INTRODUCTION

Have you ever thought about the importance of electronics in our daily life? The electronic devices and their usages have influenced our daily life in such a way that it is impossible to spend even a few hours without them. Right from the beginning of the day till the time we go to bed, we use a large number of electronic gadgets to simplify our work and to solve our problems. From small alarm watches to complex computers, from mobile to the camcorders, from kitchen to toilet, from bedroom to office, everywhere electronic items can be seen. It seems that they are omnipresent.

Why have we become so dependent on electronics? The answer is very simple. They simplify our daily activities and lifestyle. Let us take the example of mobile phone. It has changed the definition of communication. In the beginning of the history of telephone system, no one would have imagined a combination of ‘talking and walking.’ The invention of mobile phones has made talking while walking possible.

CD drives, DVD players, record players, stereos and tape recorders are the result of the advancement in electronic technology in the last few decades. With the use of headphones, music can be heard without disturbing the people nearby.

The introduction of electronic technology in cameras has completely changed the history of photography. A digital camera is now available at an affordable price. The cell phones now include a fairly sophisticated digital camera that can capture still pictures and even video pictures. The videos and pictures can be easily transferred to a computer, where they can be saved, shared on internet or printed out in hard form. Such pictures taken from a camera can be edited, cropped, enhanced or enlarged easily with the help of electronics.
Even our kitchens are equipped with electronic equipment, from water coolers to microwave ovens. Doctors and scientists have found new uses of electronic systems in the diagnosis and treatment of various diseases. Equipment such as MRI, CT and the X-rays rely on electronics in order to do their work quickly and accurately.

**Activity 1**

Prepare a list of electronic equipment that are used in your day to day life. The figure 1.1 will help you to do this activity.

![Fig 1.1 Some applications of electronics in daily life](image)

- Have you realized that electronics plays a very important role in your daily life?
- Do you wonder about the rapid development of electronic equipment in every field of life?

### 1.1 WHAT IS ELECTRONICS?

The electronic equipment mentioned in the previous section have several electronic components in it like resistors, inductors, capacitors, diodes, transistors, ICs, etc. The components like diodes, transistors and ICs are made up of semiconductor materials. The working of these components is based on the amount and direction of current flowing through them.

The word electronics means ‘pertaining to electrons’. Electronics can be defined as the branch of science and engineering which deals with the controlled flow of electrons through vacuum, gas or semiconductors.
Compared to the more established branches of engineering - civil, mechanical and electrical, electronics is a newcomer. Until around 1960, it was considered as an integral part of electrical engineering. But due to the tremendous advancement over the last few decades, electronics has now gained its own place. The advancement has been so fast that many sub-branches of electronics - such as Computer Science Engineering, Communication Engineering, Control and Instrumentation Engineering and Information Technology - are now full-fledged courses in many universities.

1.2 HISTORY OF ELECTRONICS

Invention of Vacuum Tubes

Electronics took birth in 1897 when J.A. Fleming developed a vacuum diode. Useful electronics came in 1906 when vacuum triode was invented by Lee De Forest. This device could amplify electrical signals. Later, around 1925, tetrode and pentode vacuum tubes were developed. These tubes dominated the field of electronics till the end of World War II.

Invention of Transistor

The era of semiconductor electronics began with the invention of the junction transistor in 1948 at Bell Laboratories. Soon, the transistors replaced the bulky vacuum tubes in different electronic circuits. The tubes had major limitations: power was consumed even when they were not in use and filaments burnt out, requiring frequent tube replacements. By now, vacuum tubes have become obsolete.

A vacuum tube, electron tube or thermionic valve is a device controlling electric current through a vacuum in a sealed container. The container is often made with thin transparent glass in a roughly cylindrical shape. The simplest vacuum tube, the diode, is similar to an incandescent light bulb with an added electrode inside. When the bulb’s filament is heated red-hot, electrons leave its surface into the vacuum inside the bulb. If the electrode-called a "plate" or "anode"-is made more positive than the hot filament, a direct current flows through the vacuum to the electrode.

As the current flows only in one direction, it is possible to convert an alternating current applied to the filament to direct current. As electrodes are added, these devices can be used for various other applications. Tubes with three electrodes are known as triodes, that with four as tetrodes and five as pentodes.

John Bardeen, Walter Brattain and William Shockley were awarded the Nobel Prize in Physics in 1956 for the invention of transistor.
Earlier, the transistors were made of germanium, as it was easier to purify. In 1954, silicon transistors were developed. These afforded operations up to 200°C, whereas germanium device could work well only up to about 75°C. Today, almost all semiconductor devices are fabricated using silicon.

**Invention of the Integrated Circuits (IC)**

In 1958, Jack Kilby conceived the concept of building an entire electronic circuit on a single semiconductor chip. Later, all active and passive components and their interconnections could be integrated on a single chip. This drastically reduced the size and weight, as well as the cost of electronic equipment.

The following approximate data give some indication of the increasing component count per chip of area 3 × 5 mm² and thickness comparable with human hair.

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951</td>
<td>Discrete transistors</td>
</tr>
<tr>
<td>1960</td>
<td>Small-Scale Integration (SSI), fewer than 100 transistors.</td>
</tr>
<tr>
<td>1966</td>
<td>Medium-Scale Integration (MSI), 100 to 1000 transistors.</td>
</tr>
<tr>
<td>1969</td>
<td>Large-Scale Integration (LSI), 1000 to 10000 transistors.</td>
</tr>
<tr>
<td>1975</td>
<td>Very-Large-Scale Integration (VLSI), more than 10000 transistors.</td>
</tr>
<tr>
<td>1994</td>
<td>Ultra-large-scale integration (ULSI) more than 1 million transistors.</td>
</tr>
<tr>
<td>2012</td>
<td><strong>INTEL</strong> introduced a computer processor chip (62-Core Xeon Phi) containing 5,000,000,000 transistors</td>
</tr>
</tbody>
</table>

**1.3 APPLICATIONS OF ELECTRONICS**

Electronics plays an important role in almost every sphere of our life. Electronics has penetrated in every field from an ordinary wrist watch to super computers; from telephone repeaters
buried deep under sea to the satellites far out in space; from the control of modern household appliances to the control of super tankers carrying cargo across the sea.

**Communication and Entertainment**

The progress of a nation depends upon the availability of cheaper and faster means of communication. The main application of electronics in the beginning was in the field of telephony and telegraphy. These utilize a pair of wires as communication channel. Later it was possible to transmit any message from one place to another without wires (wireless communication). Satellite communication has reduced the distance between people and places.

**Achievements of Sir J. C. Bose in the field of communication**

- He invented the Mercury Coherer (together with the telephone receiver) used by Guglielmo Marconi to receive the radio signal in his first transatlantic radio communication over a distance of 2000 miles from Poldhu, UK to Newfoundland, St. Johns in December 1901.
- In 1895, he gave his first public demonstration of electromagnetic waves, using them to ring a bell remotely and to explode some gunpowder. He sent an electromagnetic wave across 75 feet passing through walls of the room and body of the Chairman, Lieutenant Governor of Bengal.
- He holds the first patent worldwide to detect EM waves using solid-state diode detector.
- He was a pioneer in the field of microwave devices.

Radio and TV broadcasting provide a means of both communication as well as entertainment. Electronic gadgets like tape recorders, music and video players, stereo systems, public address systems, etc. are widely used for entertainment.

**Applications in Defence sector**

In a war, success or defeat of a nation depends on the reliability of its communication system. In modern warfare, communication is almost entirely electronic. Guided missiles are completely controlled by electronic circuits.

One of the most important developments during World War II was the RADAR (Radio Amplification Detection And Ranging). By using RADAR it is possible not only to detect, but also to find the exact location of the enemy aircraft. The anti-aircraft guns can then be accurately
directed to shoot down the aircraft. In fact the RADAR and anti-aircraft guns can be linked by an automatic control system to make a complete unit.

**Applications of electronics in defence: Missiles, RADARS, warplane and communication setup**

**Instrumentation**
Instrumentation plays a very important role in any industry and research organisation, for precise measurement of various quantities. Very accurate and user-friendly instruments like digital voltmeter (DVM), cathode ray oscilloscope (CRO), frequency counter, signal generator, strain gauge, pH-meter, spectrum analysers, etc. are some of the electronic equipment without which no research laboratory is complete.

**Medical Electronics**

![Fig 1.2](image_url)

Some applications of electronics in Medical field
Electronic equipment are being used extensively in the medical field. They not only assist in diagnosis but also help in the researches that provide treatment and cure for illnesses and even genetic anomalies. Examples are Electron microscope, ECG, EEG, X-rays, defibrillator, oscilloscopes, MRI, CT scanner, glucometer, etc. Some of the instruments are shown in the fig. 1.2.

Activity 2

Prepare a list of electronic devices that are used in the medical field. Mention their applications also.

- Do you know which instruments are used to determine the condition of heart of a patient?
- Which instrument is used to take pictures of the internal bone structure of a patient?

Applications in Industries

Use of automatic control systems in different industries is increasing day by day. The thickness, quality and weight of a material can be easily controlled by electronic circuits. Electronic circuits are used to control the operations of automatic door openers, lighting systems, power systems, safety devices, etc.

Use of computer has made the ticket reservations in railways and airways simple and convenient. Even the power stations, which generate thousands of megawatts of electricity, are controlled by electronic circuits.

Applications in Automobiles

Several electronic equipment are used in cars for charging battery, enabling power assisting functions, measuring gauges and monitoring and controlling the engine performance. The most important application is electronic ignition, which provides better timing of the ignition spark, especially at high speeds.

Automobile industry is one of the fastest growing sectors in the world. The end users are demanding greater fuel efficiency, security and safety. This is possible because of the rapid development in the technology. Other areas of application in automobile are parking sensors, auto wipers, auto lights, safety (e.g. Air bags), security, anti-theft systems, etc.

Consumer Electronics

We use fans in our home, class rooms, library, etc. You are familiar with the electronic regulators used with them. Have you ever thought of the mechanism behind that? Here we use an electronic component known as TRIAC to control the speed of the fan. The speed of the fan is directly proportional to the electric power reaching the motor. The regulator controls the speed by controlling the electric power. The regulator controls electric power according to the position of the knob. Special electronic components like Silicon Controlled Rectifiers (SCRs) are used in the speed-control of motors, power rectifiers and inverters.
### ELECTRONICS INSIDE A CAR

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>The engine is the heart of a car. The circuit that automates the amount of fuel that should enter the engine is governed by the Electronic Control Unit (ECU). It decides the amount of fuel to be injected inside the engine with the help of the pressure sensor, throttle position sensor, oxygen sensor, fuel injector, etc. The main aim of using the ECU is to increase the fuel efficiency of a car.</td>
</tr>
<tr>
<td>Transmission</td>
<td>Typically, there are two types of transmission used in cars - manual and automatic, also known as manual gearing or automatic gearing. Electronics plays a more significant role in automatic-transmission. Herein, the automatic transmission of a car is controlled by the Transmission Control Unit (TCU). The TCU collects information from the sensors attached to the vehicle. It further uses the data to do gear shifting at the right time, which helps to increase the car's performance.</td>
</tr>
<tr>
<td>Brakes</td>
<td>Anti-lock Brake Systems (ABS) are becoming increasingly popular in cars. This system helps to stop the car faster without losing the balance. The ABS has four major parts - speed sensors, controllers, valves and pump. The first two utilize electronic circuits.</td>
</tr>
<tr>
<td>Dashboard</td>
<td>The dashboard basically contains panels that show the readings of the different sensors. It gives indication of the fuel level, the speed at which the car is running, the information regarding the oil level, the neutral state of car, etc. The dashboard of a car can also have the GPS, audio systems, air-conditioner controls, etc.</td>
</tr>
</tbody>
</table>

Home appliances are used 24 hours a day, 7 days a week. It includes personal computers, telephones, audio equipment, televisions, calculators, washing machines, DVD players, etc. Some home appliances are shown in the fig. 1.3.

![Fig 1.3 (a) Washing machine (b) TV (c) Radio (d) Mobile Phone](image)
Activity 3

Prepare a list of electronic equipment that you know like those given below and classify them according to their fields of applications:


1.4 ELECTRONIC COMPONENTS - ACTIVE AND PASSIVE

Electronic components can be broadly classified into active and passive components. Active Components are electronic components which are capable of amplifying or processing an electrical signal, e.g.: Diodes, Transistors, etc. Passive Components are electronic components which are not capable of amplifying or processing an electrical signal, e.g.: resistors, capacitors and inductors.

1.5 RESISTORS

A resistor is a two terminal component which provides resistance to the flow of current in a circuit. The symbols are shown in fig. 1.4.

All resistors have power ratings. It is the maximum power that can be dissipated without damaging the component. Thus, a 1 watt resistor with a resistance of 100 Ω can pass a maximum current of 100 mA.

The size of a resistor is usually bigger if its wattage rating is higher, so as to withstand higher power dissipation. Resistors can be broadly classified into two groups-fixed and variable.

Fixed Resistors

A fixed resistor is one for which the value of its resistance is specified and cannot be varied in general. These resistors may be carbon-composition resistors, carbon film resistors or wire wound resistors.

Carbon composition resistor

The resistive material in carbon composition resistor is of carbon-clay composition. The two materials are mixed in the proportions needed for the desired value of the resistor. The value of the resistor is directly proportional to the amount of the mixture. The resistor element is enclosed in a plastic case as shown in figure, for insulation and mechanical strength.
The leads are made of tinned copper. Resistors of this type are readily available in values ranging from a few ohms to about 22 MΩ, with tolerance range of 5 to 20%, and wattage ratings of ¼ W, ½ W, 1 W and 2 W.

**Carbon film resistors**

Carbon film resistors are made by depositing a homogeneous film of pure carbon over a glass, ceramic or other insulating core. Its basic structure is shown in fig. 1.6.

Desired values are obtained by either trimming the layer thickness or by cutting helical grooves of suitable pitch along its length. During this process the value of resistance is monitored constantly. The cutting of grooves is stopped as soon as the desired value of resistance is obtained. Contact caps are fixed on both ends. This type of film resistor is sometimes called precision type as it can be obtained with tolerance of ±1%.

**Wire wound resistor**

When ratings of more than 1 watt are required, we generally use wire wound resistors. It uses a resistance wire such as nichrome. A thin nichrome wire is wound on a ceramic or porcelain core. The ends of the wire are attached to metal pieces inserted in the core. Tinned copper wire leads are attached to these metal pieces. This assembly is coated with enamel containing powdered glass. These resistors are available in the range of 1 Ω to 100 kΩ, and power ratings up to about 200 W.

**Colour coding of Resistors**

Carbon-composition and carbon film resistors are small in size. It becomes almost impossible to print the ratings on their body. Therefore, a standard colour coding is used to indicate the ratings.

The resistance is given in the form of four (or five) coloured signs (or bands) painted on the body. The coloured bands are always read from left to right from the end that has the bands closer to it, as shown in Fig. 1.8.
The first and second colour bands represent the first and second numbers (significant digits) of the resistance value. The third band indicates the multiplication factor. The fourth band represents tolerance. It is a measure of the precision with which the resistor was manufactured. In case the fourth band is not present, the tolerance is assumed ±20%. Resistance value calculation from colour coding is shown in Fig 1.9.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Significant figures</th>
<th>Multiplier</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>x10^0</td>
<td>±1%</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>x10^1</td>
<td>±1%</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>x10^2</td>
<td>±2%</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>x10^3</td>
<td>±2%</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>x10^4</td>
<td>±5%</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>x10^5</td>
<td>±0.5%</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>x10^6</td>
<td>±0.25%</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>x10^7</td>
<td>±0.1%</td>
</tr>
<tr>
<td>Gray</td>
<td>8</td>
<td>x10^8</td>
<td>±0.05%</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>x10^9</td>
<td>-</td>
</tr>
<tr>
<td>Gold</td>
<td>-</td>
<td>x10^1</td>
<td>±5%</td>
</tr>
<tr>
<td>Silver</td>
<td>-</td>
<td>x10^2</td>
<td>±10%</td>
</tr>
<tr>
<td>None</td>
<td>-</td>
<td>-</td>
<td>±20%</td>
</tr>
</tbody>
</table>

Fig 1.9 Colour Coding Table
For example a resistor has a colour band sequence: yellow, violet, orange and gold. With the help of the colour coding table in Fig. 1.9, we can calculate the value of this resistor as shown in the table below.

<table>
<thead>
<tr>
<th>1st band</th>
<th>2nd band</th>
<th>3rd band</th>
<th>4th band</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>Violet</td>
<td>Orange</td>
<td>Gold</td>
<td>47k Ω ± 5 %</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>10³</td>
<td>± 5 %</td>
<td></td>
</tr>
</tbody>
</table>

Now 5% of 47k Ω is 2.35k Ω. Therefore, the resistance should be within the range 47 k Ω ± 2.35 k Ω, or between 44.65 k Ω and 49.35 k Ω.

In most electronic circuits, it is not necessary to use resistors of exact values. The circuit works satisfactorily even if the resistances differ from the designed values by as much as ±20 %. Therefore, we don't have to manufacture resistors of all values.

In the case of five band coding, the first three colour bands represent the significant digits, fourth band for the multiplication factor and fifth band for tolerance.

**Standard values of commercially available resistors (with 10% tolerance)**

<table>
<thead>
<tr>
<th>Ohms (Ω)</th>
<th>Kilohms (kΩ)</th>
<th>Megohms (MΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>1.2</td>
<td>12</td>
<td>1.2</td>
</tr>
<tr>
<td>1.5</td>
<td>15</td>
<td>1.5</td>
</tr>
<tr>
<td>1.8</td>
<td>18</td>
<td>1.8</td>
</tr>
<tr>
<td>2.2</td>
<td>22</td>
<td>2.2</td>
</tr>
<tr>
<td>2.7</td>
<td>27</td>
<td>2.7</td>
</tr>
<tr>
<td>3.3</td>
<td>33</td>
<td>3.3</td>
</tr>
<tr>
<td>3.9</td>
<td>39</td>
<td>3.9</td>
</tr>
<tr>
<td>4.7</td>
<td>47</td>
<td>4.7</td>
</tr>
<tr>
<td>5.6</td>
<td>56</td>
<td>5.6</td>
</tr>
<tr>
<td>6.8</td>
<td>68</td>
<td>6.8</td>
</tr>
<tr>
<td>8.2</td>
<td>82</td>
<td>8.2</td>
</tr>
</tbody>
</table>

**Check your progress**

1. We need a resistor of 4.7 Ω with ±5 % tolerance. Find the sequence of the colour band on the resistor.
2. A resistor has a colour band sequence: red, red, green, yellow and silver. Find the range in which its value lies as per manufacturer's tolerance.

**Variable Resistors**

In electronic circuits, sometimes it becomes necessary to adjust the values of currents and voltages while the equipment is in use. For example, it is often desired to change the volume of
sound, the brightness of a television picture, etc. Variable resistors can be used to do such adjustments.

Big size variable resistors are usually called rheostats. In electronic circuits, we use small size variable resistors, and they are called potentiometers (usually abbreviated to 'pots'). The symbol for potentiometer is given in Fig. 1.10 (a). The arrow indicates the movable contact. The moving contact is used to vary the value of resistance in the circuit. Some have wire wound resistance as their primary elements, while others have a carbon film element. Figure 1.10(b) shows the basic construction of a wire wound pot. A resistance wire is wound over a dough-shaped core of Bakelite or Ceramic. There is a rotating shaft at the centre of the core. The shaft moves an arm and a contact point from end to end of the resistance element. The outer two terminals are the end points of the resistance element and the middle leads to the rotating contact.

The variation of resistance in a potentiometer can be either linear or nonlinear. As shown in Figure 1.11(a), the linear type has the core (or former) of uniform height and that is why the resistance varies linearly with the rotation of contact. In a nonlinear potentiometer fig 1.11(b), the height of the former is not uniform. The core of the non-linear type is made from a tapered strip. The pots used as volume control in radio, tape recorders, etc. are generally of nonlinear type (with logarithmic variation).

1.6 CAPACITORS

A capacitor can store electrical energy in its electric field, and release it whenever desired. A capacitor opposes any change in the potential difference applied across its terminals. The capacitance of a capacitor is measured in farads (F). Capacitors vary in shape and size, but the basic configuration is two conductors separated by an insulating medium.
In the uncharged state, the charge on both of the conductors in a capacitor is zero. A capacitor can be charged by connecting a battery across it. During the charging process, a charge $Q$ is moved from one conductor to the other, giving one conductor a charge $+Q$, and the other one a charge $-Q$. A potential difference is created, with the positively charged conductor at a higher potential than the negatively charged conductor. Note that whether charged or uncharged, the net charge on the capacitor as a whole is zero.

The simplest example of a capacitor consists of two conducting plates of area $A$, which are parallel to each other, and separated by a distance $d$, as shown in Figure 1.13.

In a capacitor the plates are separated by an insulating material known as a dielectric. The factors affecting capacitance of a capacitor are dielectric material, area of the plate, thickness of the dielectric and the distance between the plates.

All other factors being equal, larger plate area gives higher capacitance. This is because larger plate area results in more charge to be collected on the plates for a given voltage across the plates. Closer plate spacing gives higher capacitance and larger plate spacing gives less capacitance. The higher permittivity of the dielectric gives larger capacitance and less permittivity gives less capacitance.

The capacitance of any parallel-plate capacitor can be calculated by the formula:

$$C = \frac{\varepsilon A}{d} \quad .........1.1$$

Where $C$ is capacitance in farads and $\varepsilon$ is permittivity of the dielectric.

Experiments show that the amount of charge $Q$ stored in a capacitor is directly proportional to the electric potential difference ($V$) between the plates.

$$Q = CV \quad ...............1.2$$

Figure 1.14(a) shows the symbol which is used to represent capacitors in circuits. For a polarized capacitor (usually called electrolytic capacitor) which has a definite polarity, figure 1.14(b) is sometimes used. Figure 1.14(c) is used to represent a variable capacitor.

Similar to resistor, a capacitor offers resistance to a signal passing through it. This is known as capacitive reactance. Capacitive reactance is given as:

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC} \quad ...............1.3$$

Where $X_c$ is the capacitive reactance, $\omega$ is the angular frequency, $f$ is the frequency in Hertz, and $C$ is the capacitance. The unit of capacitive reactance is $\Omega$. It is clear from the above equation that the reactance of a capacitor increases with decreasing frequency.
At zero frequency (DC) the capacitor has an infinite resistance and hence behaves as an open circuit. So a low frequency signal will not pass through it. At high frequency, the capacitive reactance becomes very low and the capacitor acts almost as a short circuit. That is a high frequency signal will pass through the capacitor. From this it is clear that a capacitor blocks DC while passes AC signal. So, capacitors are used to couple AC voltage from one circuit to another and block DC voltage from reaching the next circuit.

Like resistors, capacitors can either be fixed or variable. Some of the most commonly used fixed capacitors are mica, ceramic, paper, and electrolytic. Variable capacitors are mostly air-gang capacitors.

**Fixed Capacitors**

**Mica capacitors**

Mica capacitors are made from plates of aluminium foil separated by sheets of mica, as shown in Fig. 1.15. The plates are connected to two electrodes. The mica capacitors have excellent characteristics even under temperature variations and high voltage applications. Available capacitors range from 5 to $10^3$ pF. Mica capacitors can be used upto 500 V.

**Ceramic capacitors**

A ceramic capacitor consists of a metal such as copper or silver coated on two sides of a ceramic disc. These coatings act as two plates. After attaching tinned-wire leads, the entire unit is coated with plastic and marked with its capacitance value either using numerals or colour code. The colour coding is similar to that used for resistances. Ceramic capacitors are very versatile. Their working voltage ranges from 3 V (for use in transistors) up to 6000 V. The capacitance value ranges from 3 pF to about 3 mF.

**Paper capacitors**

This capacitor consists of two metal foils separated by strips of paper. This paper is impregnated with a dielectric material such as wax, plastic or oil. Since paper can be rolled between two metal foils, it is possible to concentrate a large plate area in a small volume.

Paper capacitors have capacitances ranging from 0.0005 μF to several μF, and are rated from about 100 V to several thousand volts. They can be used for both DC and AC circuits.

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1. **DC** is the abbreviation of direct current. When a DC voltage is applied across a circuit the current always flows in the same direction. Frequency is number of cycles per second. So DC voltage has zero frequency.

2. **AC** is alternating current which when applied across a circuit, the current changes its direction periodically.
Electrolytic capacitors

An electrolytic capacitor consists of an aluminium-foil electrode which has an aluminium-oxide film covering on one side. The aluminium plate serves as the positive plate and the oxide as the dielectric. The oxide is in contact with a paper or gauze saturated with an electrolyte. The electrolyte forms the negative plate of the capacitor. Another layer of aluminium without the oxide coating is also provided for making electrical contact between one of the terminals and the electrolyte. In most cases, the negative plate is directly connected to the metallic container of the capacitor. The container then serves as the negative terminal for external connections.

The aluminium oxide layer is very thin. Therefore, the capacitor has a large capacitance in a small volume. It has high capacitance-to-size ratio. The terminals are marked +ve and -ve. The capacitance value may range from 1 μF to several thousand micro farads. The voltage ratings may range from 1 V to 500 V.

Variable capacitors

In some circuits, it is necessary to change the value of capacitance (e.g. tuning circuit used in radios to select different channels). This is done by means of a variable capacitor. The most common variable capacitor is the air-gang capacitor, shown in Fig. 1.19. The dielectric for this capacitor is air. By rotating the shaft at one end, we can change the common area between the movable and fixed set of plates. The greater the common area, the larger the capacitance.

In some applications, the user need not vary the capacitance value frequently. One setting is sufficient for all normal operations. In such situations, we use a variable capacitor called a trimmer (sometimes called padder). Both mica and ceramic are used as the dielectric for trimmer capacitors (Fig. 1.20).
1.7 INDUCTORS

An inductor is a device that stores electrical energy in the magnetic field surrounding it. Inductance is the property of a coil (the inductor) to oppose a change in current. In its simplest form, an inductor consists of a wire loop or coil. The inductance of an inductor is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of material (core) around which the coil is wound. The schematic symbols for inductors are shown in figure 1.21. The unit of Inductance is henry (H).

An inductor offers opposition to the passage of any change in current through it. This opposition is called inductive reactance. Inductive reactance is defined as:

\[ X_L = \frac{\omega L}{2\pi} \]  

where \( X_L \) is the inductive reactance, \( \omega \) is the angular frequency, \( f \) is the frequency in Hertz, and \( L \) is the inductance. The unit of inductive reactance is Ohm. The reactance of an inductor increases with increase in frequency.

At zero frequency, the inductive reactance becomes zero and the inductor acts almost as a short circuit. So low frequency signal will pass through it. At high frequency, the inductor has high resistance and hence behaves as an open circuit. It means that a high frequency signal will not pass through an inductor. From this it is clear that an inductor blocks AC whereas it passes DC signal. This is exactly opposite to the function of a capacitor.

All inductors can be classified into two categories: fixed and variable. According to the constructional features, inductors can be further classified into three: air core inductor, iron core inductor and ferrite core inductor. Air core inductor is made of thin copper wire wound without any core. It has low value inductance of the range milli and micro henry.

Iron core inductor is made of copper wire wound over a laminated iron core. Iron core inductors are very suitable for audio frequency applications.

Ferrite core inductor is made of copper wire wound on a solid core made of ferromagnetic material called ferrite. In variable type ferrite core inductors, the ferrite core is made movable in and out of the coil. When the core is completely inside the inductor, the inductance value is maximum. It is used for high frequency applications.
**1.8 TRANSFORMER**

A transformer is similar in appearance to an inductor. It consists of two inductors having same core (Fig. 1.22). One of these inductors, or windings, is called primary. The other is called secondary. When an alternating current is applied at the primary, an induced voltage appears in the secondary. In a step up transformer, the number of turns in the secondary is more than that in the primary, so the secondary voltage is more than the primary. If the number of turns in the secondary is less than that in the primary, the voltage will be stepped down. Such transformers are called step down transformers.

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**Inductors are used in different frequency ranges**

Chokes which are used in smoothing the pulsating voltage produced by rectifying AC (50 Hz) into DC are called filter chokes. The range of inductance is normally from 5 to 20 H. A filter choke has many turns of wire wound on iron core. They are usually fixed value inductors.

Audio frequency chokes (AFCs) are used for audio frequency application (20 Hz to 20 kHz). Compared to filter chokes, they are smaller in size and have lower resistance.

Radio frequency chokes (RFCs) are variable type inductors used in high frequency applications (more than 20 kHz). It has a shaft attached to its core so that the inductance can be varied by tuning it, as shown in Fig. 1.19. RFCs are having a low inductance value of the order of micro Henry.

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Fig 1.22 a) Step up transformer b) Step down transformer c) picture of a low power transformer
Let us sum up

Electronics is an integral part of every field of life. The invention of transistors is a major turning point in the development of electronics. Integrated circuits and their development through SSI, LSI, VLSI technologies led to the fast growth of electronics in all fields. Communication and entertainment, defence, control and instrumentation, medical, industrial applications, automobiles, home appliances, etc. are some of the fields of applications of electronics. Electronic components are classified into passive and active components. There are various types of resistors, capacitors and inductors which are used for various applications. The value of resistors can be found using colour coding. A capacitor passes AC and blocks DC but an inductor passes DC and blocks AC.

Learning outcomes

The learner is able to

- Explain the origin and history of development of electronics.
- Point out the significance of electronics in day to day life.
- Classify the applications of electronics into various fields.
- Identify the basic components in electronics.
- Classify the important components in electronics as active and passive.
- Recognize resistors, capacitors and inductors of various types from their physical appearance.
- Identify the value of resistors using their colour coding.
- Draw the symbols of different active and passive components.
- Explain the specifications of various types of resistors, capacitors and inductors.

What’s the best strategy for learning circuits/electrical engineering as a hobby?

1) Invest in a soldering iron and practice soldering until it becomes second nature.
2) Get some more hardware like breadboards, wire clippers, etc.
3) Subscribe magazines or purchase books, that not only provide you with schematics for simple circuitry, but also take you on a component walk-through, explaining the purpose for each part. You can likely find the books advertised in the magazines.

Read more: http://www.physicsforums.com
http://www.epanorama.net/
Multiple choice questions

1. A __________ is a circuit element which takes energy from driving source and does not return it.
   (a) capacitor   (b) resistor   (c) inductor   (d) diode

2. Example of an active device is
   (a) electric bulb   (b) diode   (c) transformer   (d) loud speaker

3. A __________ is a circuit element that stores energy in a magnetic field and returns it.
   (a) capacitor   (b) resistor   (c) zener diode   (d) inductor

4. A 100 $\mu F$ capacitor is required in an electronic circuit. Such a large value of capacitance is possible if the capacitor is a/an
   (a) ceramic capacitor   (b) mica capacitor   (c) electrolytic capacitor   (d) paper capacitor

5. A resistor has a colour band sequence: brown, black, green and gold. Its value is
   (a) 1 k$\Omega$ ± 10%   (b) 1 M$\Omega$ ± 5%   (c) 10 k$\Omega$ ± 5%   (d) 1 M$\Omega$ ± 10%

6. A __________ is the circuit element that stores energy in an electric field and returns it.
   (a) resistor   (b) inductor   (c) capacitor   (d) none of these

7. With the help of a RADAR we can
   (a) perform mathematical calculations very fast
   (b) listen to more melodious music
   (c) detect the presence of an aircraft as well as locate its position
   (d) cure the damaged tissues in the human body.

8. The colour bands on a fixed carbon resistor are brown, red, black (given sequentially). Its value is
   (a) 12 $\Omega$   (b) 21 $\Omega$   (c) 120 $\Omega$   (d) 210 $\Omega$

9. The term IC used in electronics denotes
   (a) Indian culture   (b) integrated circuits   (c) internal combustion   (d) industrial control

10. Which one of the following is used as a passive component in electronic circuits.
    (a) Vacuum triode   (b) transistor   (c) resistor   (d) field effect transistor (FET)

Answer key
1) b  2) b  3) d  4) c  5) b  6) c  7) c  8) a  9) b  10) c
1. Our daily life is influenced by electronics. Justify.
2. Differentiate between active devices and passive devices.
3. What is meant by RADAR?
4. Write at least three applications of electronics in the field of
   (a) communication and entertainment
   (b) defence
   (c) medical sciences.
5. What is meant by tolerance in resistors?
6. Explain constructional features of a carbon composition resistor. What is the wattage rating for carbon composition resistors?
7. Describe different types of potentiometers.
8. Write short notes on
   (a) capacitor
   (b) inductor.
9. Explain the applications of capacitors.
10. What forms the dielectric of an electrolytic capacitor? Why is the electrolytic capacitor polarized?
11. What are the specifications of a capacitor? State the factors affecting the capacitance of a capacitor.
12. When you adjust the volume control knob of your radio receiver, which component is varied inside the set?
13. Explain briefly the difference between air-gang (variable) and trimmer capacitors.
14. What is an inductor? What is the unit of inductance?
15. Classify the inductors and explain briefly.
16. Name a few active components used in electronic circuits.