects lest some resistance should get added in the circuit because of oxidation. There are two kinds of switches namely automatic and manual. For the case of automatic switch, it is operated by some sensor mechanism such as pressure, temperature or water flow etc. For example for a thermostat switch, it opens after a particular temperature is reached thus stopping the heating mechanism in the circuit. A manual switch is a normal switch operated manually like those used at two homes for lights and fans etc. Switches can also be classified on the basis of number of paths it allows for current flow by POLE and THROW terminology. Poles refer to number of separate switches which can be controlled by a single actuator. Example a three pole switch means three electrically separate switches being opened and closed in unison by the same mechanism. Throws refer to the number of wiring choices a switch can make for a single pole. For example a single pole-single throw (SPST) switch will have a single contact for a single pole as shown in Fig. 1.24. A Single pole double throw switch has a single pole with 2 contacts the switch can make as per the requirement of the circuit. Similarly one can have any number of choices *viz* 2P6T having 2 poles and 6 choices for contacts for each pole. More types of switches lie in the category push button switch, toggle switch, limit switch, flow switch and electronic switch (SCR, Triac, IGBT, DIAC, relay), Details of SCR, TRIAC, IGBT, DIAC can be referred to from chapter five on Devices.

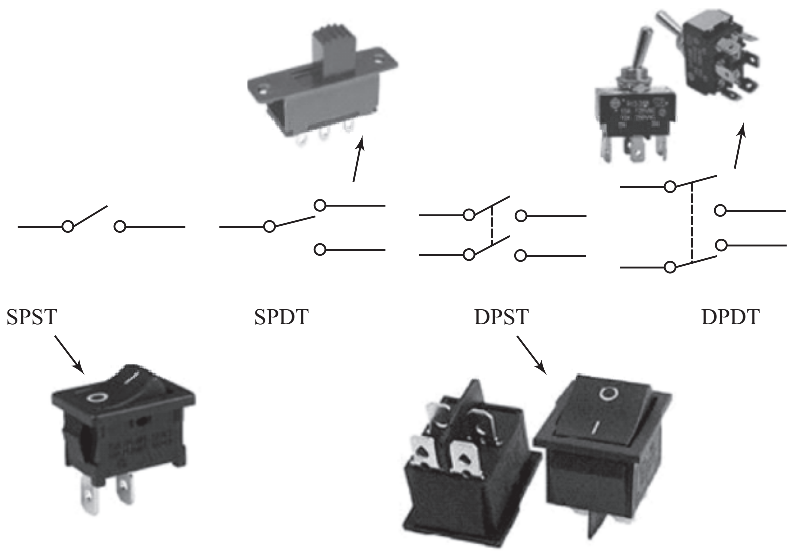


Fig. 1.24 Different Types of Switches

1.1.8. Rules for Series and Parallel Resistances

In circuits, resistors, capacitors and indicators can get connected in series or parallel and there are different rules for parallel and series connections for different components respectively.

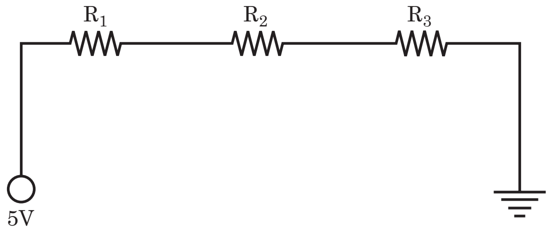


Fig. 1.25 (a) Resistances in Series

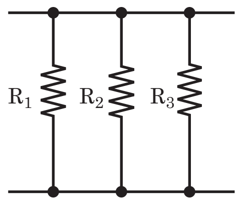


Fig. 1.25 (b) Resistances in parallel

As shown in circuit of Fig. 1.25(*a*), resistors R_1, R_2 and R_3 are connected in series such that one end of R_1 is connected to other end of R_2 and the other end of R_2 is connected R_3 and then to ground. It is like a chain and such a connection is series connection. The value of resistances get added in such a case. ($R = R_1 + R_2 + R_3$). On the other hand if these resistors are connected, such that their head and tails are tied together as in Fig. 1.25(*b*) then such resistors are said to be connected in parallel, their effective resistance is calculated as follows:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \Rightarrow R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Series and Parallel Capacitors

When capacitors are connected in series then the total effective capacitance gets lesser than capacitance of any of the capacitor. In fact they are calculated as in case of the rule for resistances in parallel.

So

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

On the other hand if capacitors are in parallel then their total capacitance gets added as the rule for resistances in series. Hence $C = C_1 + C_2 + C_3 \ldots$

Series and Parallel Inductors

The rule for series and parallel inductors is same as that of series and parallel resistors. That is in series the total effective inductance gets added and in parallel the total effective inductance as per parallel rule for resistors.

1.1.9. Voltage Division Rule

In a series circuit, containing different components, if the total input voltage is V, it gets divided into different components as per the impedance value of each component, since the current flowing through all the components is same. In Fig. 1.26, if V is the applied voltage, I is the total current flowing and Z_1 to Z_n are n impedances connected in series, then voltage drop across any nth impedance is given by $V_n = Z_n \,.\, I = Z_n .\, V/(Z_1 + Z_2 + ... + Z_n)$. Hence, the voltage drop across any impedance is the ratio of product of that impedance and total voltage to the sum of all impedances. Hence final formula for voltage drop across nth component is $V_n = \frac{V . Z_n}{Z_{total}}$.

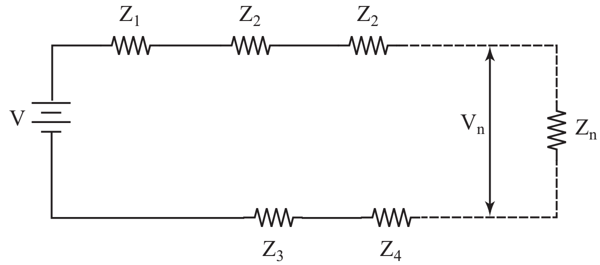


Fig. 1.26 Voltage Division Rule

1.1.10. Current Division Rule

In a parallel circuit, having a current source, the total current gets divided into different branches, as per the impedance in that branch respectively, hence the branch with a higher impedance draws lesser current and vice versa. Mathematically it is derived considering that the voltage across all the branches is same. Considering Fig. 1.27, where I is the total input current, one can write

$$I = I_1 + I_2 + ... + I_n = \frac{V}{Z_1} + \frac{V}{Z_2} + ... + \frac{V}{Z_n}$$

Using the admittance terminology, if Y_n and Y_t are admittances of nth branch and total admittance respectively then

$$\frac{I_n}{Y_n} = \frac{I}{Y_t} \Rightarrow I_n = \frac{Y_n}{Y_t} . I$$

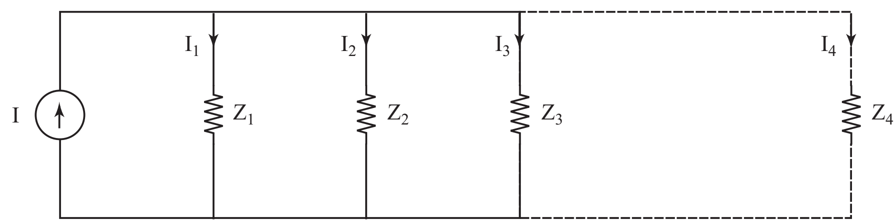


Fig. 1.27 Current Division Rule

1.1.11. Galvanometer

Galvanometer is an instrument, used for detection of magnitude and direction of a dc current. Its principle is based on the fact that when a current is passed through a current carrying conductor kept in a magnetic field, it experiences a force. Construction wise it is made up of multi turn rectangular coil made of thin insulated *Cu*. This coil is suspended by a movable torsion head in a uniform magnetic field (Fig. 1.28*a*). To improve the magnetic field a core is usually inserted in the coil. The other end of the coils is attached to Phosphor Bronze spring which is utilised to produce a counter torque which balances the magnetic torque. The deflection of the coils is measured by a plane mirror attached to the suspension wire along with a lamp and scale arrangement and zero point is at the centre of the scale for zero deflection as shown in 1.28(*b*).

Since torque (τ) is proportional to force (F) and the perpendicular distance (b) between the forces hence $\tau = F . b$. If the area of cross section (A) of the coil is ($l.b$), then torque on one turn of the coil is : $\tau = B . I . l.b$, where B is the magnetic field and I is the current. So for n turns total torque is $\tau = n . B.I.A$. Because of this magnetic torque, the coil moves, spring rotates and the angle of rotation (θ) depends on the torque. Hence one can write: $k\theta = n.B.I.A$, where k is the spring constant. In conclusion one can say that θ is proportional to current.

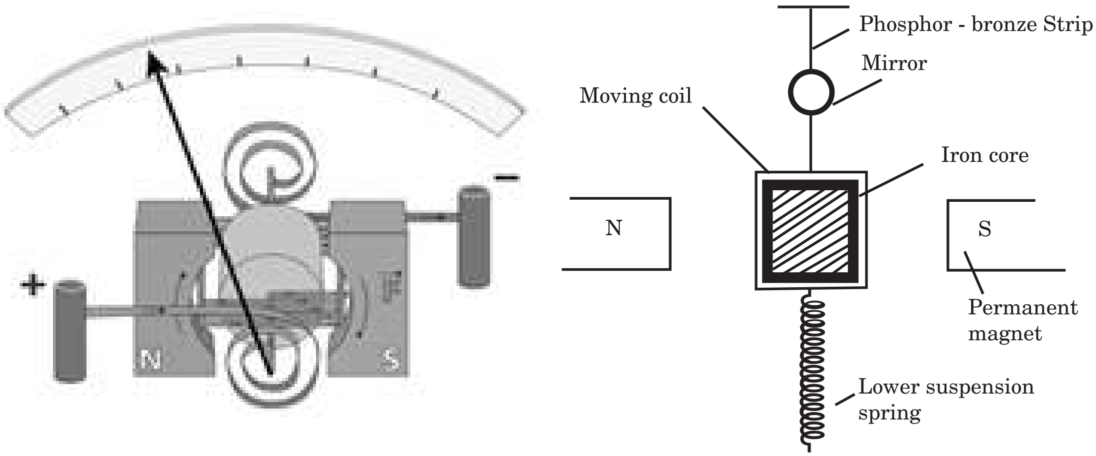


Fig. 1.28(*a*) Galvanometer (a) Movable Type (b) Suspension Type

Current sensitivity: Current sensitivity is the deflection per unit current through the coil and can be written as $\frac{\theta}{I} = \frac{n.A.B}{k}$.

Voltage sensitivity: Voltage sensitivity is the deflection per unit voltage through the coil and can be written as $\frac{\theta}{V} = n.A.\frac{B.I.}{k.V} = \frac{n.A.B}{k.R}$ where R is the resistance of the coil.

On the whole the sensitivity depends upon the area of the coil, number of turns and magnetic field.

Figure of Merit: This is the ratio of full scale deflection and the number of divisions on the scale.

1.1.12. Voltmeter

As the name suggest voltmeters are used for measuring the potential difference across two points in a circuit or a device and are connected in parallel across the component whose voltage is to be measured. The ideal internal resistance of a voltmeter is infinity but practically a resistance of highest possible value for the internal circuit is chosen. In fact the higher the internal resistance, the better are the measurement results. When a voltmeter is connected in parallel with the component (of a lower resistance), the total effective resistance is that of the lower one and the voltage across the two, is the same. If the internal resistance of the voltmeter is kept high then very less current passes through it, hence the meter does not dissipate heat. In fact the aim is not to disturb the circuit so that the circuit under measurement draws maximum current. This is also defined in terms of a parameter called sensitivity, which is defined as ohms / volt: i.e. the ratio of series resistance to the full scale voltage. Hence if the full scale is 100V and the resistance in series is 100 K then the meter would only draw 1 mA from the circuit. There are different classes of voltmeters: Permanent Magnet Moving coil (PMMC) Moving Iron (MI), Electro Dynamometer type, Rectifier type, Induction type, Electrostatic type and Digital Voltmeter (DVM). The pmma type voltmeter is based on the principle that when a current(voltage) is applied to the coil in the meter, the deflecting needle experiences a torque proportional to the current (voltage) and the needle deflects accordingly which is the principle of galvanometer also. Thus, a galvanometer can be converted to a voltmeter by connecting a resistance (R) in series. To choose the value of a series high resistance for the voltmeter, consider the circuit in Fig. 1.29 where G is the internal resistance the galvanometer coil and R is the resistance in series. Let I be the current entering and I_g be the maximum current that can pass through the galvanometer. Hence current $I-I_g$ passes through the component, whose voltage (V) is to be measured.

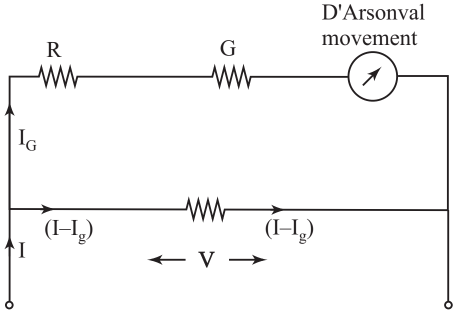


Fig. 1.29 Principle of Voltmeter

So $$V = I_g \,.\, (G + R) \Rightarrow R = V/I_g - G$$

In the moving iron (MI) type, the deflection is based on the heating effects and it is based on the principal of movement of an iron piece, which gets attracted by a coil, through which the current passes. For electro-dynamo type, there is an electromagnet instead of a permanent magnet in the instrument. For the digital voltmeter, the input analog signal value gets converted to its corresponding digital value and displayed on the LCD screen, as shown in Fig. 1.30. Voltmeters can also be classified as ac or dc voltmeters. To measure an ac signal, a rectifier circuit is added before the signal goes to the coil, so that the deflection is only in one direction.

Fig. 1.30 Digital Voltmeter

1.1.13. Ammeter

An ammeter is used to measure the current in the circuit and is always connected in series with the component whose current is to be measured, since current in series is same. Same as in the case of voltmeter, a moving coil galvanometer can also be converted into an ammeter but here a low value shunt resistance is added in parallel with the galvanometer coil. Let the value of shunt resistance be R_{sh}, I be the total current entering, I_g is the current for full scale deflection and G be the internal resistance of the galvanometer as in Fig. 1.31. Since the value of voltage is same across shunt and galvanometer and $I - I_g$ passes through the shunt then $(I - I_g) \,.\, R_{sh} = I_g \,.\, G \Rightarrow R_{sh} = I_g \,.\, G/(I - I_g)$. Ammeters can also be of various other types i.e., Moving Iron (MI), Electro Dynamometer type, Hot wire and Digital ammeter. As in the case of dc voltmeter, for dc ammeter also a rectifier circuit is added to make the current unidirectional. Refer Fig. 1.32 for the method of connecting an ammeter for measurement of current in a circuit.

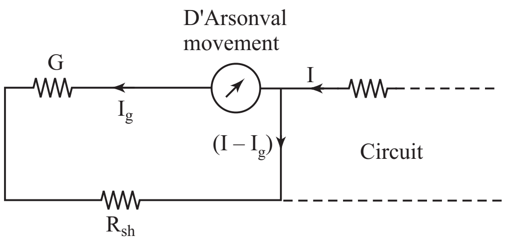


Fig. 1.31 Principle of Ammeter

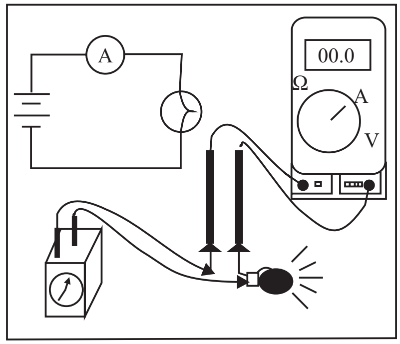


Fig. 1.32 Measument of current in a cirtuit

1.1.14. Ohm Meter

This is an instrument used for measurement of resistance. It consists of a galvanometer connected with a resistance and a source. ***Since it has an internal source of power supply hence this instrument should never be connected to a circuit having its own source because then the two sources will interfere with each other***. From amongst various types, three most types of ohmmeters are (*i*) series type, (*ii*) shunt type and (*iii*) multi range type. If the source and internal resistance are connected in series then it is of series type.

Series Ohmmeter: When the resistance to be measured is zero or when the terminals are shorted, there is maximum current through the meter and the needle deflects to extreme right as per adjustment of the internal resistance. When the terminal is open or for infinite resistance there is no current and the deflection is 0. Hence the movement of needle here is opposite to that of voltmeter and ammeter that is for 0 reading it shows maximum deflection and vice versa. As the potential of the battery decreases, the zero adjustment has to be made for the needle, for infinite resistance.

Multirange Ohmmeter : Refer Fig. 1.33 for the circuit of Multirange ohmmeter. Here the resistance to be measured is connected in parallel to the meter. The range is selected as per the component and the adjuster is adjusted for full scale deflection. Example for 1 ohm resistance, 1 ohm range is selected and the deflection is put to full scale for 1 ohm by the variable resistor. For short circuit or zero resistance the deflection is set to zero.

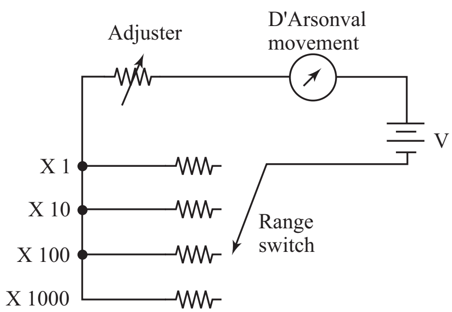


Fig. 1.33 Multirange Ohmmeter

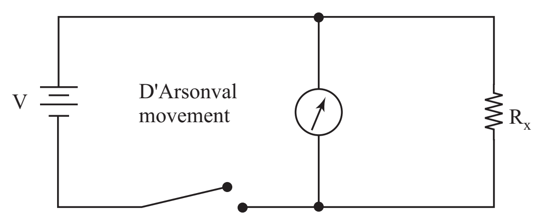


Fig. 1.34 Shunt Ohmmeter

Shunt Ohmmeter : Refer Fig. 1.34 where the resistance (R_x) is connected in parallel with the meter. When the resistance is zero or the terminals are shorted then there is no current through the meter and the deflection is zero. For very high resistance, the current through the meter is maximum leading to maximum deflection. Again here the variable resistor is adjusted for full scale deflection and also battery discharging problem remains such that adjustment needs to made before the measurement starts.

1.1.15. Analog Multimeter (VOM)

Another name for analog multimeter as shown in Fig. 1.35 is, volt ohm meter (VOM) since it is used for measuring voltage, current and resistance or is also called as AVO meter for measurement of current (A) , voltage (V) and resistance (Ohms). It is basically a PMMC meter working on the principle of d'Arsonval movement and is split into three branches for different measurements as shown in the block diagram in Fig. 1.36. There is a switch for Voltage, current or resistance measurement for which the circuits inside are same as that for individual voltmeter, ammeter or ohmmeter respectively. A major advantage of VOM is that it can detect sudden changes in signals and a very efficient increase or decrease can be observed by the needle. Its limitations are : (*i*) It is very bulky, (*ii*) Can't be used for very high frequency measurements and (*iii*) The earth's magnetic field interferes with the permanent magnet present in the VOM.

While using a VOM for measurement, it is to be noted that there is always some loading effect on the circuit because of which the measurements are not absolutely accurate *i.e.*, the reading might be little lower than the actual value. This is because for example for full scale deflection if the meter draws 50 μA of current then it may load a high impedance circuit giving a lower value. Sensitivity factors are same as those defined in the voltmeter section.

Fig. 1.35 Analog Multimeter

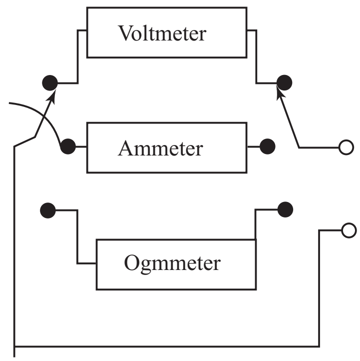


Fig. 1.36 Block Diagram of Analog Multimeter

How to use a VOM: Voltage measurement:

1. Estimate the maximum voltage expected and set it to a scale higher than the maximum voltage. Check for AC or DC and set the knob accordingly.
2. Generally there are three holes provided namely 'COM', '+10A' and 'VmAΩ' Connect the two leads (black and red)to the multimeter holes marked as 'COM' and 'VmAΩ' respectively and the other ends across the component, whose voltage is to be measured as shown in Fig. 1.37.
3. The reading is to be read as per the scale selected; for example in the diagram the scale is set to 250 V so the value is 110 V and not 25 V.

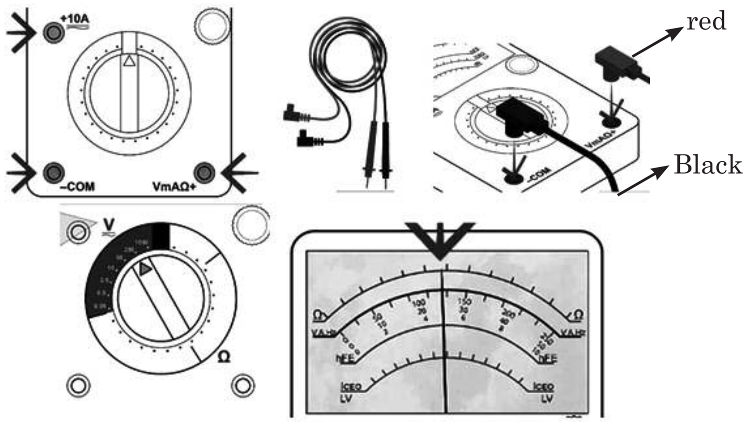


Fig. 1.37 Use of VOM for Voltage Measurement

1.1.16. Digital Multimeter (DMM)

DMM comes handy when the voltage, current or resistance values need to be read in numeric form. Higher range DMM also have features to measure more parameters like **capacitance, inductance, temperature, frequency, diode test, transistor test and can even store and graph dynamic online data**. The front panel of DMM contains: LCD screen, selection range knobs, +10A port V-mA-Ω port and port for common as shown in Fig. 1.38 More advanced DMM have additional features like:

Auto range: This is a special feature with DMM which avoids overloading. Here the meter selects its own range of voltage current or resistance when some component in circuit is connected for measurements.

Auto Off: It turns off itself if user forgets to turn it off.

Back lit LCD screen: No day light or other source is required to read the screen. It is a back lit screen having a five or six digit display screen and one digit represents the sign

Auto polarity: If the polarity of probes is connected opposite to what it should be, then it automatically reads and displays the reading with a negative sign.

Continuity test: To test the open or short conditions between two points, the range switch is directed towards the continuity selector and usually there is provision of beep for a short condition between two points.

Construction and Block Diagram

As shown in Fig. 1.39, the whole circuitry of a DMM can be divided into two parts namely DISPLAY module and testing circuitry. The display consists of an LCD screen connected to 200 mV module. The input of the measurement circuit has a mode selector switch for OHM, AC V, dc V ac current etc. In addition there is an analog to digital (A/D) convertor and BCD output.

OHMS Mode: If on Ω or resistance mode, the external resistance forms part of a potential divider circuit and is connected to a shunt current source present inside. Thus the voltage created across the shunt gets fed to a buffer amplifier. The resistance then gets converted to a voltage form, gets calibrated and then displayed as digital units on the screen in numeric form.

AC voltage mode: If the selector is on ac voltage mode, it first gets connected to a calibrated attenuator, then rectified and fed to the display module.

DC voltage mode: It is same as ac voltage mode except that rectification is not required here.

DC current mode: Here the unknown current flows through a shunt and the voltage developed is calibrated and fed to display module.

AC current mode: Here again the current passing through a shunt inside, gets converted to voltage and then passes through ac to dc converter, calibrated and fed to display module.

Fig. 1.38 Digital Multimeter

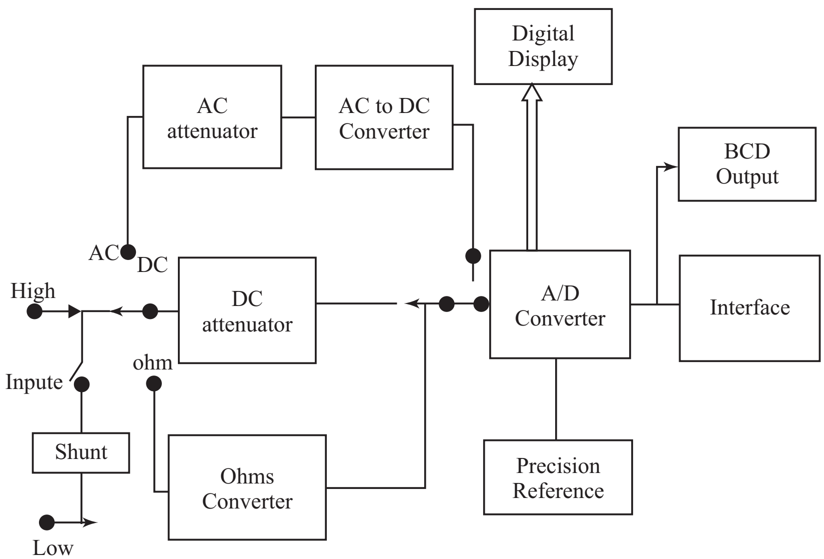


Fig. 1.39 Block Diagram of Digital Multimeter

How to use a DMM As in the case of a VOM, the mode selector switch is switched to the mode required mode example ohms mode or dc voltage and if not auto ranging, then the range is selected too. The connecting wires are then connected in parallel to a voltage measurement and in series for a current measurement. The display gives the reading in numeric form. Refer Fig. 1.40 for diagrams on the connection schemes for OHMS measurement.

Fig. 1.40 Measurement with Digital Multimeter

1.1.17. Function Generator (FG)

Function generators are used for generation of different waveforms like Sine, Square, triangular or Sawtooth of variable frequencies and amplitudes. These waveforms are required for testing of circuits and for application of signals to circuits. Some function generators are capable of doing modulations, addition of a dc voltage to the generated waveform (offset) and even phase locking with an external source. Refer Fig. 1.41 for front panel of commonly used F.G. in labs.

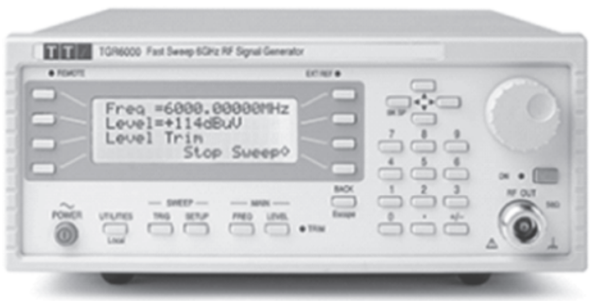


Fig. 1.41 Function Generator

Block Diagram. As shown in the block diagram of Fig. 1.42, the starting wave of an FG is a triangular wave which gets further converted to Sine or Square by separate circuits. To generate a triangular wave, the rising portion of the triangular waveform is generated by an integrator which is fed by the first voltage controlled current source. If the value of current increases, the rise is faster and the frequency changes. During the rise period, at a predetermined value, a multivibrator changes the state of the integrator and disconnects voltage source one and connects another voltage source to the integrator such that there is a linear fall in the waveform. Again at a predetermined lower value, the multivibrator changes state. and the integrator starts to rise in the waveform. Thus a triangular wave gets produced whose frequency can be changed by the current source. A saw tooth waveform can be produced by charging the integrator very slowly and very fast discharge.

The triangular waveform can be fed to any of the two shaper circuits which can convert it to either square wave or sine wave for shaper circuits, one can refer to chapter on OPAMPS.

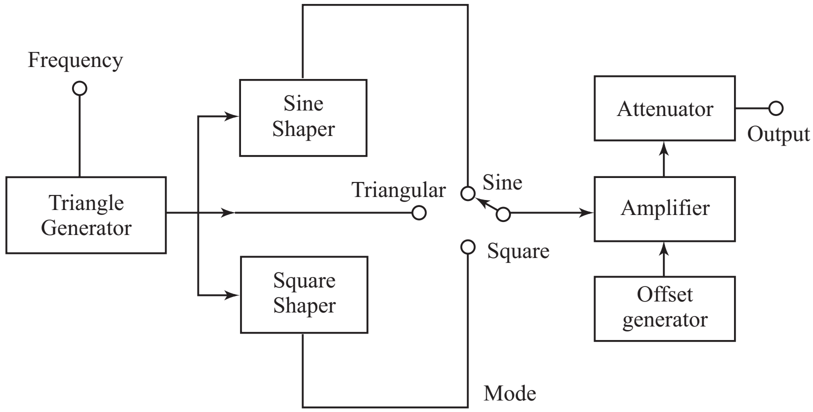


Fig. 1.42 Block Diagram of Digital Function Generator

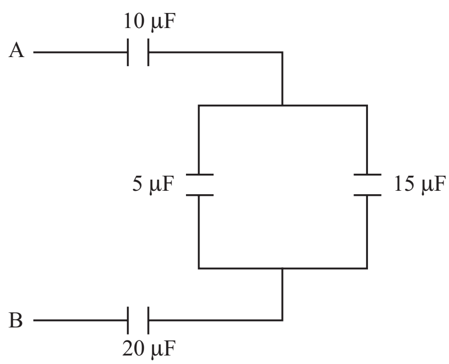
1.1.18. Audio Oscillator

An audio oscillator works on lower frequencies in the range of 20 Hz – 20 KHz. Unlike an F.G. it has simple RC or LC oscillator circuits to generate sine wave and for square wave multi vibrator circuit or shaper circuits are used. Typical front panel view of an audio oscillator is given in Fig. 1.43.

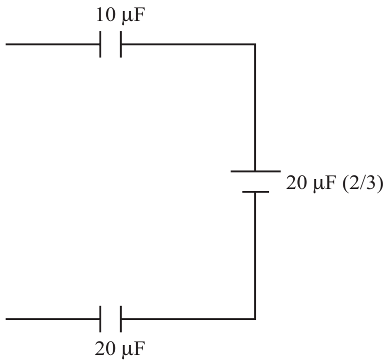
Fig. 1.43 Audio Oscillator

1.2. SOLVED EXAMPLES

Ex. 1.2.1. Calculate the equivalent capacitance in the following circuit.



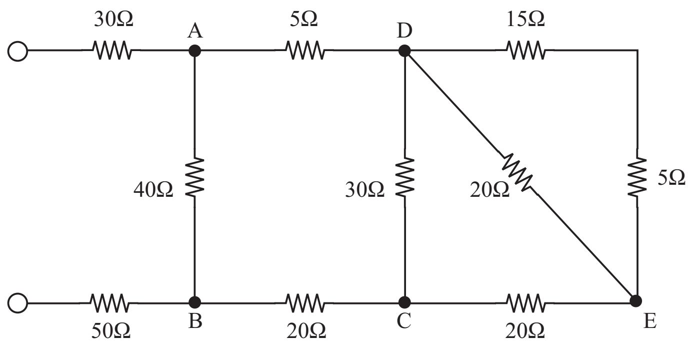
Sol. Parallel capacitance of 5 μF and 15 μF add up to give 20 μF as shown below.



From above figure, the final equivalent capacitance is

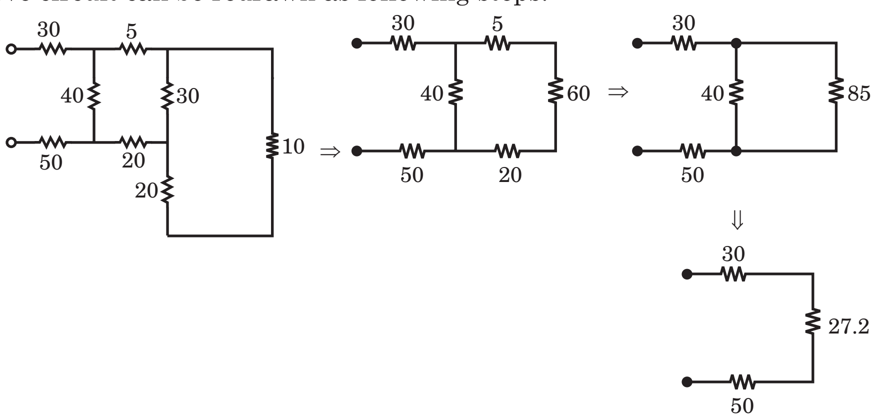
$$C = \frac{1}{\frac{1}{10}+\frac{1}{20}+\frac{1}{20}} = 5\mu F\,.$$

Ex. 1.2.2. Calculate the equivalent resistance for the following



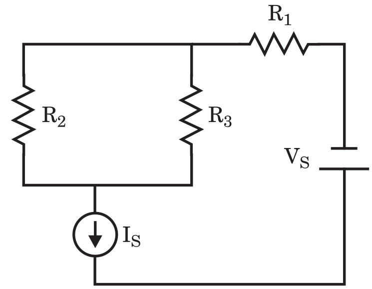
Sol.

The above circuit can be redrawn as following steps:



Hence final equivalent resistance is 30 Ω + 50 Ω + 27.2 Ω = 107.2 Ω

Ex. 1.2.3. Find currents through the resistors $R_1 = 2\Omega$, $R_2 = 4\Omega$ and $R_3 = 1\Omega$, $I_s = 5A$ and $V_s = 4V$.



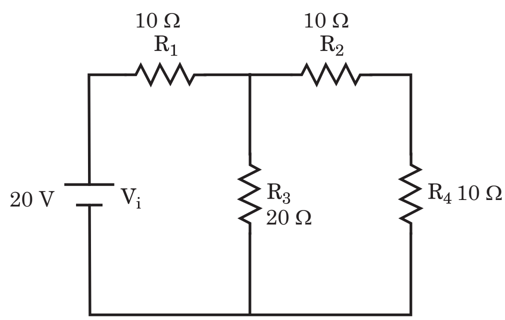
Sol. By current division rule

$$I_{R_2} = \frac{R_3}{R_2 + R_3} \times I_S = \frac{1}{1+4} \times 5 = 1\,A$$

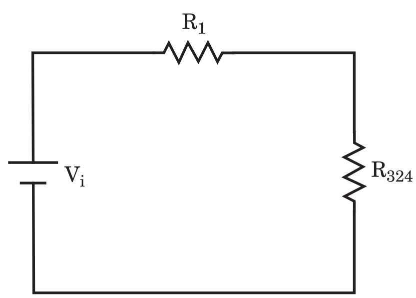
$$I_{R_3} = \frac{R_2}{R_2 + R_3} \times I_S = \frac{4}{1+4} \times 5 = 4\,A$$

Current from I_S passes through V_s and R_1 and = 5A.

Ex. 1.2.4. Find the voltage drops across all the resistors in the following circuit.

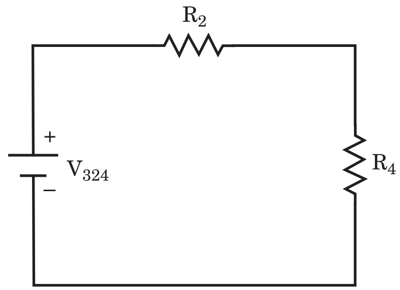


Sol. The resistors R_2, R_3 and R_4 can be combined as follows $R_3 \| (R_2 + R_4) = R_{324} = 10\ \Omega$



Hence
$$V_{R_{324}} = \frac{R_{324}}{R_{324} + R_1} \times V_1 = \frac{10}{10+10} \times 20 = 10V$$

Now one can write the voltage drops across R_3 and R_4 as



And Write:

$$V_{R_2} = \frac{R_2}{R_2 + R_4} V_{R_{324}} = \frac{10}{10+10} 10 = 5V$$

$$V_{R_4} = \frac{R_4}{R_2 + R_4} V_{R_{324}} = \frac{10}{10+10} 10 = 5V$$

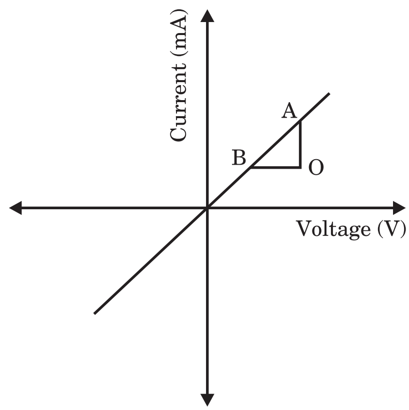
1.3. EXPERIMENTS

1.3.1. Objective

Verify Ohm's law for the given circuits, and to find out the value of unknown resistance by using (*a*) constant power supply and rheostat (*b*) by using a variable power supply

Apparatus. Resistances, breadboard, jumper wires, variable power supply, voltmeter, ammeter, multimeter, rheostat.

Theory. Ohm's law states that under unchanged physical conditions and constant temperature, current I through a conductor between two points is directly proportional to the potential difference V between the points. Hence $I \propto V$. Introducing a constant of proportionality R, which is also the resistance of that conductor, one gets $I = V/R$. Hence resistance can be calculated by taking slope of current voltage characteristics shown in as follows. $R = 1/\text{slope} = OB/OA$.



Ohm's Law

Pre-requisite and pre-test

1. What is Ohm's law?
2. How does a rheostat work as a voltage divider?
3. What are the two rheostat settings?
4. What is meant by rating and tolerance of resistor?
5. What are the expected ranges of voltmeter or ammeters to be used?

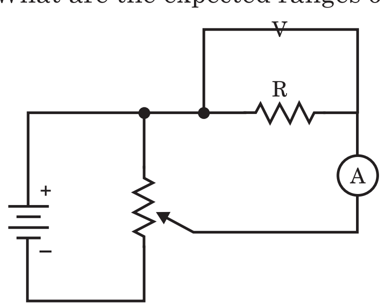


Fig. 1.44

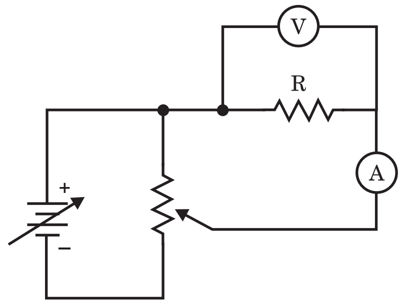


Fig. 1.45

Procedure

1. Test the bread board for continuity, as given in section 1.15.
2. Connect the circuit as shown in Fig. 1.44 for part "*a*", with power supply in the OFF position.
3. Starting from 0V increase the voltage, in steps of 2 V, till a maximum of 20 V and note the readings of voltage and current in the Table 1.4. plot the graph.
4. Next for part "*b*", connect the circuit as in Fig. 1.45, with power supply in off position such that the rheostat tab should in an extreme position.
5. Next switch on the power supply such that its reading is 20 V (with rheostat tab is on extreme end). Note the voltage and current readings. Now slide the tab such that there is an increment of 2 volts and note the corresponding voltage and current readings in Table 1.5.
6. Repeat the observations by sliding of tab, with increment of 2 V in each step, plot the graph.

Observations and Calculations:

Table 1.4

S.N.	*Voltage (V)*	*Current (mA)*	*R (Ω)*
1	0	0	
2	2	1	2k
3	4	2	2k
	. .	. .	. .

Table 1.5

S.N.	*Voltage (V)*	*Current (mA)*	*R (Ω)*
1	0	0	
2	2	1	2k
3	4	2	2k
	. .	. .	. .

Results. As calculated from the slope of the graph, the value of unknown resistance was found to be ....k from both tables. Also the multimeter value was found to be the same as well.

Precautions

1. The connections should be tight.
2. If using a VOM, care should be taken to avoid parallax error.
3. The power supply should not be switched on before the connections are made.
4. Care should be taken not to exceed the approximate rating of the resistor.

Sources of Error

1. If using a VOM or an analog meter, parallax error is common.
2. The value of resistor may not be necessarily be that as marked.

1.3.2. Objective

To calculate the current through resistance R_x and verify it experimentally.

Apparatus. Resistances, breadboard, jumper wires, power supply, voltmeter, ammeter, multimeter.

Pre-requisite and pre-test

1. What is current division rule?
2. What is a current source?
3. How does a rheostat work as a voltage divider?

Procedure

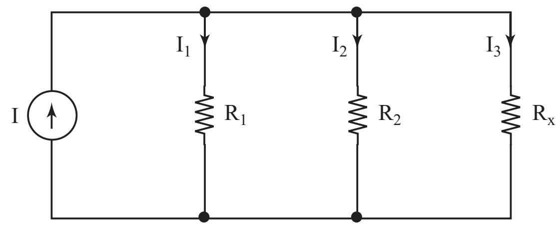


Fig. 1.46 Circuit for determination of Current.

1. Test the bread board for continuity
2. Connect the circuit as shown in Fig. 1.46 with power supply on OFF position.
3. Calculate the current by current division rule through R_1, R_2 and R_x.
4. Connect an ammeter or a multimeter and observe the current reading in different branches and verify with theoretical values.

Observations and Calculations:

	Voltage	*Current*	*Resistance*
R1	6		1k
R2	6		2k
R3	6		3k
Total	6		

Current through any resistor $Rn = I_T \,.\, R_T/R_n$

Result: The current division rule was verified experimentally and theoretically.

Precautions

1. The connections should be tight.
2. If using a VOM, care should be taken to avoid parallax error.
3. The power supply should not be switched on before the connections are made.
4. Care should be taken not to exceed the approximate rating of the resistor.

Sources of Error

If using a VOM or an analog meter, parallax error is common

1.3.3. Objective

To calculate the voltage across all resistors and verify it experimentally

Apparatus. Resistances, breadboard, jumper wires, power supply, voltmeter, and ammeter, multimeter.

Pre requisite and pre test

1. What is voltage division rule?
2. Same as in exp 1.31 and exp 1.32.

Procedure

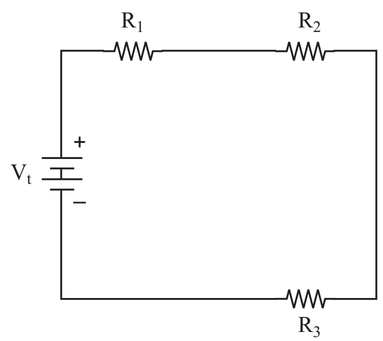


Fig. 1.47 Circuit for determination of voltages

1. Test the bread board for continuity
2. Connect the circuit as shown in Fig. 1.47 with power supply on OFF position.
3. Calculate the voltage by voltage division rule, for R1, R2 and R3.
4. Connect a voltmeter or a multimeter and observe the voltage values across all resistors.

Observations and Calculations:

	Voltage	*Current*	*Resistance*
R_1			1 k
R_2			2 k
R_3			3 k
Total R_t			

Voltage through any resistance is given by $V_n = V_t . R_n/R_t$,$R_t = R_1 + R_2 + R_3$

Results The voltage division rule was verified experimentally and theoretically

Precautions

1. The connections should be tight.
2. If using a VOM, care should be taken to avoid parallax error.
3. The power supply should not be switched on before the connections are made.
4. Care should be taken not to exceed the approximate rating of the resistor.

Sources of Error

If using a VOM or an analog meter, parallax error is common.

1.4. PROJECT

Objective: Control the color of a bicolor LED with the help of a POT, spdt switch and 9 volt battery.

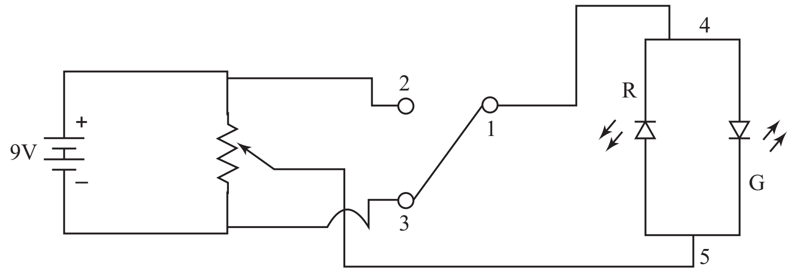


Fig. Circuit for conts of color of LED

In the above circuit, 500 Ω or 1 k pot is used. Bicolor LED has 2 terminals 4 and 5. If 4 is at higher potential than 5 then green colors is emitted and if 4 is at lower potential than 5 then red color is emitted. Terminal 5 is connected to center point of rheostat as shown. Configuration 1,2,3 is of a spdt. If 1 is thrown at 2 then green glows since terminal 4 is at 9 V and terminal 5 is at 4.5 V. If 1 is connected to 3 then red glows since now terminal 4 is at 0 V and terminal 5 is at 4.5 V.

1.5. SUMMARY

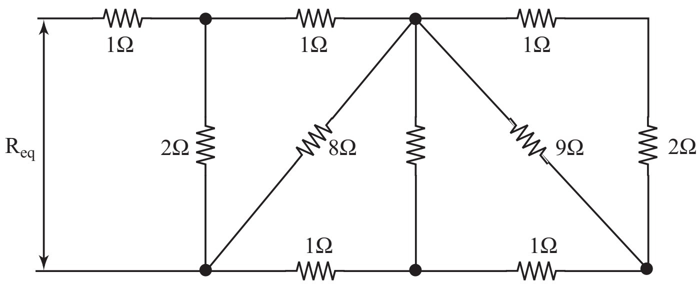
1. Active components are generally made of semiconductors which are capable of amplifying or modulating an input signal and can modify the direction of current viz diodes, transistors. Passive components do not need an external supply for biasing and generally dissipate power through them Example are resistors, capacitors and relays etc.
2. Resistors are components capable of reducing the current and dissipate heat through them. They can be of standard or variable type. The color code of standard resistors is given by BBROYGBVGW and the last two bands are given for tolerance. They have a power rating beyond which, if the current flows, the resistor would burn.
3. A rheostat or potentiometer can either be used as a variable resistor or a potential divider.
4. Capacitor is capable of storing and discharging of charges. It is a component having a dielectric surrounded by two conducting plates. It offers short to an ac current and of open for a dc current. They can be of electrolytic and non-electrolytic types and also variable type. $C = \epsilon_o \epsilon_r A/d$
5. Inductors are made up of a conductor coil with or without a core in between. Their main use is for storing charge in the form of magnetic field and inducing of an emf. $L = \mu_o \mu_r N^2 A/l$. The core in an inductor helps to save and direct the magnetic field lines.
6. Relays are based on the principle of electromagnetic induction. They are used as ON or OFF switches which are themselves triggered by a very small current transduced by energy forms like light or temperature and finally help to trigger an output circuit of much higher power.
7. Transformer is based on the principle of electromagnetic induction. It has primary and a secondary coils wound around a core. It is usually used for stepping up or stepping down of voltages. The input power and output power of an ideal transformer is conserved. $V_2/V_1 = N_2/N_1 = n$ is the transformation ratio. Its EMF equation is $E = 4.44$ f.N. ϕ_m.
8. Breadboard is a board for testing and connecting prototype circuits. It has patterned horizontal and vertical lines of holes which are connected from the back and is made of plastic.

9. Resistance box is made up of standard resistors such that the user has a choice to select a resistance and connect in a circuit without disconnecting the circuit again and again. Just two knobs of the box are connected to the circuit. It has brass lugs at the back and top sheet is made of Bakelite.
10. Voltage division rule: The voltage drop across nth component of resistance R_n, in a series circuit is the ratio of product of R_n and total voltage (V_t) to total resistance (R_t) of all series components. $V_n = V_t . R_n/R_t$.
11. Current Division Rule states that in a circuit having parallel branches, the current through a branch of admittance Y_n is $Y_n = I_t . Y_n/Y_t$, where, I_t is total current and Y_t is total admittance of all branches.
12. Switches are used for bringing a circuit in open and closed positions. Nomenclature wise, terms of throws and poles are used. SPDT means single throw double pole.
13. Voltmeter has to be connected in parallel across the component whose voltage is to be measured.
14. Voltmeter internal resistance should be very high and its value is $R = V/I_g - G$. Sensitivity is defined as the ratio of series resistance to the full scale voltage and its unit is ohms/ volts. If the internal resistance is 100k and full scale deflection is 100V then it draws 100mA circuit.
15. Ammeter needs to be connected in series in the circuit.
16. It has a low shunt internal resistance given by $R_{sh} = I_g . G/(I - I_g)$.
17. Ohm meter has an internal voltage source and a series or parallel resistance inside. It can not be connected to a component for measurement while the circuit is on or when the component is connected in a closed circuit.
18. VOM-(volt ohm meter) is an analog meter for measurement of volts, ohm and current.
19. Digital multimeter (DMM) has circuits to convert all data (like current, resistance) to an equivalent analog voltage which then gets converted to its digital form and displayed on the LCD screen as numerics. Advanced DMM have features to measure capacitance, inductance, temperature and can even store digital data or dynamic online data and display in graphical form.
20. Function generators can give waveforms of sine, square, triangular or sawtooth, with variable frequencies, amplitudes, attenuation, frequency modulation and phase locking facilities. It basically converts a generated triangular waveform to sine or square shapes. The inital triangular wave is generated by an integrator circuit.
21. Audio oscillators can give sine or square waveforms in audio frequency range of variable amplitude and attenuation. The circuits inside may be of a RC, LC or bridge oscillator or it can be of op amp type.

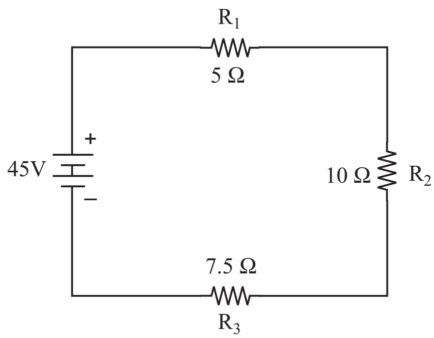
1.6. QUESTIONS

1. How does resistance change with temperature for a conductor and a semiconductor?
2. Differentiate between a rheostat and a potentiometer.
3. What are the conditions under which ohm's law is not applicable?
4. Is ohm's law valid for AC circuits?
5. Differentiate between an electrolytic and a non-electrolytic capacitor.
6. State the principle of a transformer.
7. Can a transistor voltage amplifier be replaced by a transformer?

8. How does a relay work?
9. Can a two winding normal transformer be converted to a center tap transformer?
10. What is the use of lamination in transformer coils?
11. Why is the rating of transformer given in KVA and not watts?
12. What is an ideal transformer?
13. What are the different losses in a transformer and how can they be reduced?
14. Calculate the effective resistance in the circuit.



15. In the following figure find the voltages across all the components by voltage division rule.
16. How is a SPDT different than SPST switch?
17. What resistance must be connected to enable the galvanometer of resistance 5Ω and with a full scale deflection 15 mA to read 1.5V?
18. Why should a voltmeter have a very high internal resistance?



19. Why can't the measurements of resistance be made while connected in a circuit?
20. What are the advantages and disadvantages of digital and analog meters?
21. Why is there a log scale on ohmmeters?
22. How does one test if a dc offset has been added to the signal in the function generator?
23. What is the function of attenuation knob in FG?
24. Differentiate between an audio oscillator and a function generator.
25. Why is the name function generator given to it and why is an audio oscillator coined as audio oscillator.
26. Why is a fuse required in a multimeter?
27. What will happen if one connects a multimeter in parallel across a component to measure the voltage but puts the DMM on current mode accidentally instead of voltage mode?
28. What will happen if a voltmeter is connected in series?