

Lab Manual

ET-104L

Electrical Fundamentals – Lab



**Institute of Aviation Studies
University of Management and Technology Lahore**



Institute of Aviation Studies
University of Management and Technology

Course Outline

Course code: ET-104L Course title: Electrical Fundamentals - Lab

Program	BSc AMET
Credit Hours	1
Duration	1 semester
Learning Methodology:	Lab instructions and experiment

Course Learning Outcomes (CLOs) and their Mapping to Program Learning Outcomes (PLOs):

Semester	Course Code	Title	Course Learning Outcomes	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
2	ET 104 L	Electrical Fundamentals	CLO1	Conduct and Interpret the results of experiments and demonstrations of electrical components.			✓								
			CLO2	Effectively communicate experiment results through both written reports and oral Presentations									✓		

Grade Evaluation Criteria

Components	Percentage
Class activity	5%
Lab Report	30%
Term Project	20%
Final Evaluation(external viva and performance for given experiment)	45%
Total	100

Serial No.	Description
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1.	Safety Precautions and Basic Tools of Electric Shop
2.	Introduction to Cables and Earthing
3.	Implementation of Series and Parallel DC Circuits
4.	Ohm's Law and Familiarization with the Lab Instruments
5.	Implementation of Superposition and Maximum Power Transfer Theorem
6.	Investigation of the voltage regulation of a single phase transformer
7.	Implementation of Series and Parallel RL circuits
8.	Implementation of Series and Parallel RC circuits
9.	Implementation of RLC series and Parallel Circuits
10.	Low Pass and High Pass Filters
11.	Band Pass Filters And Band Stop Filters
12.	Current And Voltages In Balanced Three Phase System
13.	To study the Characteristics of Universal Motor

Lab 1: SAFETY PRECAUTIONS AND BASIC TOOLS OF ELECTRIC SHOP

OBJECTIVES

To familiarize the students with:

1. Basic concepts of Electricity
2. Safety Precautions in Electric Shop
3. Basic Tools used in Electric Shop

BASIC CONCEPTS OF ELECTRICITY

Electricity is characterized by the flow of electrons through a conductor. To understand this phenomenon, you must know something about chemical elements and atoms.

Elements and Atoms:

Elements are the most basic of materials. Every known substance - solid, liquid, or gas - is composed of elements. An atom is the smallest particle of an element that retains all the properties of that element. Each element has its own kind of atom; i.e., all hydrogen atoms are alike, and they are all different from the atoms of other elements. However, all atoms have certain things in common. They all have an inner part, the nucleus, composed of tiny particles called protons and neutrons. An atom also has an outer part. It consists of other tiny particles, called electrons, which orbit around the nucleus. Neutrons have no electrical charge, but protons are positively charged. Electrons have a negative charge. The atoms of each element have a definite number of electrons, and they have the same number of protons. An aluminum atom, for example, has thirteen of each. The opposite charges - negative electrons and positive protons - attract each other and tend to hold electrons in orbit. As long as this arrangement is not changed, an atom is electrically balanced. However, the electrons of some atoms are easily moved out of their orbits. This ability of electrons to move or flow is the basis of current electricity. When electrons leave their orbits, they are referred to as free electrons. If the movement of free electrons is channeled in a given direction, a flow of electrons occurs. A material that contains many free electrons and is capable of carrying an electric current is called a conductor. Metals and (generally) water are conductors. Gold, silver, aluminum and copper are all good conductors. Materials that contain relatively few free electrons are called insulators. Non-metallic materials such as wood, rubber, glass and mica are insulators. Fair conductors include the human body, earth, and concrete. There are several ways to produce electricity. Friction, pressure, heat, light, chemical action, and magnetism are among the more practical methods used to make electrons move along a conductor.

SAFETY PRECAUTIONS IN ELECTRIC SHOP

1. Turn off and unplug equipment before removing the protective cover to clear a jam, replace a part, adjust or troubleshoot. Ask a qualified person to do the work if it involves opening equipment and creating an exposure to energized parts operating at 50 volts or more.

2. Don't use an electrical outlet or switch if the protective cover is ajar, cracked or missing.
3. Only use DRY hands and tools and stand on a DRY surface when using electrical equipment, plugging in an electric cord, etc. When possible, wear nonconductive gloves and shoes with insulated soles.
4. Never put conductive metal objects into energized equipment.
5. Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
6. Always pick up and carry portable equipment by the handle and/or base. Carrying equipment by the cord damages the cord's insulation.
7. Unplug cords from electrical outlets by pulling on the plug instead of pulling on the cord.
8. Re-route electrical cords or extension cords so they aren't run across the floor, under rugs or through doorways, etc. Stepping on, pinching or rolling over a cord will break down the insulation and will create shock and fire hazards.
9. Don't overload extension cords, multi-outlet strips and wall outlets.

BASIC TOOLS USED IN ELECTRIC SHOP

Given below is a brief description of all the tools used and available in Electric shop.

- **Screw Driver**

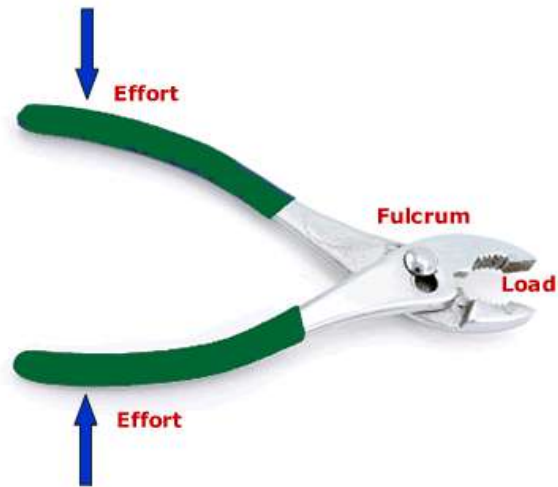
A screwdriver is a tool, manual or powered, for turning (driving or removing) screws. A typical simple screwdriver has a handle and a shaft, and a tip that the user inserts into the screw head to turn it. Different types of screw drivers are shown below.



- **Pair of Pliers**

Pliers are a hand tool used to hold objects firmly, possibly developed from tongs used to handle hot metal in Bronze Age Europe. They are also useful for bending and compressing a wide range of materials. Generally, pliers consist of a pair of metal first-class levers joined at a fulcrum positioned closer to one end of the levers, creating short *jaws* on one side of the fulcrum, and longer *handles* on the other side. This arrangement creates a mechanical advantage, allowing the force of the hand's grip to be amplified and focused on an object with

precision. The jaws can also be used to manipulate objects too small or unwieldy to be manipulated with the fingers.



- **Bradawl**

A bradawl is a tool with a blade similar to that of a straight screwdriver and a handle made from wood or plastic. A bradawl is used to make an indentation in wood or other materials in order to ease the insertion of a nail or screw.



- **Wire Cutter**

Diagonal pliers (or wire cutters or diagonal cutting pliers or diagonal cutters) are pliers intended for the cutting of wire.



- **PVC Conduit**

An electrical conduit is a tubing system used for protection and routing of electrical wiring. PVC conduit is the lightest in weight compared to other conduit materials, and usually lower in cost than other forms of conduit.



- **PVC Tee**

A form of conduit:



- **PVC Bend**

Bent form of conduit:



- **PVC Round Block**

For joining conduits from four sides



- **Kit Kat Fuse**

It is a Rewirable Porcelain fuse.

In electronics and electrical engineering, a fuse is a type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection, of either the load or source circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects. Short circuits, overloading, mismatched loads, or device failure are the prime reasons for excessive current. Fuses are an alternative to circuit breakers.

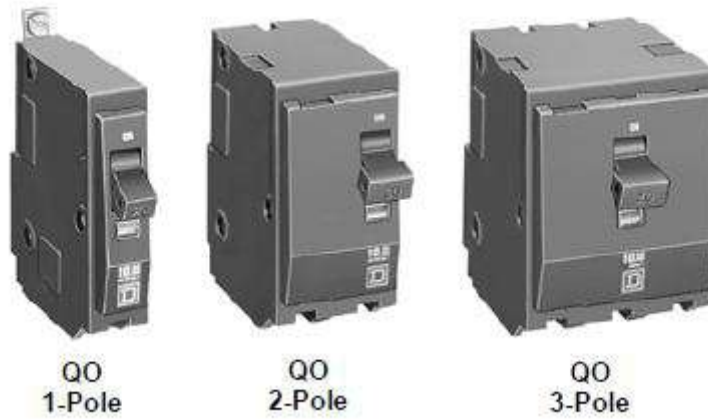


- **Single, Two and Three Pole Circuit Breakers**

A **circuit breaker** is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

A single pole breaker is used with a typical 120v circuit, having one hot wire and one neutral wire. A double pole breaker is used with a typical 220v circuit (like for a dryer or heater) having two hot wires. If there is a short circuit to either hot wire, both poles are ganged together so both trip together.

A three pole breaker is used when there is a need for three live conductors to be interrupted when any combination of poles is tripped, and are externally ganged together to ensure this happening.



- **Two and Three Pole Change Over Switches**

In a switch where the contacts remain in one state unless actuated, such as a push-button switch, the contacts can either be normally open until closed by operation of the switch, or normally closed and opened by the switch action. A switch with both types of contact is called a *changeover switch*. These may be "make-before-break" ("MBB" or shorting) which momentarily connects both circuits, or may be "break-before-make" ("BBM" or non-shorting) which interrupts one circuit before closing the other.

- **Two Pin Socket**



- **Three Pin Socket**



- **Ceiling Rose**



- **Batten Type Lamp Holder**



- **Two Pin Plug**

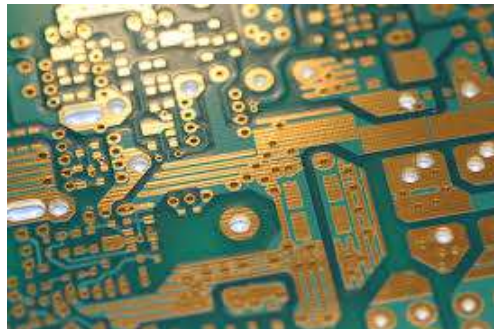


- **Three Pin Plug**



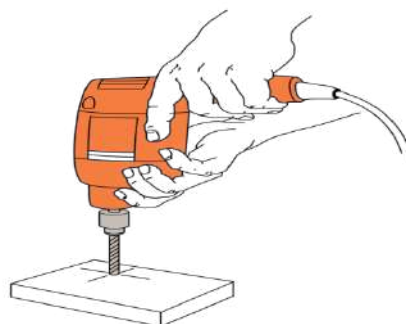
- **Printed Circuit Board**

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer.



- **Drill Machine**

A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for boring holes in various materials.



- **Soldering Iron**

A soldering iron is a hand tool used in soldering. It supplies heat to melt the solder so that it can flow into the joint between two work pieces.



- **Soldering Wire**

Soldering wire is a fusible metal alloy used to join together metal workpieces and having a melting point below that of the work pieces.



- **Soldering Paste**

Solder paste (or solder cream) is used to connect the leads of surface mount integrated chip packages to attachment points (lands) in the circuit patterns on a printed circuit board.



Lab 2: INTRODUCTION TO CABLES AND EARTHING

OBJECTIVES

To familiarize the students with:

1. Cables, their sizes and current ratings
2. Switchgear used on domestic installations
3. Earthing, its importance and methods of Earthing
4. Measurement of resistance to earth an electrical equipment

CABLES

A cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover. Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements. In general, a cable must fulfill the following necessary requirements:

- The conductor used in cables should be tinned stranded copper or aluminium of high conductivity. Stranding is done so that conductor may become flexible and carry more current.
- The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop within permissible limits.
- The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.
- The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.
- The materials used in the manufacture of cables should be such that there is complete chemical and physical stability throughout.

CLASSIFICATION OF CABLES

Cables for underground service may be classified according to (i) the type of insulating material used in their manufacture (ii) the voltage for which they are manufactured (iii) No. of conductors in cable.

(i) Insulating material of the Cable

Cables are also classified on the basis of insulation provided in the cable. Following are the type of cables on the basis of insulation used in the cable:

- PIC or PILC: Paper Insulated Cable - Paper is used as insulation to the conductor.
- PVC: Poly Vinyl Chloride Cable - PVC is used as insulation to the conductor.
- PE: Poly Ethylene - Poly Ethylene is used as insulation to the conductor.
- PTFE: Poly Tetra Fluoro Ethylene - PTFE is used as insulation to the conductor.
- XLPE: Cross Linked Poly Ethylene - Cross Linked Poly Ethylene is used as insulation. This is most commonly used cable in Industry.

(ii) Voltage Rating of the Cable

Cables are also classified on the basis of voltage levels. Various types of cables are shown below.

- Low-tension (L.T.) cables — upto 1000 V

- High-tension (H.T.) cables — upto 11,000 V
- Super-tension (S.T.) cables — from 22 kV to 33 kV
- Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
- Extra super voltage cables — beyond 132 kV

(iii) No. of Conductors in Cable

On the basis of number of conductors in the cable, cables can be classified into single core cables, 2 core cables and 3 core cables. Single core cable have only one conductors , while two and three core cable have two and three conductors respectively as shown in Fig. 2.1. Multi core cables are also available in the market. These cables can be used as per requirement e.g. for a 3-phase service, either 3-single-core cables or three-core cable can be used depending upon the operating voltage and load demand.



Figure 2.1

SWITCHGEAR

The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchgear. During normal operation, switchgear permits to switch on or off generators, transmission lines, distributors and other electrical equipment. On the other hand, when a failure (e.g. short circuit) occurs on any part of the system, heavy current flows through the equipment, threatening damage to the equipment and interruption of service to the customers. However, the switchgear detects the fault and disconnects the unhealthy section from the system. In this way, switchgear protects the system from the damage and ensures continuity of supply.

Switchgear covers a wide range of equipment concerned with switching and interrupting currents under both normal and abnormal conditions. It includes switches, fuses, circuit breakers, relays and other equipment. A brief account of these devices is given below.

SWITCHES

A switch is a device which is used to open or close an electrical circuit in a convenient way. It can be used under full-load or no-load conditions but it cannot interrupt the fault currents. Switches that are used for domestic level are commonly classified as: (a) Single Pole Single Throw (SPST) (b) Single Pole Double Throw (SPDT) (c) Double pole, single throw (d) Double pole, double throw (e) Momentary Switches.

(a) SPST Switch

A Single Pole Single Throw (SPST) switch is a switch that only has a single input and can connect only to one output. This means it only has one input terminal and only one output terminal. Below is an example of a circuit which utilizes a single pole single throw switch (Fig. 2.2).

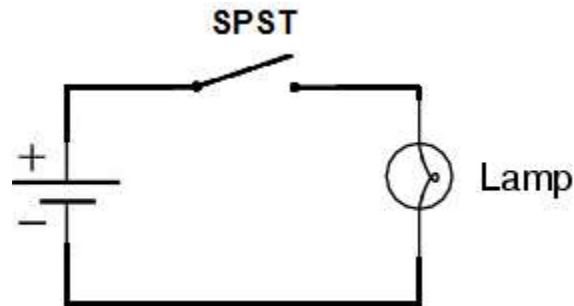


Figure 2.2

(b) SPDT Switch

A Single Pole Double Throw switch can serve a variety of functions in a circuit. It can serve as an on-off switch, depending on how the circuit is wired. Or it can serve to connect circuits to any 2 various paths that a circuit may need to function in. For example, a SPDT switch can connect to create a Ready Mode and a Standby Mode in a printer. Below is an example of a circuit which utilizes a single pole double throw switch (Fig. 2.3).

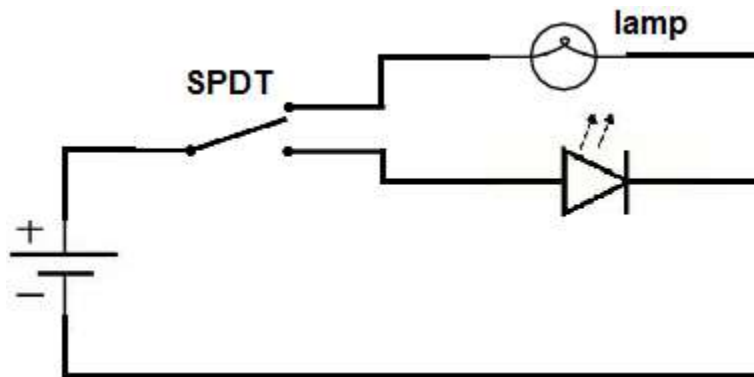


Figure 2.3

(c) DPST Switch

A Double Pole Single Throw (DPST) switch is a switch that has 2 inputs and 2 outputs; each input has 1 corresponding output. Each of the terminals of a double pole single switch can either be in the on position (closed) or in the off position (open). A Double Pole Single Switch has a lot of versatility being that it accepts 2 inputs, which makes it then be able to drive 2 different outputs in a circuit. What it drives depends on the circuit design and what the circuit is intended to do. But DPST have enormous applications in circuits. Below is an example of a circuit which utilizes a double pole single throw switch (Fig. 2.4).

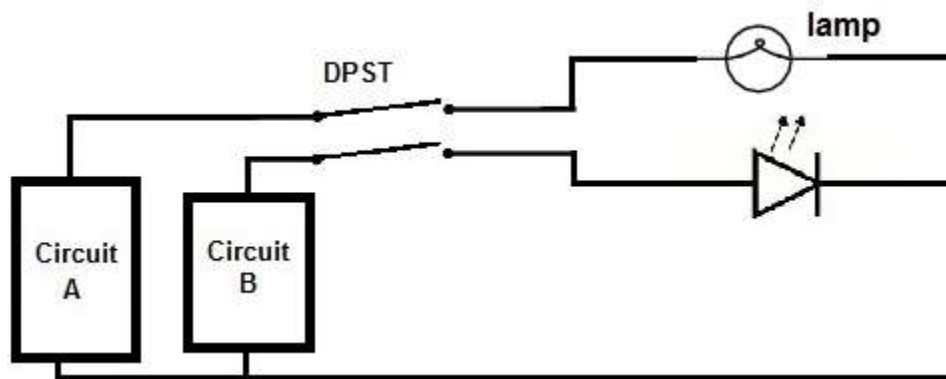


Figure 2.4

(d) DPDT Switch

A Double Pole Double Throw (DPDT) switch is a switch that has 2 inputs and 4 outputs; each input has 2 corresponding outputs that it can connect to. Each of the terminals of a double pole double switch can either be in 1 of 2 positions. This makes the double pole double switch a very versatile switch. With 2 inputs, it can connect to 4 different outputs or reroute a circuit into 4 different modes of operation. A Double Pole Single Switch is actually two single pole double (SPDT) switches. Below is an example of a circuit which utilizes a double pole double throw switch (Fig. 2.5).

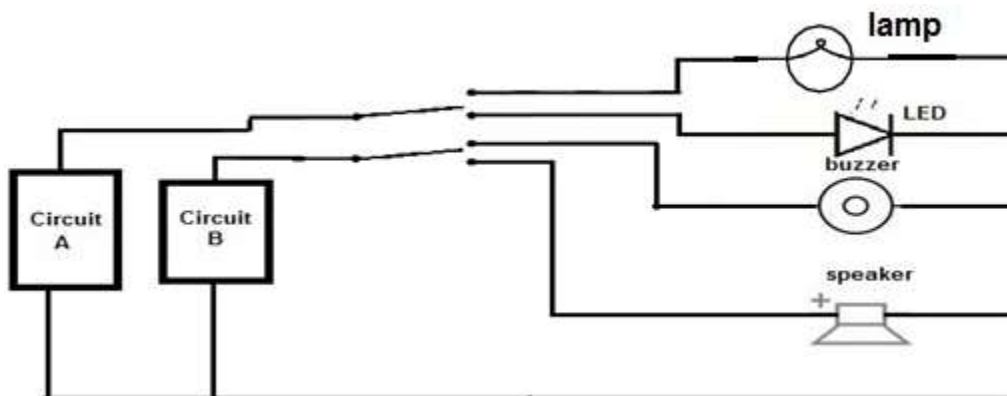


Figure 2.5

(e) Momentary Switches

Momentary switches (shown in Fig. 2.6) are switches which only remain in their on state as long as they're being actuated (pressed, held, magnetized, etc.). Most often momentary switches are best used for intermittent user-input cases; stuff like reset or keypad buttons.

Push-button switches are the classic momentary switch. Typically these switches have a really nice, tactile, “clicky” feedback when you press them. They come in all sorts of flavors: big, small, colorful, and illuminated (when an LED shines up through the button). They might be terminated as through-hole, surface-mount, or even panel-mount.

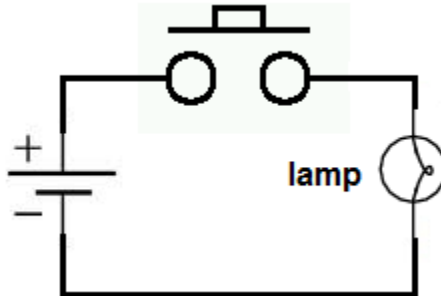


Figure 2.6

FUSE

A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the circuit to be protected. Under normal operating conditions, the fuse element let the current to pass at a temperature below its melting point. Therefore, it carries the normal load current without overheating. However, when a short circuit or overload occurs, the current through the fuse element increases beyond its rated capacity and this raises the temperature and the fuse element melts (or blows out), disconnecting the circuit protected by it. In this way, a fuse protects the machines and equipment from damage due to excessive currents. It is worthwhile to note that a fuse performs both detection and interruption functions. Fuse are available in different current ratings e.g. 2A, 5A, 30A, etc. which can be used in the circuit according to requirement (shown in Fig. 2.7).



Figure 2.7

CIRCUIT BREAKERS

A circuit breaker (shown in Fig. 2.8) is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from

small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

Low-voltage (less than 1,000 VAC) types are common in domestic, commercial and industrial application, and include: MCB (Miniature Circuit Breaker)—rated current not more than 100 A and trip characteristics are normally not adjustable.

There are three main types of MCBs: 1. Type B - trips between 3 and 5 times full load current; 2. Type C - trips between 5 and 10 times full load current; 3. Type D - trips between 10 and 20 times full load current.

MCCB (Molded Case Circuit Breaker)—rated current up to 2,500 A. Trip current may be adjustable in larger ratings. Low-voltage power circuit breakers can be mounted in multi-tiers in low-voltage switchboards or switchgear cabinets.



Figure 2.8

EARTHING (GROUNDING)

The process of connecting the metallic frame (i.e. non-current carrying part) of electrical equipment or some electrical part of the system (e.g. neutral point in a star-connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) is called grounding or earthing. This connection to earth may be through a conductor or some other circuit element (e.g. a resistor, a circuit breaker etc.) depending upon the situation. Grounding or earthing may be classified as: (a) System grounding and (b) Equipment grounding.

System grounding refers to the process of connecting some electrical part of the power system (e.g. neutral point of a star-connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) and **Equipment grounding** refers to the process of connecting non-current-carrying metal parts (i.e. metallic enclosure) of the electrical

equipment to earth (i.e. soil) in such a way that in case of insulation failure, the enclosure effectively remains at earth potential.

IMPORTANCE OF EARTHING (GROUNDING)

One is frequently in touch with electrical equipment of all kinds, ranging from domestic appliances and hand-held tools to industrial motors. The need of effective grounding can be elaborated by considering a single-phase circuit composed of a 230 V source connected to a motor M as shown in Fig. 2.9. Note that neutral is grounded at the service entrance. In the interest of easy understanding, the discussion is divided into three heads viz. (a) Ungrounded enclosure (b) enclosure connected to neutral wire (c) ground wire connected to enclosure (d) importance of system grounding

(a) Ungrounded enclosure:

Fig. 2.9 shows the case of ungrounded metal enclosure. If a person touches the metal enclosure, nothing will happen if the equipment is functioning correctly. But if the winding insulation becomes faulty, the resistance R_e between the motor and enclosure drops to a low value (a few hundred ohms or less). A person having a body resistance R_b would complete the current path as shown in Fig. 2.9. If R_e is small (as is usually the case when insulation failure of winding occurs), the leakage current I_L through the person's body could be dangerously high. As a result, the person would get severe electric shock which may be fatal. Therefore, this system is unsafe.

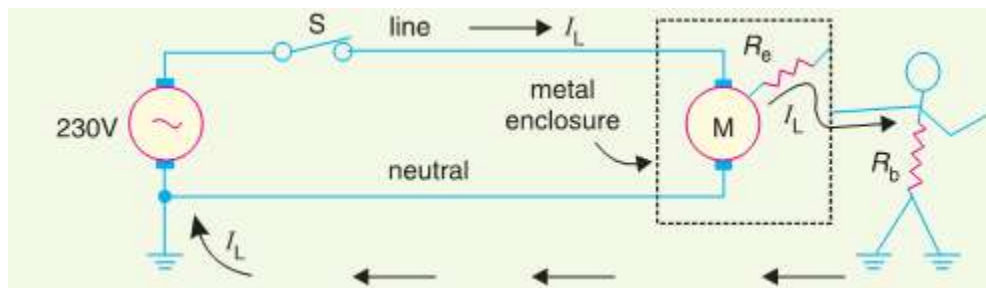


Figure 2.9

(b) Enclosure connected to neutral wire:

It may appear that the above problem can be solved by connecting the enclosure to the grounded neutral wire as shown in Fig. 2.10. Now, the leakage current I_L flows from the motor, through the enclosure and straight back to the neutral wire. Therefore, the enclosure remains at earth potential. Consequently, the operator would not experience any electric shock.

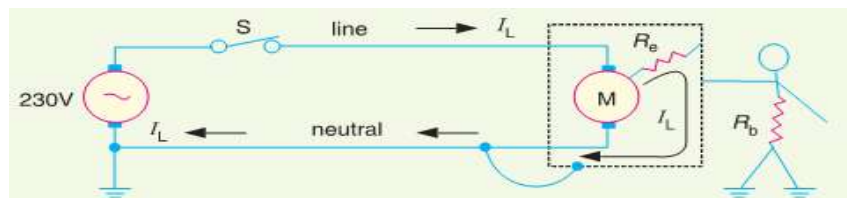


Figure 2.10

The trouble with this method is that the neutral wire may become open either accidentally or due to a faulty installation. For example, if the switch is inadvertently in series with the neutral rather than the live wire, the motor can still be turned on and off (Fig. 2.11). However, if someone touched the enclosure while the motor is off, he would receive a severe electric shock. It is because when the motor is off, the potential of the enclosure rises to that of the live conductor.

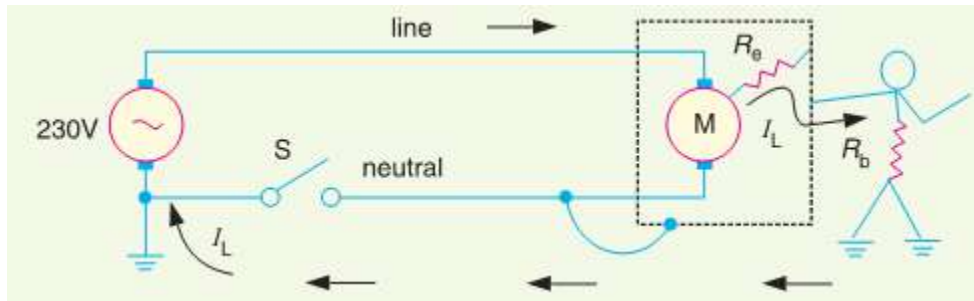


Figure 2.11

(c) Ground wire connected to enclosure:

To get rid of this problem, we install a third wire, called ground wire, between the enclosure and the system ground as shown in Fig. 2.12. The ground wire may be bare or insulated. If it is insulated, it is colored green.

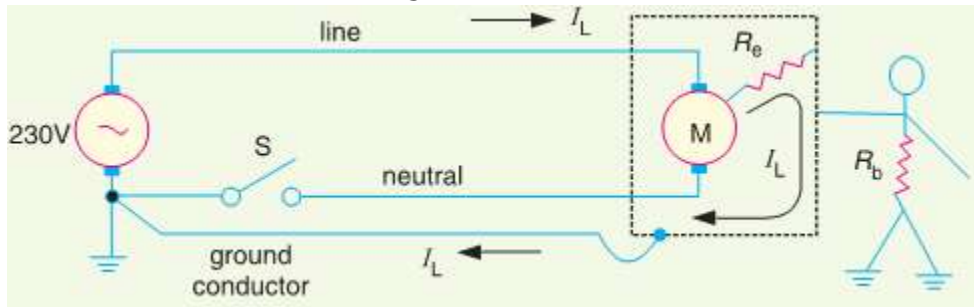


Figure 2.12

Importance of system grounding:

Now, consider a case of a system grounding, a distribution transformer whose primary is connected with 11kV line and the secondary conductors are ungrounded (as shown in Fig. 2.13(i)). Suppose that the high voltage line (11 kV in this case) touches the 230 V conductor. This could be caused by an internal fault in the transformer or by a branch or tree falling across the 11 kV and 230 V lines. Under these circumstances, a very high voltage is imposed between the secondary conductors and ground. This would immediately puncture the 230V insulation and cause a massive flashover. This flashover could occur anywhere on the secondary network, possibly inside a home or factory. Therefore, ungrounded secondary in this case is a potential fire hazard and may produce grave accidents under abnormal conditions.

If one of the secondary lines is grounded as shown in Fig. 2.13(ii), the accidental contact between an 11 kV conductor and a 230 V conductor produces a dead short. The short-circuit

current (i.e. fault current) follows the dotted path. This large current will blow the fuse on the 11 kV side, thus disconnecting the transformer and secondary distribution system from the 11 kV line. This explains the importance of system grounding in the line of the power system.

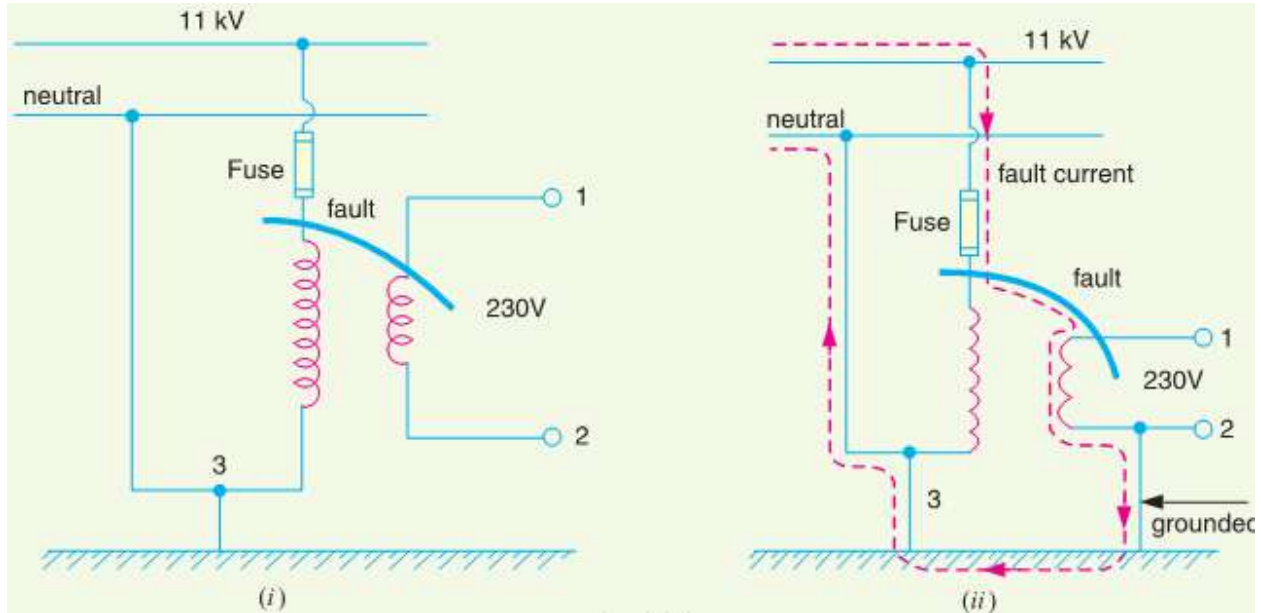


Figure 2.13

METHODS OF EARTHING

Earthing is done through connecting a metallic pipe, plate etc. to the earthing electrode. The most commonly used methods for earthing are:

- Plate Earthing
- Pipe Earthing
- Rod Earthing
- Wire Earthing

These techniques are briefly discussed below:

(a) Plate Earthing:

In this type of earthing, plate either of copper or of Galvanized Iron (G.I.) is buried into the ground at a depth of not less than 3 meter from the ground level (Fig. 2.14). The earth plate is embedded in alternative layer of coke and salts for a minimum thickness of about 15cm. The earth wire (copper wire for copper plate earthing and G.I. wire for G.I. plate earthing) is securely bolted to an earth plate with the help of bolt nut and washer made of copper, in case of copper plate earthing and of G.I. in case of G.I. plate earthing.

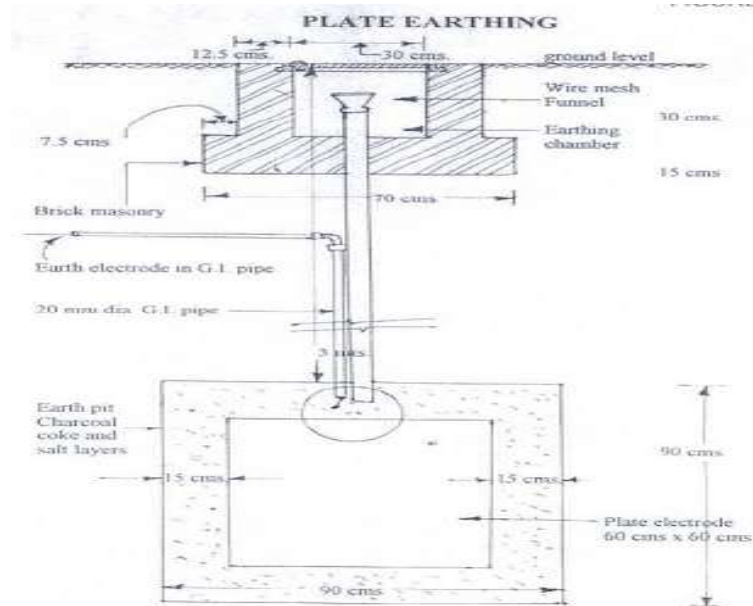


Figure 2.14

(b) Pipe Earthing

Pipe earthing (Fig. 2.15) is best form of earthing and it is cheap also in this system of earthing a GI pipe of 38 mm dia and 2 meters length is embedded vertically in ground to work as earth electrode but the depth depends upon the soil conditions, there is no hard and fast rule for this. But the wire is embedded up to the wet soil. The earth wire is fastened to the top section of the pipe with nut and bolts. The pit area around the GI pipe filled with salt and coal mixture for improving the soil conditions and efficiency of the earthing system. It can take heavy leakage current for the same electrode size in comparison to plate earthing. The earth wire connection with GI pipes being above the ground level can be checked for carrying out continuity test as and when desired, while in plate earthing it is difficult. In summer season, to have an effective earthing, three or four buckets of water are put through the funnel for better continuity of earthing.

(c) Rod Earthing

In this system of earthing (Fig. 2.15), 12.5 mm diameter solid rods of copper or 16mm diameter solid rod of GI or steel or hollow section of 25 mm GI pipe of length not less than 3 meters are driven vertically into the earth. In order to increase the embedded length of electrode under the ground, which is some time necessary to reduce the earth resistance to desired value, more than one rod section are hammered one above the other. This is suitable for areas which are sandy in character and is also very cheap.

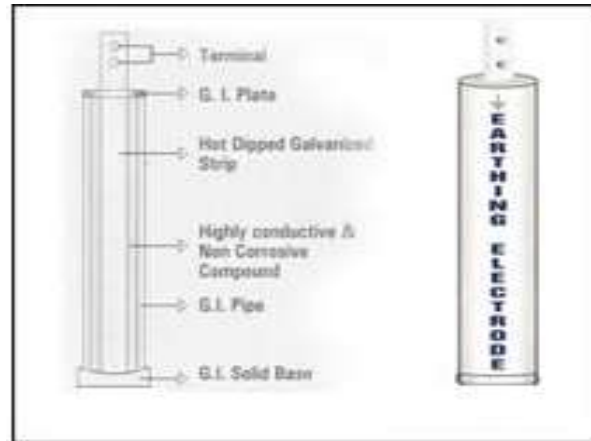


Figure 2.15

(d) Wire Earthing

In this system of earthing (Fig. 2.16), strip electrode of cross section not less than 25mm x 1.6mm of copper or 25mm x 4mm of GI or steel are buried in horizontal trenches of minimum depth of 0.5m. The length of buried conductor shall be sufficient to give the required earth resistance (about 0.5Ω to 1.5Ω) and shall not be less than 15 m. The electrode shall be as widely distributed as possible in a single straight or circular trenches radiating from a point. This type of earthing is used in rocky soil earth bed because at such places excavation work for plate earthing is difficult.



Figure 2.16

Lab 3: Implementation of Series and Parallel DC circuits

EQUIPMENT REQUIRED

Resistors

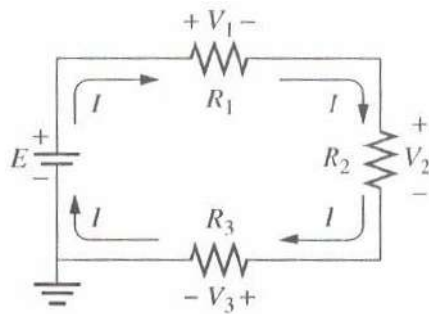
100K Ω , 220K Ω , 330K Ω , 470K Ω , 680K Ω , 1k Ω , 1M Ω (1/4-W), Two 2.2K Ω (1/4W)

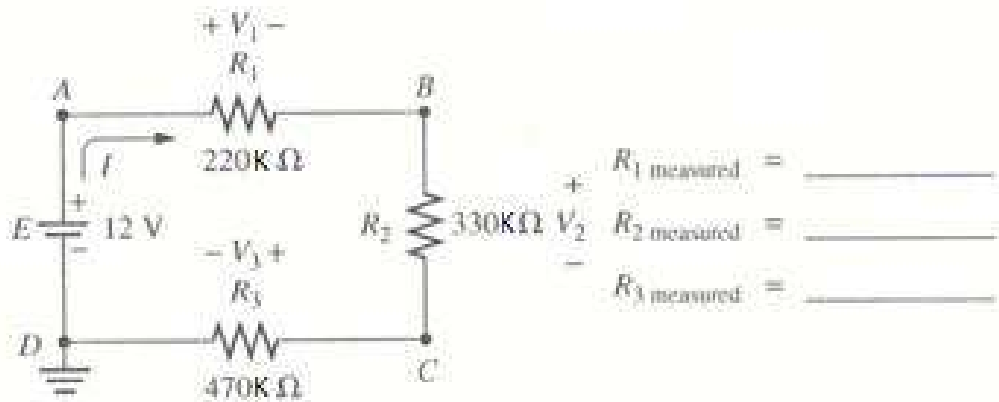
Instruments

1. DMM (Digital Multimeter)
2. DC Power supply

PROCEDURE:

Patch up the circuits as shown and measure the currents and voltages.





Comments:

Lab 4: Ohm's Law and Familiarization with the Lab Instruments

EQUIPMENT REQUIRED

Resistors

Different Resistors

1-kΩ, 3.3-kΩ (1/4-W)

Instruments

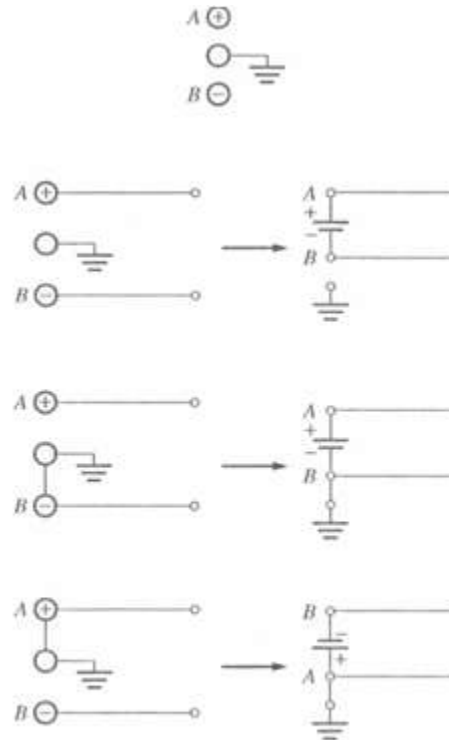
1. VOM (Volt-Ohm-Milliammeter)
2. DMM (Digital Multimeter)
3. DC power supply
4. Oscilloscope
5. Function generator

RÉSUMÉ OF THEORY

In any active circuit there must be a source of power. In the laboratory, it is convenient to use a source that requires a minimum of maintenance and, more important, whose output voltage can be varied easily. Power supplies are rated as to maximum voltage and current output. For example, a supply rated 0—40 V at 500 mA will provide a maximum voltage of 40 V and a maximum current of 500 mA at any voltage.

Most dc power supplies have three terminals, labelled as shown in Fig. 3.1. The three terminals permit the establishment of a positive or negative voltage, which can be grounded or ungrounded. The variable voltage is available only between terminals A and B. Both A and B must be part of any connection

scheme. If only terminals A and B are employed, as shown in Fig. 3.2, the supply is considered “floating” and not connected to the common ground of the network. For common ground and safety reasons, the supply is normally grounded as shown in Fig. 3.3 for a positive voltage and as in Fig. 3.4 for a negative voltage.



When measuring voltage levels, make sure the voltmeter is connected in parallel (across) the element being measured, as shown in Fig. 3.5. In addition, recognize that if the leads are connected as shown in the figure, the reading will be up-scale and positive. If the meter were hooked up in the reverse manner, a negative (down-scale, below-zero) reading would result. The voltmeter is therefore an excellent instrument not only for measuring the voltage level but also for determining the polarity. Since the meter is always placed in parallel with the element, there is no need to disturb the network when the measurement is made.

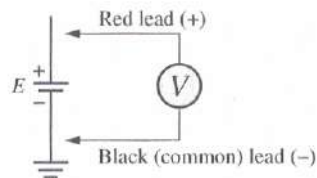


Figure 1.1

Ammeters are always connected in series with the branch in which the current is being measured, as shown in Fig. 1.2, normally requiring that the branch be opened and the meter inserted. Ammeters also have polarity markings to indicate the manner in which they should be connected to obtain an up-scale reading. Since the current I of Fig. 1.2 would establish a voltage drop across the ammeter as illustrated, the reading of the ammeter will be up-scale and positive. If the meter were hooked up in the reverse manner, the reading would be negative or down-scale. In other words, simply reversing the leads will change a below-zero indication to an up-scale reading.



Figure 1.2

Until you become familiar with the use of the ammeter, draw in the ammeter in the network with the polarities determined by the current direction. It is then easier to ensure that the meter is connected properly to the surrounding elements. This process will be demonstrated in more detail in a later experiment.

For both the voltmeter and the ammeter, always start with the higher ranges and work down to the operating level to avoid damaging the instrument. When the VOM and DMM are returned to the stockroom, be sure the VOM is on the highest voltage scale and the DMM is in the off position,

The voltage across and the current through a resistor can be used to determine its resistance using Ohm's law in the following form:

$$R = V/I$$

The magnitude of R will be determined by the units of measure for V and I .

PROCEDURE

TASK 1. Setting the Output Voltage of a dc Power Supply with a DMM and VOM

- (a). Connect the DMM to the dc power supply as shown in Fig. 1.3

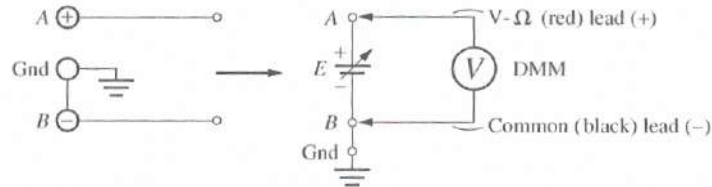


Figure 1.3

Using the DMM set the power supply to the voltage levels E_{AB} appearing in Table. Ignore the meter on the supply when setting the voltage levels. For each setting choose that scale of the DMM that will result in the highest degree of accuracy. Once a particular level is set, remove the DMM and measure the same voltage with the VOM using the scale of the meter that results in the most accurate reading. Do not be influenced by the level set with the DMM. Simply remove the DMM from the supply when the voltage E_{AB} is set and measure the terminal voltage with the VOM.

DMM E_{AB} (V)	VOM	% Difference
1		
4		
5.5		
8.25		
9.6		
12.1		
16.4		
18.75		

TABLE 1.1

Calculate the magnitude of the percent difference between the DMM setting and the VOM reading using the following formula and complete Table.

$$\% \text{ Difference} = \left| \frac{\text{DMM} - \text{VOM}}{\text{DMM}} \right| * 100\%$$

Is the magnitude of the percent difference for each level sufficiently small to verify the fact that the reading of one meter will be very close to the other even though one is analog and the other digital?

- (b). This part of the experiment will provide some additional practice in the use of the DMM and VOM. The supply voltage will now be set by the VOM and the setting checked by the DMM. Set the voltage levels indicated in Table with the VOM and then measure the set level with the DMM. For each setting calculate the magnitude of the percent difference using Equation and complete Table.

$$\% \text{ Difference} = \left| \frac{\text{DMM} - \text{VOM}}{\text{DMM}} \right| * 100\%$$

VOM E _{AB} (V)	DMM	% Difference
1		
4		
5.5		
8.25		
9.6		
12.1		
16.4		
18.75		

TABLE 1.2

How do the magnitudes of the percent differences of Table compare to those of second Table?

Can you make any general conclusions based on the results?

- (c).** We will now investigate the effect of reversing the leads of the meter when measuring a voltage. Using the setup of Figure , reset the voltage E_{AB} to 5 V using the DMM. Then disconnect the DMM and connect the red, or V- Ω , lead to the B terminal and the black, or COM, lead to the A terminal. What is the effect on the reading?

Repeat the previous reading using the VOM and the connections just described. What is the effect on the reading'?

- (d).** Based on the results of parts 1 (a)—(c), Answer the following questions.

1. Which meter do you prefer to use?

2. Does one appear more accurate?

3. What are the relative advantages of one compared to the other?

TASK 2. Reading the resistor colour code

In this task, the resistance of a series of ½ W carbon resistors will first be determined from the colour code and then compared with the measured value.

The first two bands (those closest to the end of the resistor) determine the first two digits of the resistor value, while the third band determines the power of the power of 10 multiplier (actually the number of zeros to follow the first two digits). If the third band is silver (0.01) or gold (0.1), it is a multiplying factor used to establish resistor values less than 10Ω. The fourth band is the percent tolerance for the chosen resistor.

Black	Brown	Red	Orange	Yellow	Green	Blue	Purple	Gray	White
0	1	2	3	4	5	6	7	8	9

Enter the numerical value of each color in the next column, as shown by the example.

Resistor Ω (nominal value)	Color Bands - Color				Color Bands – Numerical Value			
	1	2	3	4	1	2	3	4
22	Red	Red	Black	Gold	2	2	0	5%

91		
220		
3.3k		
10k		
470k		
1M		

TABLE 1.3

The percent tolerance is used to determine the range of resistance levels within which the manufacturer guarantees the resistor will fall. It is determined by first taking the percent tolerance and multiplying by the nominal resistance level. For the example in Table 1.3, the resulting resistance level

$$(5\%) (22 \Omega) (0.05)(22\Omega) = 1.1\Omega$$

is added to and subtracted from the nominal value to determine the range as follows:

$$\text{Maximum value} = 22\Omega + 1.1\Omega = 23.1\Omega$$

$$\text{Minimum value} = 22\Omega - 1.1 \Omega = 20.9\Omega$$

Colour Bands				Numerical Value	Tolerance
1	2	3	4		
Brown	Black	Blue	Gold		
Yellow	Violet	Orange	Gold		
Brown	Gray	Gold	None		
Red	Yellow	Silver	Gold		

Green	Brown	Green	Silver		
Green	Blue	Black	None		

TABLE 1.4

TASK 3. Ohm's Law (Determining I)

In this section the current of a dc series circuit will be determined by a direct measurement and using Ohm's law. In practice, most current levels are determined using Ohm's law and a measured voltage level to avoid having to break the circuit to insert the ammeter. However, one should be aware of the procedure associated with using an ammeter and should feel confident that the measured value and that calculated using Ohm's law are very close in magnitude.

- (a). Construct the circuit of Fig. using the DMM as a milliammeter. Be sure the milliammeter is connected so that conventional current enters the red (positive) terminal of the meter and leaves the black (negative) terminal to ensure a positive reading. Insert the measured value of R in Fig. and Table. Initially set the DMM on (the high milliammeter scale). For most DMMs the red, or positive, lead must be moved from the V- Ω connection to the A terminal of the meter. The COM connection remains the same.

Adjust the power supply until $V_R = 2\text{ V}$ (the voltage across the resistor, not the supply voltage) using the VOM to monitor V_R . Be sure the red (positive) lead is connected to the point of higher potential (the terminal that conventional current enters) and the black (negative) lead is connected to the point of lower potential (the terminal that conventional current leaves). You may find that searching for the best scale (or the milliammeter will affect the voltage across V_R since changing ammeter scales will change the internal resistance of the milliammeter. Find a scale that provides a reading of good accuracy with V_R set at the required 2 V.

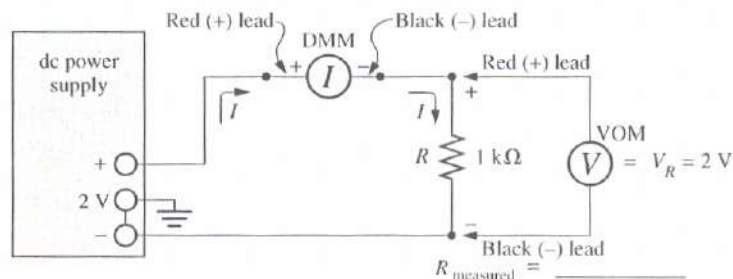


Figure 1.4

In Table record the measured value of I_R from the DMM. Then calculate the level of I_R using Ohm's law and the measured resistor value and record in Table (using mA as the unit of

measurement for I_R). Finally, determine the magnitude of the percent difference from the following equation and complete the line for $V_R = 2\text{ V}$ in Table.

$$\% \text{ Difference} = \left| \frac{I_R (\text{DMM}) - I_R (\text{Ohm's law})}{I_R (\text{DMM})} \right| \times 100\%$$

Repeat this procedure for the other levels of V_R in Table. Note that when $V_R = 0\text{ V}$, $I_R = 0\text{ mA}$ and percent difference 0%.

$R = 1\Omega$ and $R_{\text{measured}} =$ _____

V_R (VOM) V	I_R (DMM) mA	$I_R = V_R / R_{\text{measured}}$ mA	% Difference
0			
2			
4			
8			
10			

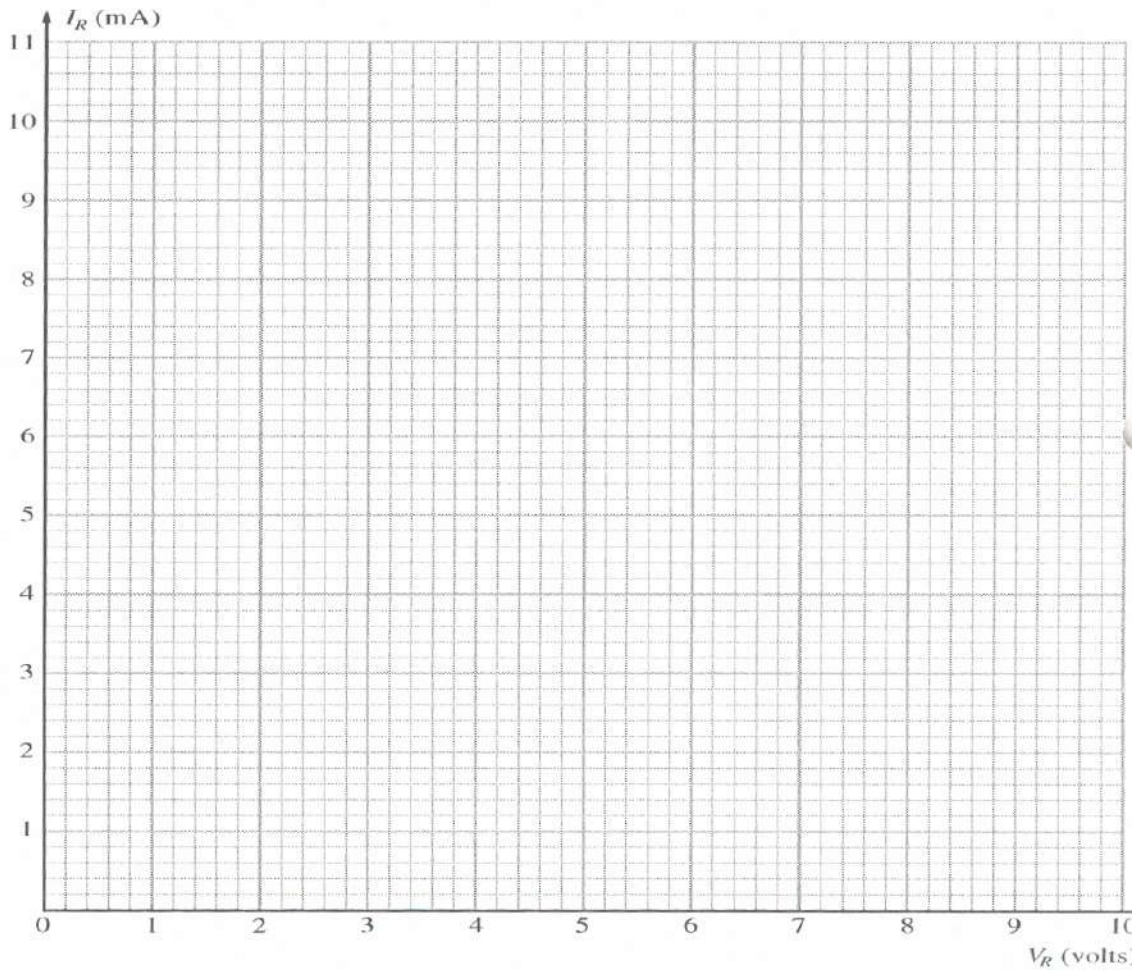
TABLE 1.5

Comment on the level of percent difference in Table. Are the percent differences sufficiently small to establish firmly the fact that the current determined by Ohm's law will be very close (if not equal) to that measured directly?



Plotting Ohm's Law

- (a). Using the data (measured values) of Table, plot I_R (DMM) versus V_R (VOM) on Graph 1.1. Clearly indicate each data point on the graph. Also label the curve as $R = 1\text{ k}\Omega$.



Graph 1.1

- (b). Once the curve of part (a) is drawn, the level of resistance can be determined at any level of voltage or current.

For instance, at I_R 5.6 mA draw a horizontal line from the vertical axis to the curve. Then draw a line down from the intersection to the horizontal voltage axis. Record the level of V_R below and calculate the resistance using Ohm's law.

$V_R =$ _____

Calculation:

$R =$ _____

Using a similar procedure, determine the level of V_R corresponding to $I_R = 1.2$ mA. Determine the value of R using Ohm's law and compare with the level at I_R 5.6 mA.

$V_R =$ _____

Calculation:

$R =$ _____

(c). The resistance level can also be determined from the equation

$$R = \frac{\Delta V_R}{\Delta I_R} \dots (1.1)$$

Where ΔV is the change in V due to a change in current ΔI (or vice versa), as demonstrated by Fig.

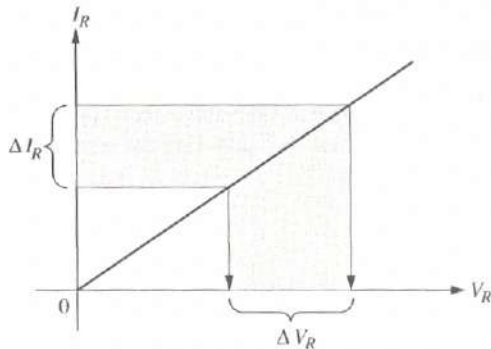


Figure 1.5

For instance, if we choose $\Delta I_R = 6 \text{ mA} - 2 \text{ mA} = 4 \text{ mA}$ for the $1\text{-k}\Omega$ resistor of Graph 1.1, we can determine the resulting ΔV_R and apply Eq. That is, draw a horizontal line from $I_R = 2 \text{ mA}$ and 6 mA on the vertical axis to the curve and then drop lines down to the horizontal axis to determine the corresponding values of V_R . Find the resulting change in V_R and apply Eq. (1.1).

Determine ΔV_R for $\Delta I_R = 6 \text{ mA} - 2 \text{ mA} = 4 \text{ mA}$ for the $1\text{-k}\Omega$ resistor of Graph 1.1.

$\Delta V_R =$ _____

Determine R using equation 1.1

Calculation:

$R =$ _____

Determine ΔI_R for $\Delta V_R = 4.6 \text{ mA} - 3.2 \text{ mA} = 1.4 \text{ mA}$ for the $1\text{-k}\Omega$ resistor of Graph 1.1.

$\Delta I_R =$ _____

Determine R using Eq. (1.1).

Calculation:

R = _____

(d). The slope of a curve is related to the resistance by

$$\text{Slope} = m = \frac{\Delta y}{\Delta x} = \frac{\Delta I_R}{\Delta V_R} = \frac{1}{R} \quad (\text{siemens S}) \quad \dots (1.2)$$

Revealing that the smaller the resistance, the steeper the slope, or the more resistance, less is the slope.

Determine the slope for the I-kΩ resistor in mS using the measured resistor value from graph. 1.1.

Calculation:

m = _____

Part 4 Plotting $R = 3.3 \text{ k}\Omega$

- (a). Reconstruct the circuit of Fig. 1.4 using $R = 3.3 \text{ k}\Omega$. Insert the measured value of R in Table and use this value for all the calculations.

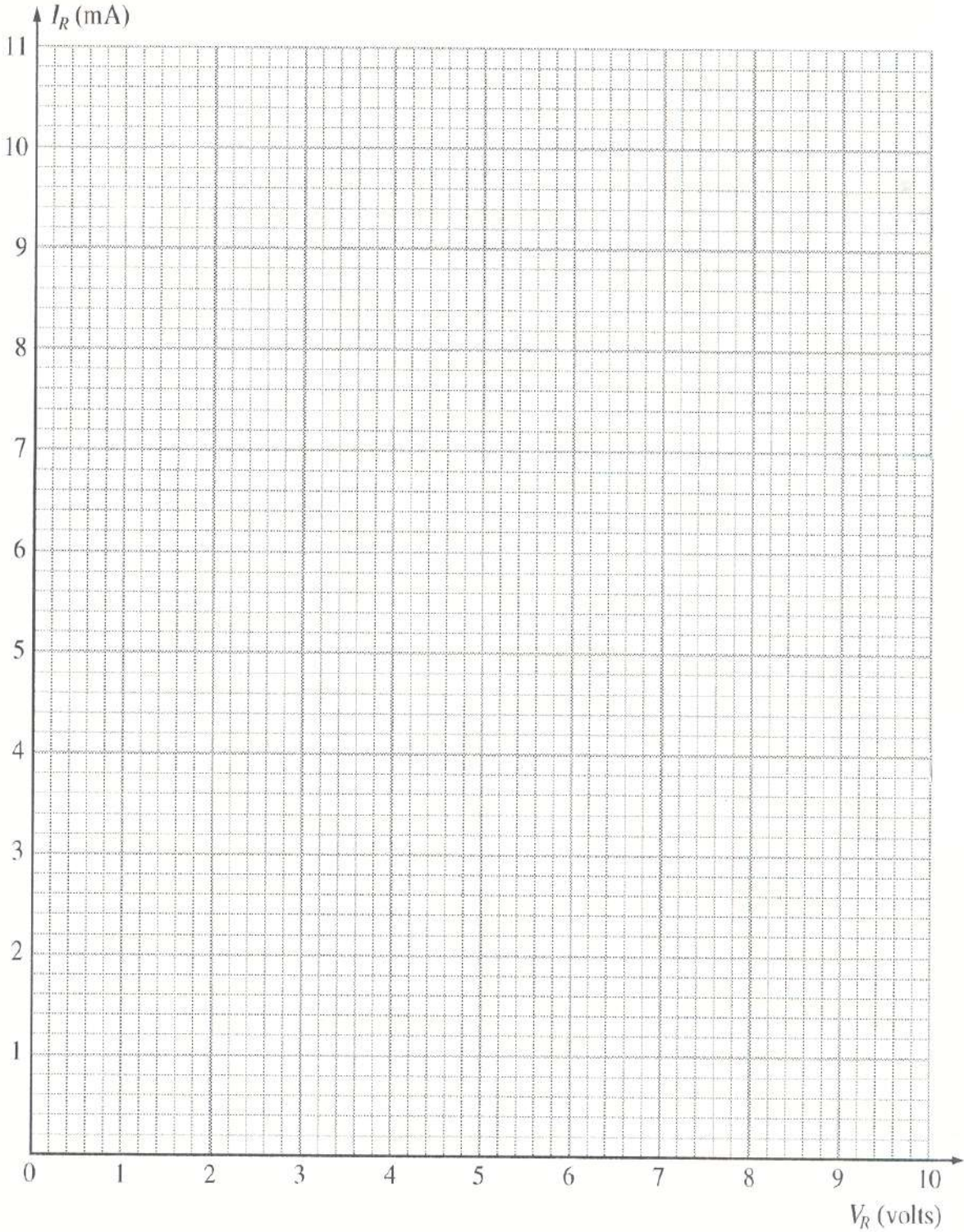
Using the procedure described in part 2, complete Table 1.4.

$R = 3.3 \text{ k}\Omega$ and $R_{\text{measured}} = \underline{\hspace{2cm}}$

V_R (VOM) V	I_R (DMM) mA	$I_R = V_R / R_{\text{measured}}$ mA	% Difference
0			
2			
4			
8			
10			

TABLE 1.6

- (b). Using the data of Table, plot I_R (DMM) versus V_R (VOM) on Graph 1.2. Clearly indicate each data point on the graph. Also label the curve as $R = 3.3 \text{ k}\Omega$.



Graph 1.2

- (c). Determine the level of V_R corresponding to $I_R = 2.4 \text{ mA}$ and calculate the resistance using Ohms Law

$$V_R = \underline{\hspace{2cm}}$$

Calculation:

$$R = \underline{\hspace{2cm}}$$

- (d). Determine ΔV_R corresponding to $\Delta I_R = 2.2 \text{ mA} - 1.4 \text{ mA} = 0.8 \text{ mA}$ and calculate the resistance

$$V_R = \underline{\hspace{2cm}}$$

Calculation:

$$R = \underline{\hspace{2cm}}$$

- (e). Determine the slope of the $3.3\text{-k}\Omega$ resistor using the measured value (from Table) and Eq. 1.2.

Calculation:

m = _____

How does the magnitude of the slope compare to the magnitude determined for the 1 -k Ω resistor?

Is the following conclusion verified: The larger the resistance, the less the slope?

TASK 4 SERIES RESISTANCE

The total resistance R_T of a series circuit is the sum of the individual resistances.

$$R_T = R_1 + R_2 + R_3$$

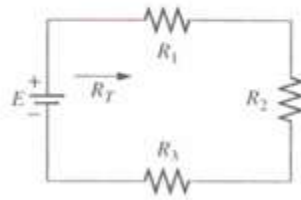


Figure 1.6

For equal series resistors, the total resistance is equal to the resistance of one resistor times the number in series; that is,

$$R_T = nR \quad \dots(1.3)$$

For any system, such as that appearing in Figure 1.7, the total resistance can be determined by the following form of Ohm's law:

$$R_T = E/I \quad \dots(1.4)$$

That is, for an applied voltage E the current I (Figure 1.4) is applied to determine the resistance of the network.

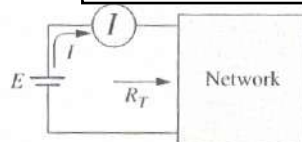


Figure 1.7

Two Series Resistors

(a). Construct the circuit of Fig. 1.8.

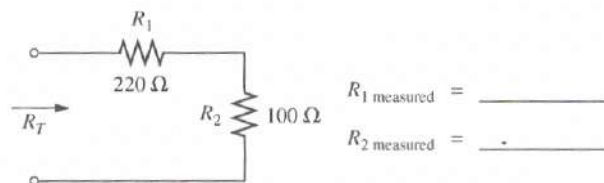


Figure 1.8

- (b). Calculate the total resistance using the measured resistor values. Show all work! Apply units to all results.

$$R_T = \underline{\hspace{2cm}}$$

- (c). Measure the total resistance using the ohmmeter section of your DMM.

$$R_T = \underline{\hspace{2cm}}$$

How do the measured and calculated values compare? Calculate the magnitude of the percent difference from

$$\% \text{ Difference} = \left| \frac{\text{Measured} - \text{Calculated}}{\text{Calculated}} \right| \times 100\%$$

$$\% \text{ Difference} = \underline{\hspace{2cm}}$$

- (d). Set the supply to 8 V using the DMM. Then turn off the supply and construct the circuit of Fig. 4.4. Using the same DMM as a milliammeter (be sure to set up the DMM as a milliammeter by choosing the A (ampere) terminal for the positive lead and putting the meter in series with the supply, with conventional current entering the positive terminal and leaving the negative, or COM, terminal). We are unaware of the current levels, so set the ammeter to the highest available scale. Once the circuit is constructed and carefully checked, turn on the supply and record the ammeter reading below. Be sure to use the scale of the ammeter that provides the most accurate reading.

$$I = \underline{\hspace{2cm}}$$

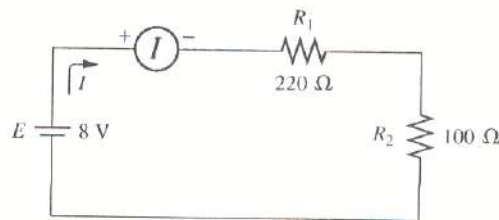


Figure 1.9

- (e). Using the supply voltage and ammeter reading of part 1(d), calculate the total resistance using Eq. (1.4).

$R_T =$ _____

How do the results of this part and part 1(c) compare?

TASK 5. Familiarization with the Oscilloscope and Function Generator

The oscilloscope is the most important instrument available to the practicing technician or engineer. It permits the visual display of a voltage signal that can reveal a range of information of the operating characteristics of a circuit or system that is not available with a standard multimeter. At first glance the instrument may appear complex and difficult to master. Be assured, however, that once the function of each section of the oscilloscope is explained and understood and the system is used throughout a set of experiments, your expertise with this important tool will develop quite rapidly.

In addition to the display of a signal, it can also be used to measure the average value, rms value, frequency, and period of a sinusoidal or non-sinusoidal signal. The screen is divided into centimeter divisions in the vertical and horizontal directions. The vertical sensitivity is provided (or set) in volts/div., while the horizontal scale is provided (or set) in t time (s/div.). If a particular signal occupies 6 vertical

divisions and the vertical sensitivity is 5 mV/div., the magnitude of the signal can be determined from the following equation:

Amplitude of signal voltage = voltage sensitivity

(V/div.) x deflection (div.)

$$V_s = (5 \text{ mV/div.}) (6 \text{ div.}) = 30 \text{ mV} \quad (1.1)$$

If one cycle of the same signal occupies 8 divisions on the horizontal scale with a horizontal sensitivity of 5 μ s/div., the period and frequency of the signal can be determined using the following equations:

Period of signal voltage = horizontal sensitivity (s/div.) x deflection (div.)

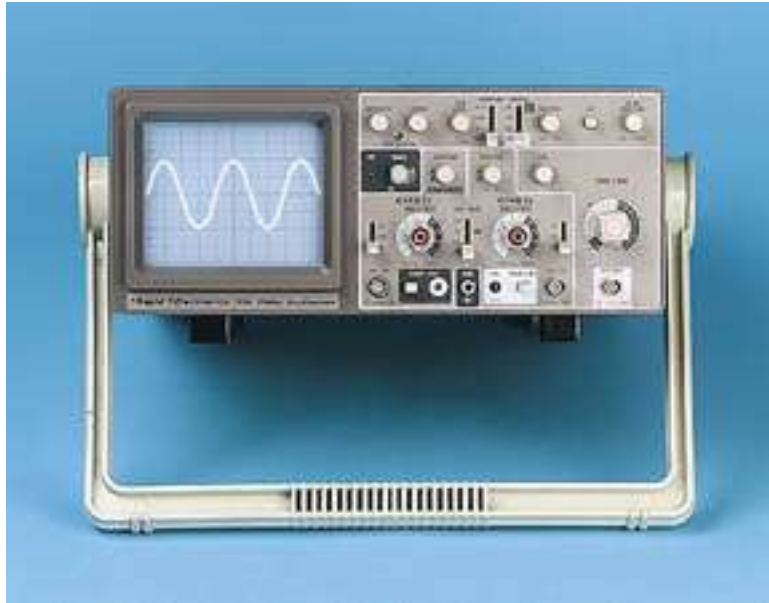
$$T = (5 \mu\text{s /div.}) (8 \text{ div.}) = 40 \mu\text{s} \quad (1.2)$$

$$f = 1/T = 40 \mu\text{s} = 25 \text{ kHz}$$

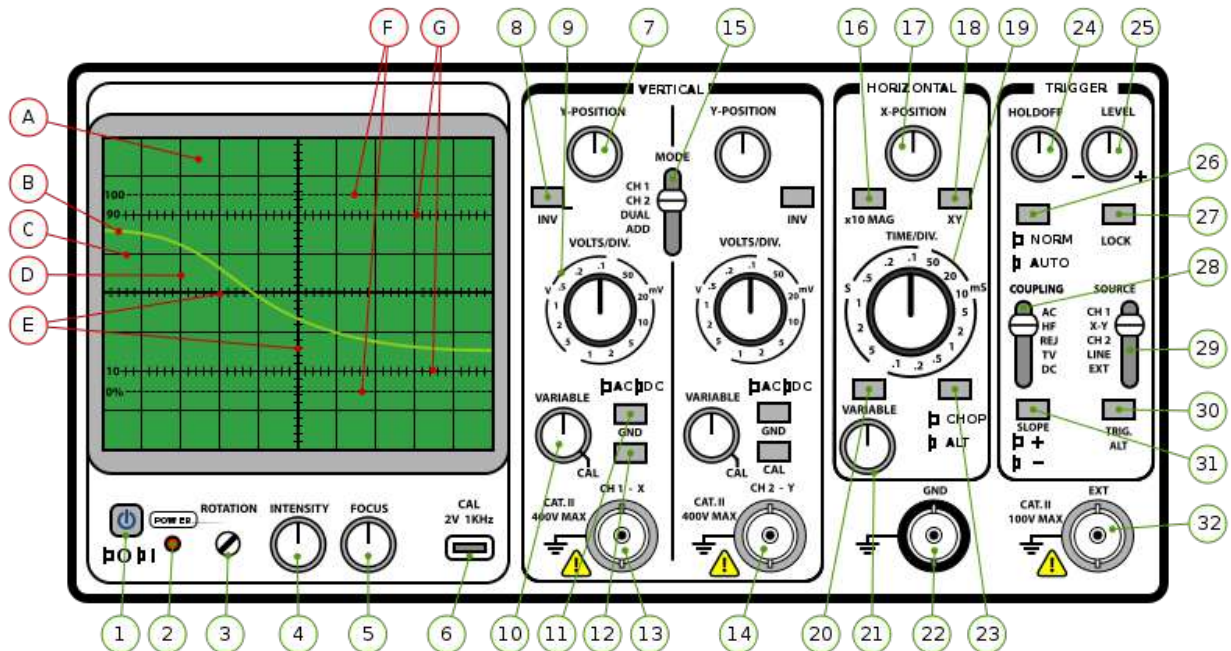
2. FUNCTION GENERATOR

The function generator is a voltage supply that typically provides a sinusoidal, square-wave, and triangular voltage waveform for a range of frequencies and amplitudes. The frequency and the amplitude of these voltage functions can be set by the proper dial positions and their associated multipliers. For more precise settings of these parameters, the oscilloscope is used.

Both the scope and the function generator are built to withstand some abuse, so do not be afraid to try various combinations of dial settings to fully develop your abilities with this laboratory experiment. If you are working in a group, every group member should be involved in the experimental work. It is important to learn how to use the laboratory equipment, such as the function generator and the oscilloscope, properly. Such acquired skills are essential for the job of the electrical engineer and technician.



CRO (Front Panel)



Horizontal Sensitivity

1. Determine the period of the 1000 Hz sinusoidal waveform in milliseconds using the equation $T = 1/f$. Show all work for each part of the experiment.

T (calculated) = _____

2. Set the horizontal sensitivity of the scope to 0.2 ms/div. Using the oscilloscope, measure the number of required divisions and insert below. How does the result compare to the calculated number of divisions?

Number of divisions (measured) = _____

Vertical Sensitivity

1. Do not touch the controls of the function generator but set the sensitivity of the scope to 0.2 ms/div. and set the vertical, sensitivity to 2 V/div. Using this latter sensitivity, calculate the peak-to-peak value of the sinusoidal waveform on the screen by first counting the number of vertical divisions between peak values and multiplying by the vertical sensitivity.

Peak-to-peak value (calculated) = _____

Exercises

1. Make all the necessary adjustments to clearly display a 5000-Hz Vp-p sinusoidal signal on the oscilloscope. Establish the zero volt line at the center of the screen. Record the chosen sensitivities:

Vertical sensitivity = _____
 Horizontal sensitivity = _____

2. Draw the waveform on Fig. 1.1, carefully noting the required number of horizontal and vertical divisions. Add vertical and horizontal dimensions to the waveform using the chosen sensitivities listed above.

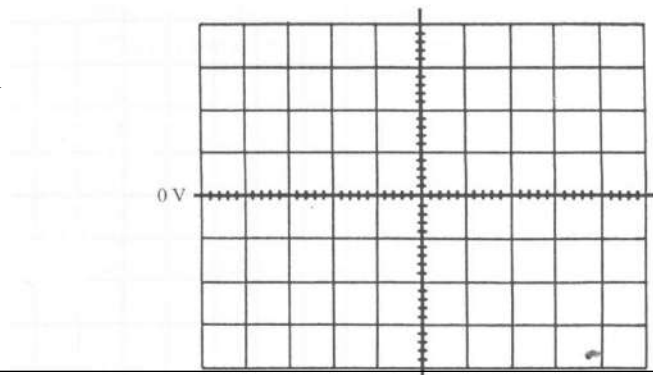


Figure 1-1

1. Calculate the period of the waveform on the screen using the number of horizontal divisions for a full cycle as shown.

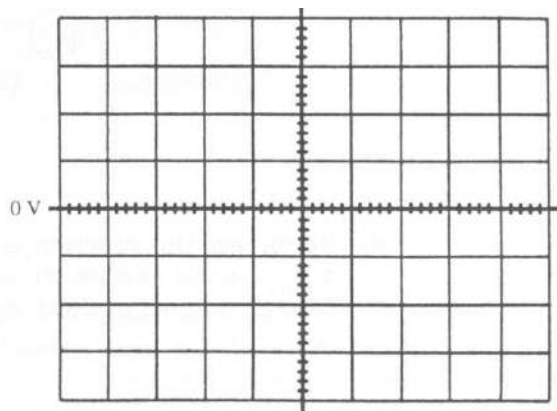
T (calculated) = _____

2. Repeat Part 3(1) for a 200-Hz 0.8 V_{p-p} sinusoidal waveform on Fig. 1.2

Vertical sensitivity = _____

Horizontal sensitivity = _____

T (calculated) = _____



Analysis(Results and Discussion)

Conclusion

Learning Outcomes Assessment Questions:

- 1- State the modes of DC power supply.**
- 2- How to use DC power supply as a floated mode?**
- 3- How to use DC power supply as a grounded mode?**
- 4- How can we measure voltage across any component?**
- 5- How can we measure current from any branch?**
- 6- Why we use very high resistance in voltmeter?**
- 7- Why we use very low resistance in ammeter?**
- 8- State the two internal attenuator's of oscilloscope?**
- 9- What is vertical sensitivity?**
- 10- What is horizontal sensitivity?**

Lab 5: Implementation of Superposition and Maximum Power Transfer Theorem

1. RESISTORS

1—91 Ω , 220 Ω , 330 Ω , 470 Ω , 1-k Ω , 2.2-k Ω , 3.3-k Ω (1/4-W)

1—0—1- Ω potentiometer, 0—10-k Ω potentiometer

2. INSTRUMENTS

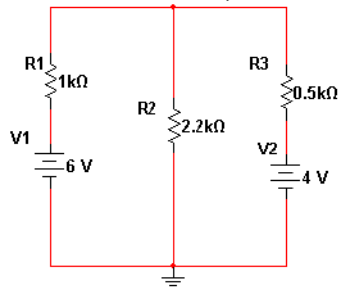
1—DMM

1—dc Power supply

SUPERPOSITION THEOREM

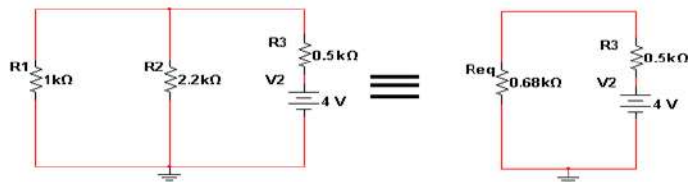
In a network of linear resistances containing more than one generator (or source of e.m.f.), the current which flows at any point is the sum of all the current which would flow at that point if each generator were considered separately and all the other generators replaced for the time being by resistances equal to their internal resistances.

1. In this network, there are two sources and three resistors.



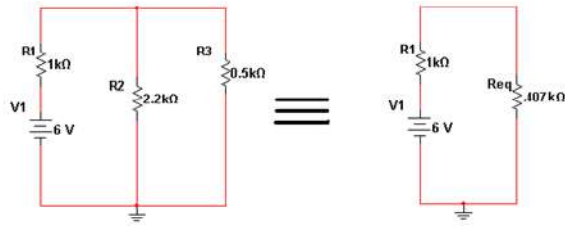
2. To find the voltage caused by the 4V generator, replace the 6V generator by short circuit. Using Ohm's law, and the potential divider equation:

$$V = 2.315V$$



3. To find the voltage caused by the 6V generator, replace the 4V generator by short circuit. Using Ohm's law, and the potential divider equation:

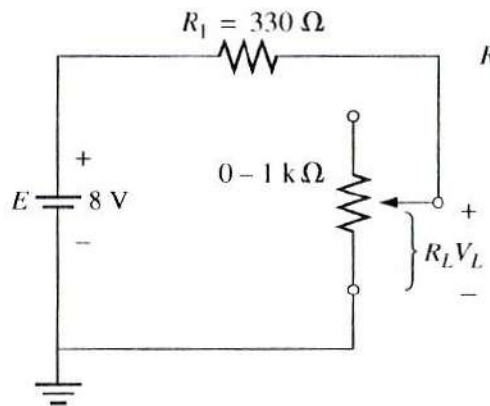
$$V = 1.736V$$



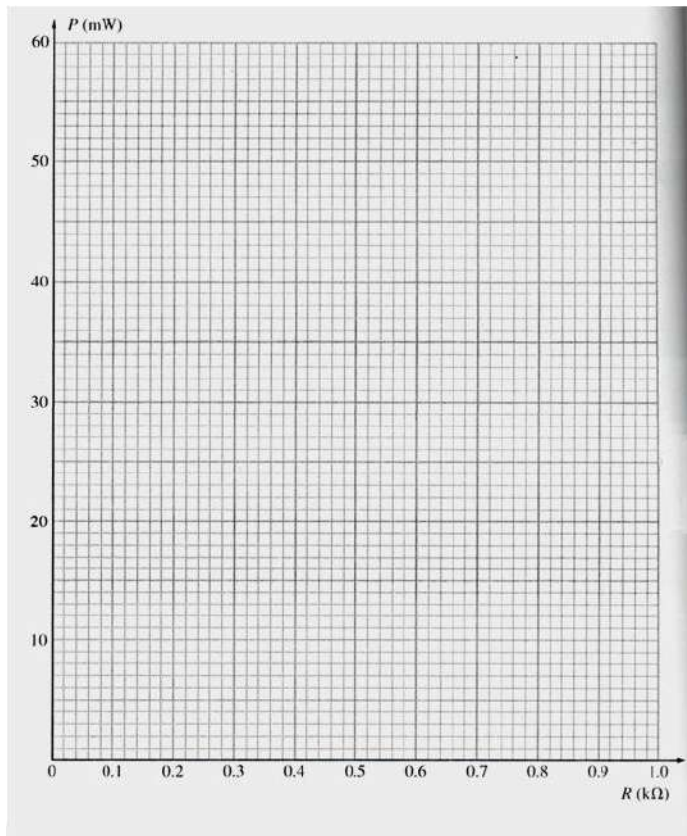
4. Now the total voltage of the original circuit is sum of the two voltages and that is : $V = 4.051 \text{ V}$

MAXIMUM POWER TRANSFER THEOREM

a) Construct the network of Fig. 6.1 and set the potentiometer to 50Ω . Measure the voltage across as you vary R_L through the following values: 0, 100, 200, 300, 330, 400, 600, 800, and 1000 Ω . Be sure to set the resistance with the ohmmeter section of your meter before each reading. Remember to turn off the dc supply and disconnect one terminal of the potentiometer when setting the resistance level. Complete Table 6.2 and plot P_L versus R_L on Graph 6.1.



R_L	V_L	$P = \frac{V_L^2}{R_L}$ (mW)
0 Ω	0 V	0 mW
50 Ω		
100 Ω		
200 Ω		
300 Ω		
$R_{\text{measured}} =$ _____		
400 Ω		
600 Ω		
800 Ω		
1000 Ω		



Comments:

Lab6: Investigation of the voltage regulation of a single phase transformer

Learning Objective:

At the end of this Lab, students will be able to:

- ✓ Operate the single phase transformer.
- ✓ Examine the concept of voltage Regulation.

Apparatus:

Single Phase and Transformer instruments panel containing following instruments

- ✓ Ammeter, 1 A AC
- ✓ Voltmeter 220V AC
- ✓ Wattmeter
- ✓ Rheostats
- ✓ Variable AC Power Supply
- ✓ Connecting leads

Circuit Diagram:

Besides the propeller, the other major component of the system is the governor. The propeller governor is an rpm – sensing device which responds to a change in system rpm by directing oil to or releasing oil from the propeller to change the blade angle and return the system rpm to the original value. The governor may be set up for a specific rpm by the cockpit propeller control.

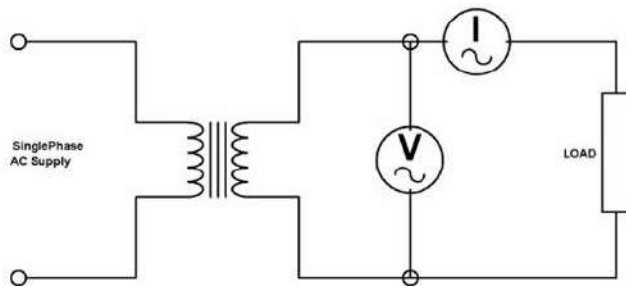
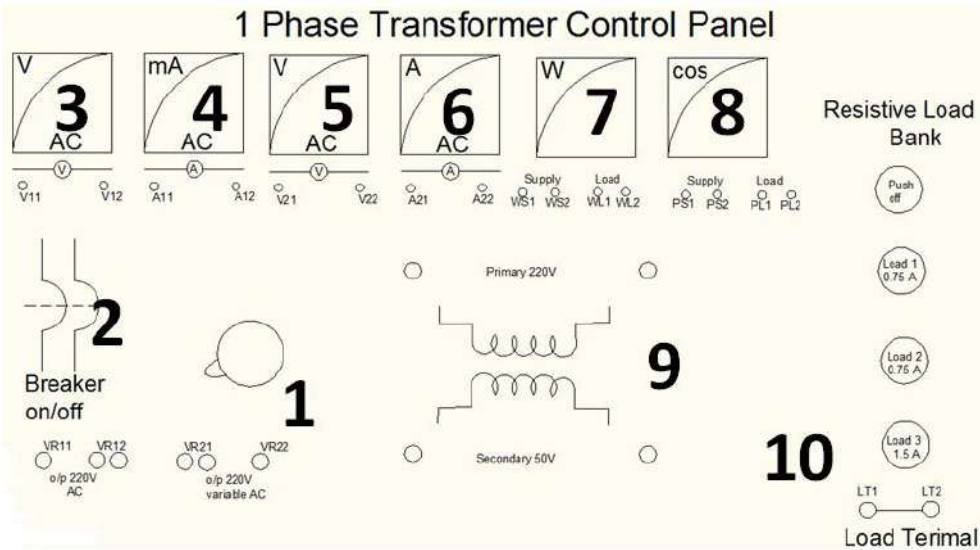
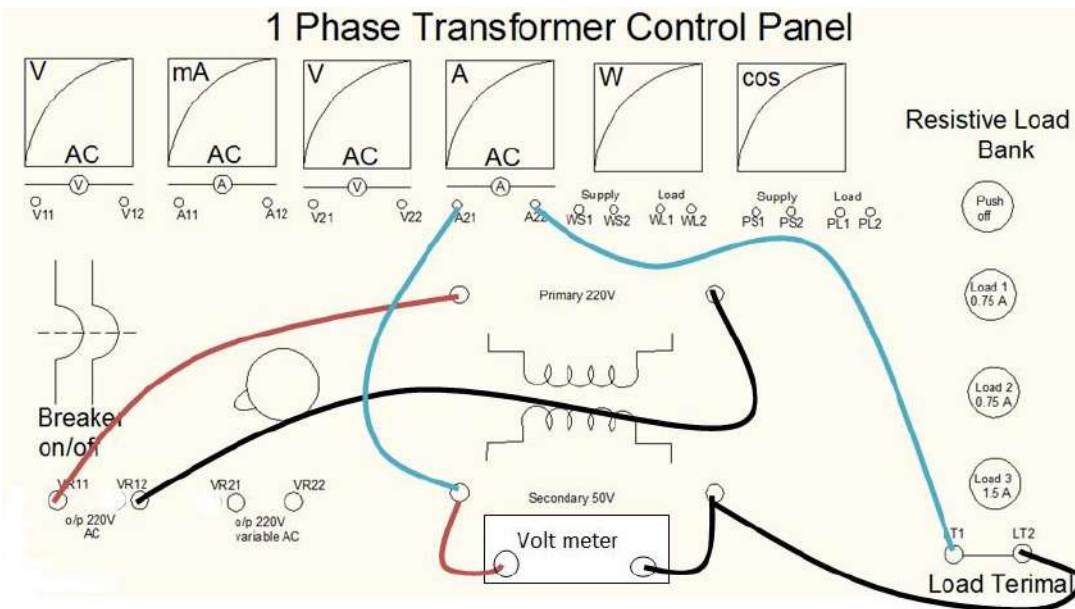


Figure-1. 1: Regulation of Single phase Transformer.

Panel Diagram:



Circuit Connections:



Procedure:

- 1- Measure the output voltage without load with the help of voltmeter and record in Table 1.1
- 2- Gradually increase the load current (i.e apply load) and measure the output terminal voltage.
- 3- Calculate the % voltage regulation and record the values in Table-1.1.
- 4- Draw a graph of output voltage and %age regulation vs. load current.

Lab 7: Implementation of Series and Parallel RL circuits

EQUIPMENT REQUIRED

Resistors

1-10 Ω , 1k Ω -6 k Ω

Inductors

1-10mH

Instruments

1-DMM

1-dc Power Supply

1-SPST switch

INTRODUCTION

The inductor, like the capacitor is an energy storing device. The capacitor stores energy in the form of an electric field while the inductor stores it in the form of a magnetic field. The energy stored by an inductor (in Joules) W is given by

$$W = \frac{1}{2}(LI^2)$$

In any circuit containing an inductor, the voltage across the inductor is determined by the inductance (L) and the rate of change of the current through the inductor:

$$V_L = L \frac{\text{Change of current}}{\text{change of time}} = L \frac{\Delta I}{\Delta t}$$

The step response of a system in a given initial state consists of the time evolution of its outputs when its control inputs are Heaviside step functions. In electronic engineering and control theory, step response is the time behavior of the outputs of a general system when its inputs change from zero to one in a very short time. The concept can be extended to the abstract mathematical notion of a dynamical system using an evolution parameter.

PROCEDURE

TASK 1. Series RL dc Circuit

Construct the circuit of following figure 11.1. Insert the measure values of R_1 and R_L

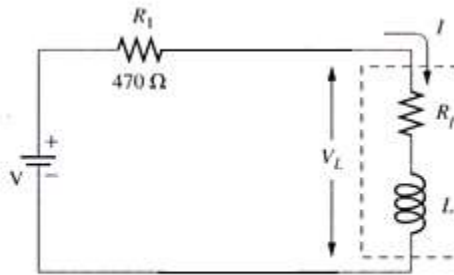


Figure 11.1

- a) Calculate the current (I) and the voltage (V_L) for steady- state conditions.

$$I = \underline{\hspace{2cm}} \qquad V_L = \underline{\hspace{2cm}}$$

- b) Measure V_L and determine I by measuring the voltage across the 470- Ω resistor and using Ohm's Law with measured resistor value.
- c) Now construct the circuit according to following diagram, adding a switch.

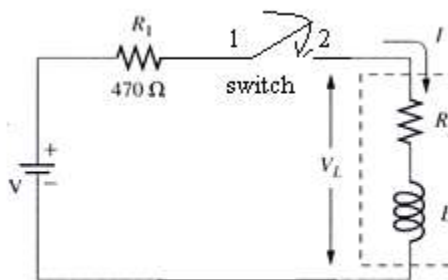


Figure 11.2

- d) Calculate the current (I) and the voltage (V_L) for when switch is closed, and when it is open .

$I =$ _____

$V_L =$ _____

- e) Make a graph between current and time for Inductor.

Task 2. Parallel RL dc Circuit

- a) Construct the circuit according to following diagram.

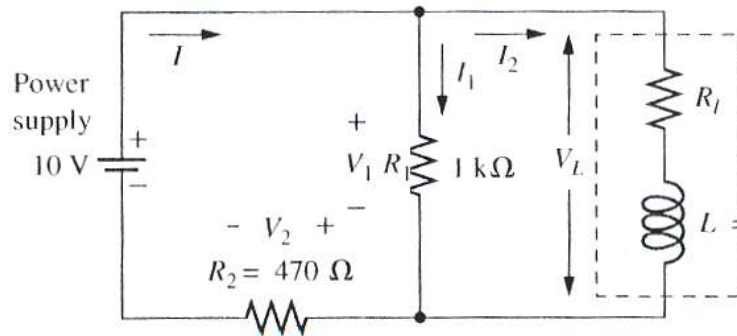


Figure 11.3

$R_{1 \text{ measured}} =$ _____

$R_{2 \text{ measured}} =$ _____

$R_{L \text{ measured}} =$ _____

- b) Calculate I , I_1 and I_2 assuming an ideal inductor ($R_L = 0\Omega$). Use measured resistor values.

$I =$ _____

$I_1 =$ _____

$I_2 =$ _____

- c) Measure V_1 and V_2 , and using measured resistor values determine I , I_1 and I_2 using the equations

$$I = V_2/R_2$$

$$I_1 = V_1/R_1$$

$$I_2 = I - I_1$$

$$V_1 = \underline{\hspace{4cm}}$$

$$V_2 = \underline{\hspace{4cm}}$$

$$I = \underline{\hspace{4cm}}$$

$$I_1 = \underline{\hspace{4cm}}$$

$$I_2 = \underline{\hspace{4cm}}$$

- d) Now construct the circuit as shown in the following figure,

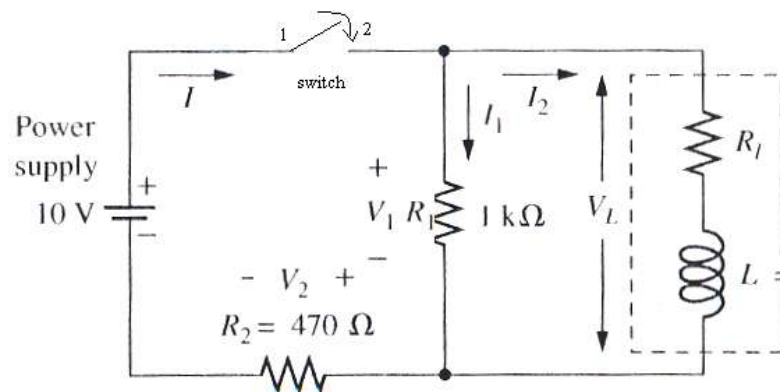


Figure 11.4

- e) Repeat all the procedure as done above, and make a table for values of currents and voltages, as switch is closed and when open.
- f) Make a graph for inductor current and time.

Practical Applications of RL Circuits:

1. **Electronic Filters:**

Electronic filters are [analog circuits](#) which perform [signal processing](#) functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones, or both. RL series circuits are the most used Filter circuits. The major types are **Low Pass, High Pass, Band Pass, Band Reject** filters. Frequently RL circuits are used for DC power supplies to RF amplifiers, where the inductor is used to pass DC bias current and block the RF getting back into the power supply.

Analysis(Results and Discussion)

Conclusion

Learning Outcomes Assessment Questions:

- 1- What is dynamical system?
- 2- What is step response of a system?
- 3- What is time constant?
- 4- Write the formula of energy stored in inductor?
- 5- Which type of field store across the inductor?
- 6- What is the role of inductor in DC circuit?
- 7- What is the equivalent capacitance if 5 inductors are connected in parallel?
- 8- What is the condition of inductor after charging?
- 9- How inductor respond to dc input at a very start?
- 10- What is the practical application of RL circuit?

Lab 8: Implementation of Series and Parallel RC circuits

EQUIPMENT REQUIRED

1. RESISTORS

2—1k Ω

2. Capacitors

1-1 μ F

2. INSTRUMENTS

1—VOM

1—DMM

1—dc Power supply

3. Miscellaneous

1-SPST switch

INTRODUCTION

Capacitor is an energy storing element, it stores energy in form of electric field between its plates. The energy stored by it is given by

$$W = \frac{1}{2}CV^2$$

Current through the capacitor is generally calculated by this formula

$$I_c = C \frac{dV}{dt}$$

So voltage must be changing if we want to get some non zero value through capacitor.

Capacitors do not play an important role in DC circuits because it is impossible for a steady current to flow across a capacitor. If an uncharged capacitor **C** is connected across the terminals of a battery of voltage **V** then a *transient* current flows as the capacitor plates charge up. However, the current stops flowing as soon as the charge **Q** on the positive plate reaches the

value $Q=CV$. At this point, the electric field between the plates cancels the effect of the electric field generated by the battery, and there is no further movement of charge. Thus, if a capacitor is placed in a DC circuit then, as soon as its plates have charged up, the capacitor effectively behaves like a *break* in the circuit.

One thing should also be kept in mind that capacitors are added in parallel whenever we want to calculate equivalent capacitance because of added capacitors so $C_{eq}=C1+C2+C3+.....+Cn$ and opposite is true when they are in series so formula for equivalent capacitance is given by

$$1/C_{eq} = 1/C1 + 1/C2 + 1/C3 + + 1/Cn$$

PROCEDURE

TASK 1. Series RC circuit

First of all consider the following circuit as shown in Figure 12.1 and wire it on bread board.

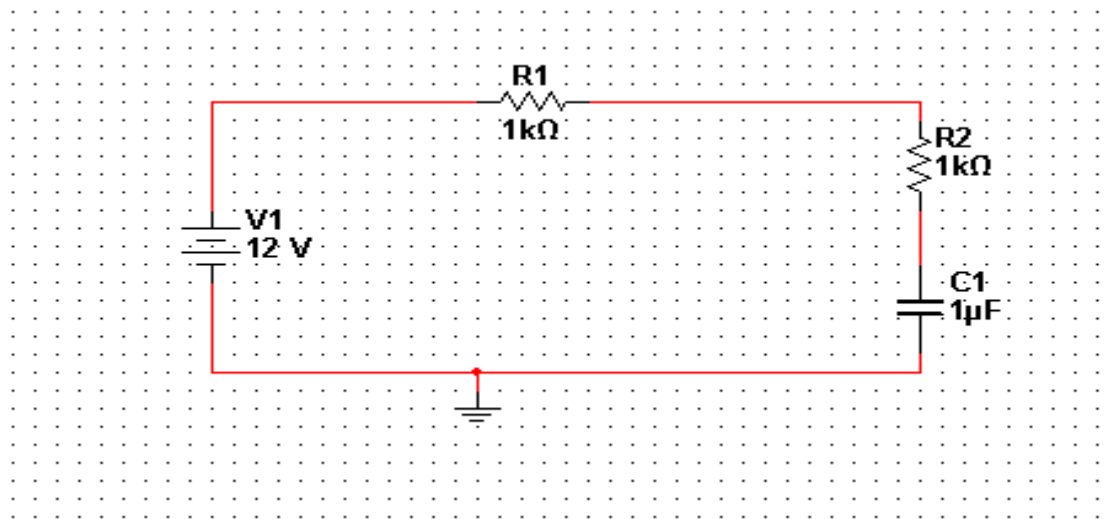


Figure 12.1

Calculate the voltage across each element of circuit and also current through the circuit.

$V_{R1} =$ _____ $V_{R2} =$ _____ $V_{C1} =$ _____

$I =$ _____

Measure the voltage across each element of circuit and also current through the circuit.

$V_{R1} =$ _____ $V_{R2} =$ _____ $V_{C1} =$ _____

$I =$ _____

Justify and compare your results with theoretical explanation about the behavior of capacitor to DC when connected in series.

TASK 2. Parallel RC circuit

Now consider the following circuit as shown in Figure 12.2 and wire it on bread board.

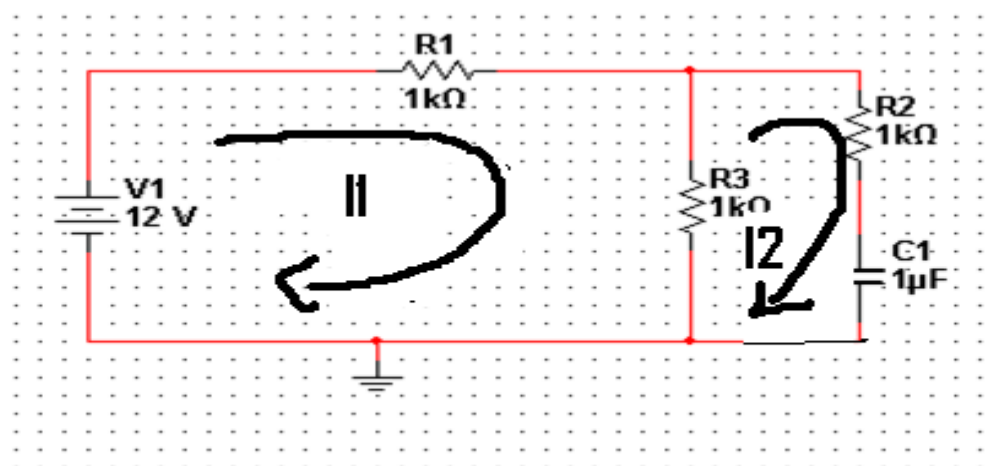


Figure 12.2

Calculate the voltage across each element of circuit and also current through the circuit in each loop.

$V_{R1} =$ _____ $V_{R2} =$ _____ $V_{R3} =$ _____

$V_{C1} =$ _____

$I_1 =$ _____ $I_2 =$ _____

Measure the voltage across each element of circuit and also current through the circuit.

$V_{R1} =$ _____ $V_{R2} =$ _____ $V_{R3} =$ _____

$V_{C1} =$ _____

$I_1 =$ _____ $I_2 =$ _____

Justify and compare your results with theoretical explanation about the behaviour of capacitor to DC when connected in parallel.



Analyze the step response of the capacitor by connecting switches at appropriate places in above two circuits as told by instructor and write your observations in space given below.

Practical Applications of RC Circuits:

1. Time Delay;

RC circuits are used in the applications where some function is needed after a specified delay. The product of resistance and capacitance defines the Time constant.

2. Electronic Filters:

RC circuit also act as electronic filters for AC circuits.

3. Integrators and Differentiators:

The combination of R and C when used along with Operational Amplifier gives integrator and Differentiators.

Analysis(Results and Discussion)

Conclusion

Learning Outcomes Assessment Questions

- 1- What is dynamical system?
- 2- What is step response of a system?
- 3- What is time constant?
- 4- Write the formula of energy stored in capacitor?
- 5- Which type of field store across the capacitor?
- 6- What is the role of capacitor in DC circuit?
- 7- What is the equivalent capacitance if 5 capacitors are connected in parallel?
- 8- What is the practical application of RC circuit?
- 9- Why capacitor behaves as an open circuit after charging?
- 10- Why capacitor requires heavy current at a very start when it is uncharged?

Lab9: Implementation of RLC series and Parallel Circuits

EQUIPMENT REQUIRED

1. RESISTORS
2. INDUCTORS
3. CAPACITOR

2. INSTRUMENTS

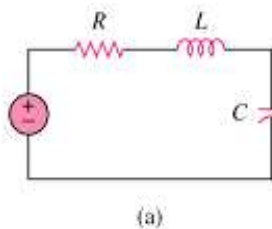
1—VOM

1—DMM

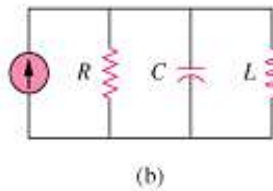
1—dc Power supply

INTRODUCTION

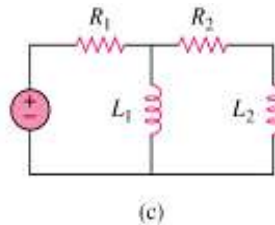
A second-order circuit is characterized by a second-order differential equation. It consists of resistors and the equivalent of two energy storage elements



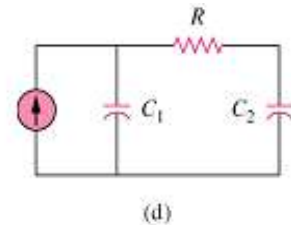
RLC Series



RLC Parallel



RL T-config

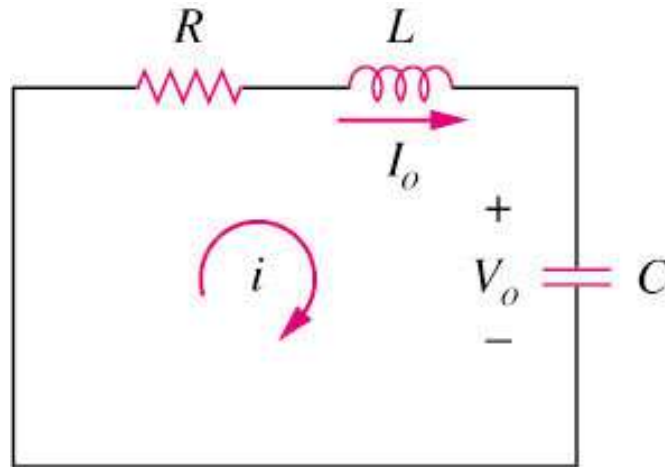


RC Pi-config

PROCEDURE

TASK1.Source-Free Series RLC Circuits

1. The solution of the source-free series RLC circuit is called as the natural response of the circuit.
2. The circuit is excited by the energy initially stored in the capacitor and inductor.



$$\frac{d^2 i}{dt^2} + \frac{R}{L} \frac{di}{dt} + \frac{i}{LC} = 0$$

Solutions: There are three possible solutions for the following 2nd order differential equation:

$$\frac{d^2 i}{dt^2} + \frac{R}{L} \frac{di}{dt} + \frac{i}{LC} = 0$$

$$\frac{d^2 i}{dt^2} + 2\alpha \frac{di}{dt} + \omega_0^2 i = 0$$

Where;

$$\alpha = \frac{R}{2L} \quad \text{and} \quad \omega_0 = \sqrt{\frac{1}{LC}}$$

1. If $\alpha > \omega_0$ over-damped case

$$i(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

And the roots of above equation are;

$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

2. If $\alpha = \omega_0$, critical damped case

$$i(t) = (A_2 + A_1 t) e^{-\alpha t}$$

Both roots are real and same

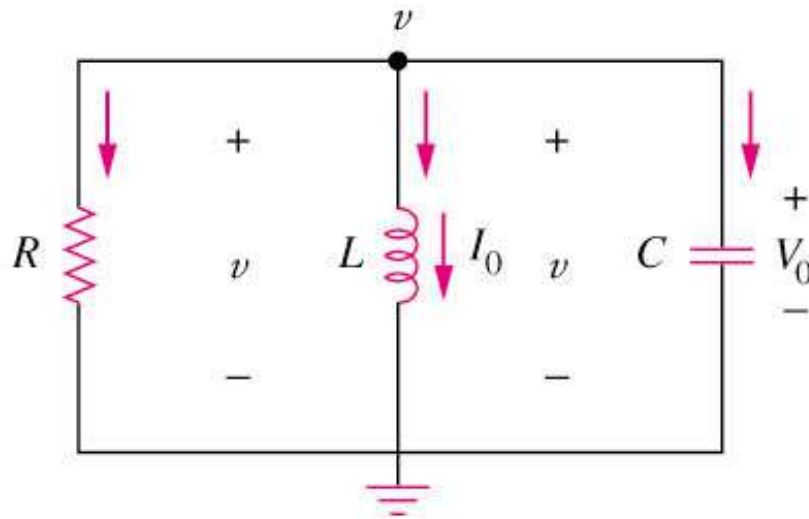
$$s_{1,2} = -\alpha$$

3. If $\alpha < \omega_0$, under-damped case

$$i(t) = e^{-\alpha t} (B_1 \cos \omega_d t + B_2 \sin \omega_d t)$$

$$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

TASK2.Source-Free Parallel RLC Circuits



$$i(0) = I_0 = \frac{1}{L} \int_{-\infty}^0 v(t) dt$$

$$\frac{v}{R} + \frac{1}{L} \int_{-\infty}^t v dt + C \frac{dv}{dt} = 0$$

$$\frac{d^2 v}{dt^2} + \frac{1}{RC} \frac{dv}{dt} + \frac{1}{LC} v = 0$$

Solutions: There are three possible solutions for the following 2nd order differential equation:

$$\frac{d^2 v}{dt^2} + 2\alpha \frac{dv}{dt} + \omega_0^2 v = 0 \quad \text{where} \quad \alpha = \frac{1}{2RC} \quad \text{and} \quad \omega_0 = \sqrt{\frac{1}{LC}}$$

1. If $\alpha > \omega_0$ over-damped case

$$v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}$$

$$s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$$

2. If $\alpha = \omega_0$, critical damped case

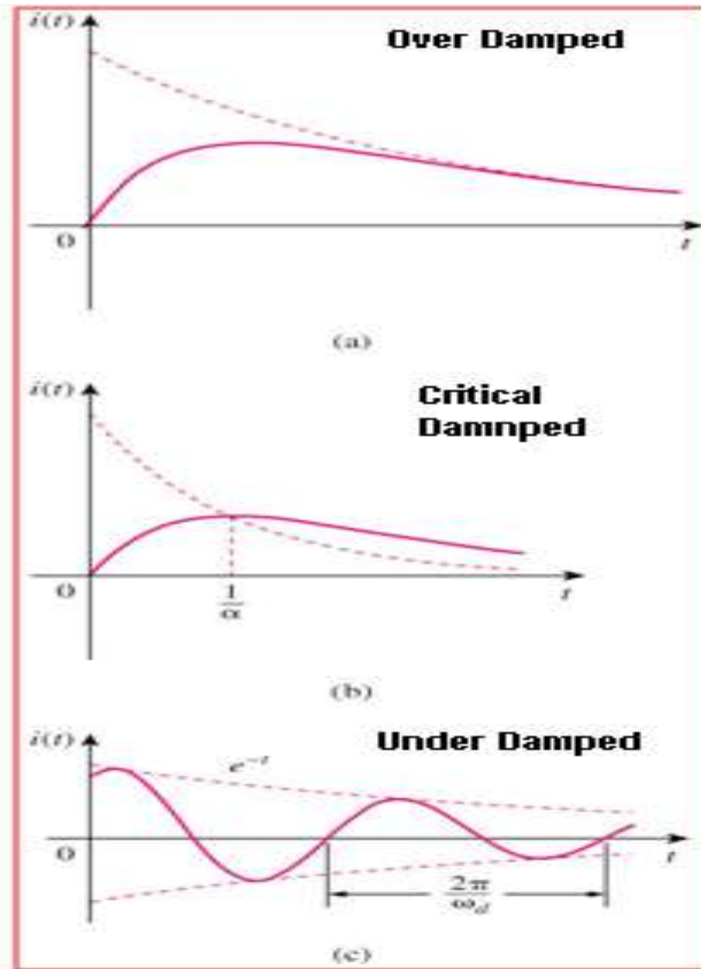
$$v(t) = (A_2 + A_1 t) e^{-\alpha t}$$

$$s_{1,2} = -\alpha$$

4. If $\alpha < \omega_0$, under-damped case

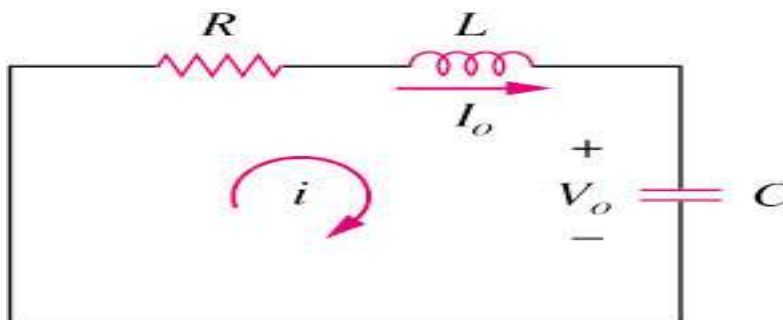
$$v(t) = e^{-\alpha t} (B_1 \cos \omega_d t + B_2 \sin \omega_d t)$$

$$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

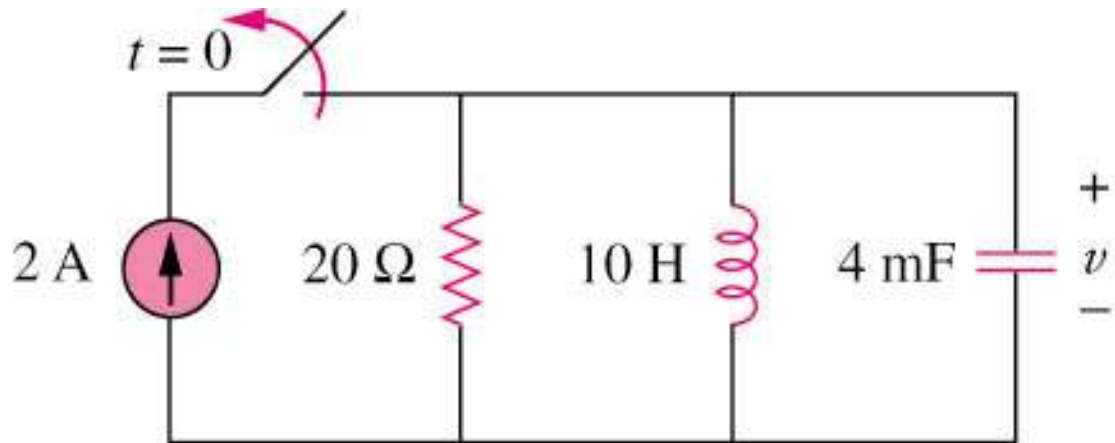


LAB ASSIGNMENT

P1. If $R = 10 \Omega$, $L = 5 \text{ H}$, and $C = 2 \text{ mF}$ in 8.8, find α , ω_0 , s_1 and s_2 . What type of natural response will the circuit have?



P2. Refer to the circuit shown below. Find $v(t)$ for $t > 0$.



Analysis(Results and Discussion)

Conclusion

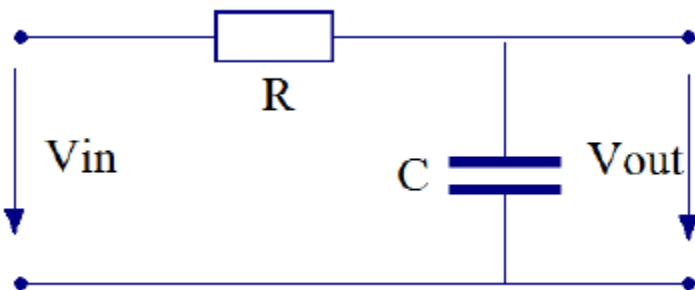
Learning Outcomes Assessment Questions:

- 1- What do you mean by second order circuit?
- 2- What is the neutral response of the circuit?
- 3- What is over-damped case? Draw its graph?
- 4- What is under-damped case? Draw its graph?
- 5- What is critical damped case? Draw its graph?
- 6- What is time constant?
- 7- What is resonance frequency?
- 8- What is damping factor?
- 9- What is natural frequency?
- 10- What are the conditions for over, under and critical damped system?

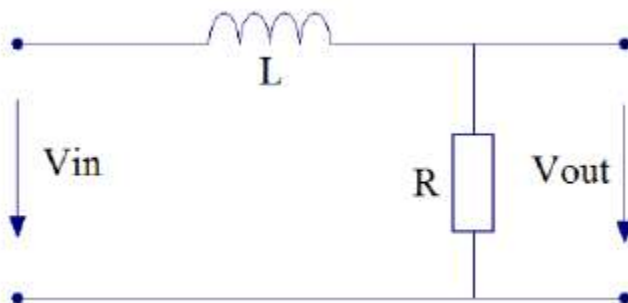
Lab10: Low Pass and High Pass Filters

1. Use the given figures to set up the circuits for the different types of filters mentioned.
2. Change the frequency of operation and observe the effects on the output response.
3. Compare the calculated and the measured cut-off frequencies.

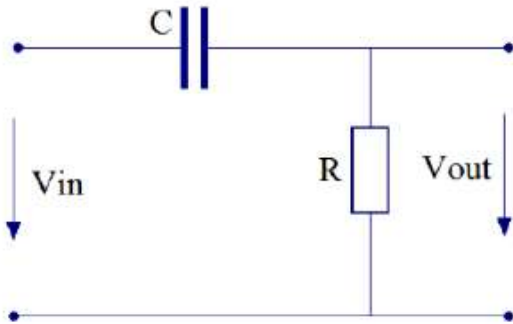
RC Low Pass Filter



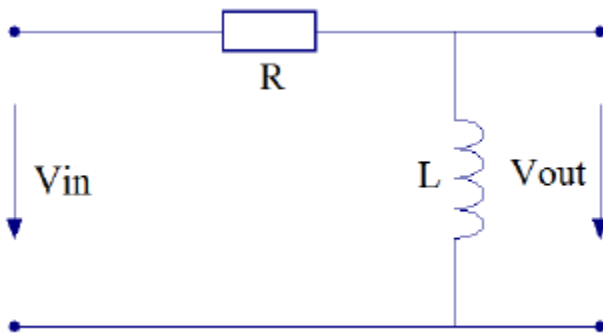
RL Low Pass Filter



RC High Pass Filter



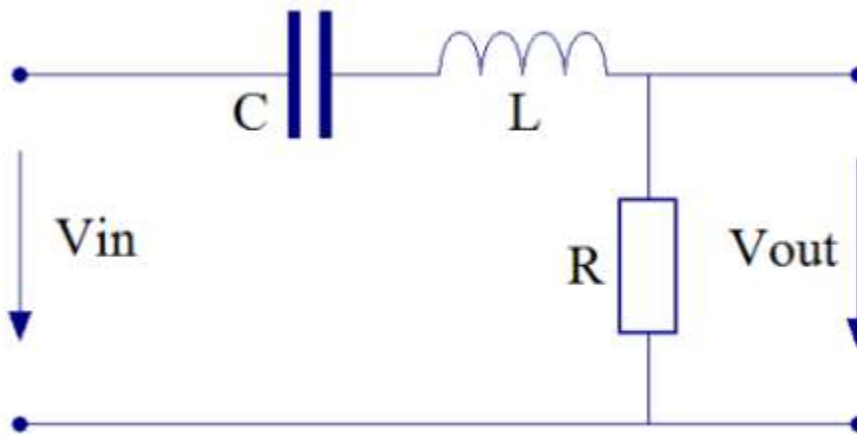
RL High Pass Filter



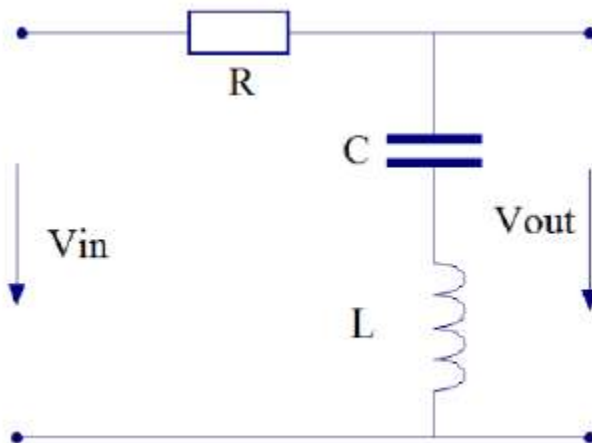
Lab 11: Band Pass Filters and Band Stop Filters

Use the given diagrams to perform the experiment in line with Experiment 10.

Bandpass Filter



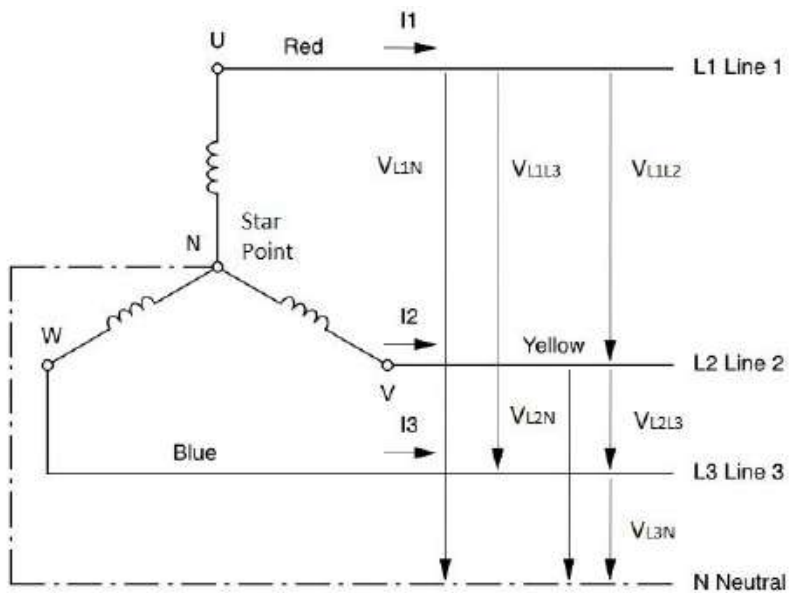
Band-stop Filter



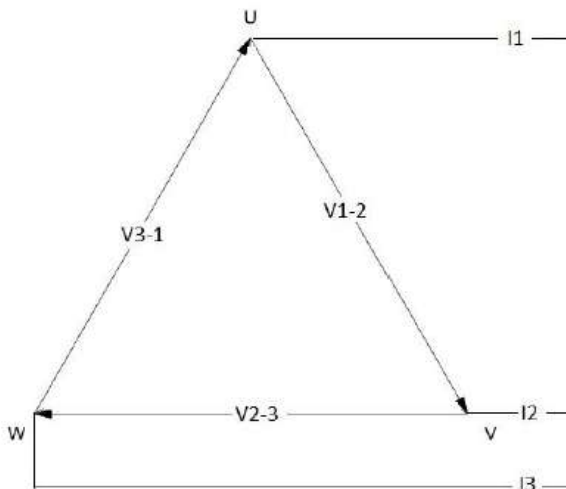
Lab 12: Current and Voltages In Balanced Three Phase System

Use the given configuration to set up the circuits of three phase systems and measure all the line and phase voltages.

Star Connection



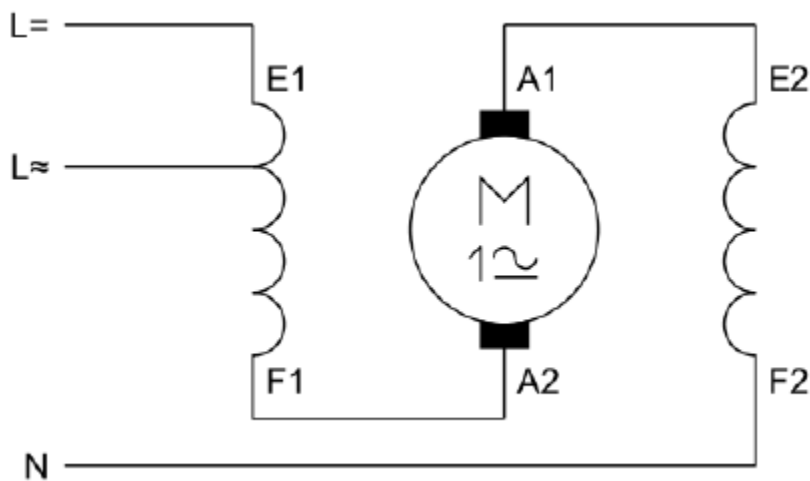
Delta Connection



Comments:

Lab 13: To study the Characteristics of Universal Motor

The universal motor is so named because it is a type of electric motor that can operate on AC or DC power. It is a commutated series-wound motor where the stator's field coils are connected in series with the rotor windings through a commutator. It is often referred to as an AC series motor. The universal motor is very similar to a DC series motor in construction, but is modified slightly to allow the motor to operate properly on AC power. This type of electric motor can operate well on AC because the current in both the field coils and the armature (and the resultant magnetic fields) will alternate (reverse polarity) synchronously with the supply. Hence the resulting mechanical force will occur in a consistent direction of rotation, independent of the direction of applied voltage, but determined by the commutator and polarity of the field coils. Universal motors have high starting torque, can run at high speed, and are lightweight and compact. They are commonly used in portable power tools and equipment, as well as many household appliances. They're also relatively easy to control, electromechanically using tapped coils, or electronically. However, the commutator has brushes that wear, so they are much less often used for equipment that is in continuous use. In addition, partly because of the commutator, universal motors are typically very noisy, both acoustically and electromagnetically.



Comments:

