

**Laboratory Manual**  
**Electronic Devices and Circuits**  
B.Sc. Electrical Engineering

**Session: 2019-2023**

**Subject Code: EE-213**

**Program: Electrical Engineering**



**Department Of Electrical Engineering**  
**University College of Engineering & Technology**  
**University of Sargodha**

## **Objective:**

The laboratory emphasizes the practical, hands-on component of this course. It complements the theoretical material presented in lecture, and as such, is integral and indispensable to the mastery of the subject. There are several items of importance here including proper safety procedures, required tools, and laboratory reports. This exercise will finish with an examination of scientific and engineering notation, the standard form of representing and manipulating values.

## **Lab Safety and Tools:**

If proper procedures are followed, the electrical lab is a perfectly safe place in which to work. There are some basic rules: No food or drink is allowed in lab at any time. Liquids are of particular danger as they are ordinarily conductive. While the circuitry used in lab is normally of no shock hazard, some of the test equipment may have very high internal voltages that could be lethal (in excess of 10,000 volts). Spilling a bottle of water or soda onto such equipment could leave the experimenter in the receiving end of a severe shock. Similarly, items such as books and jackets should not be left on top of the test equipment as it could cause overheating.

Each lab bench is self-contained. All test equipment is arrayed along the top shelf. Beneath this shelf at the back of the work area is a power strip. All test equipment for this bench should be plugged into this strip. None of this equipment should be plugged into any other strip. This strip is controlled by a single circuit breaker which also controls the bench light. In the event of an emergency, all test equipment may be powered off through this one switch. Further, the benches are controlled by dedicated circuit breakers in the front of the lab. Next to this main power panel is an A/B/C class fire extinguisher suitable for electrical fires. Located at the rear of the lab is a safety kit. This contains bandages, cleaning swaps and the like for small cuts and the like. For serious injury, the Security Office will be contacted.

A lab bench should always be left in a secure mode. This means that the power to each piece of test equipment should be turned off, the bench itself should be turned off, all AC and DC power and signal sources should be turned down to zero, and all other equipment and components properly stowed with lab stools pushed under the bench.

It is important to come prepared to lab. This includes the class text, the lab exercise for that day, class notebook, calculator, and hand tools. The tools include an

electronic breadboard, test leads, wire strippers, and needle-nose pliers or hemostats. A small pencil soldering iron may also be useful.

Safety is always an important topic whenever laboratory work is being considered, and it is certainly true in the case of EDC labs. Safety is important. The experiments in the laboratory use low voltages and low currents. However, the lab equipment is powered by the 110V, 60Hz, line voltage. Be careful with the line voltages. Do not touch exposed prongs on the equipment plugs when connecting the equipment to the lines. Take care when using power supplies, which may be low voltage but can supply currents in the ampere range. Shorting such a supply can lead to a serious burn as high currents arc and can ignite flammable material. This is precisely why a car battery needs to be treated with respect. The hundreds of amps a battery can supply are sufficient to cause serious burns.

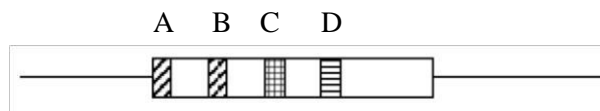
The equipment is heavy enough to be generally stable on the bench. Be sure to keep the equipment away from the edges of the benches to avoid having a piece of equipment fall off the bench. Besides endangering people who might be struck, falling equipment endangers everyone in vicinity by stressing the power cords, possibly causing a line short or live fault on the equipment, not to mention damage to the expensive lab equipment. In general electronic equipment does not survive harsh treatment.

The capacitors furnished in your lab kits are electrolytic capacitors with positive and negative terminals. Be sure to always connect the positively marked terminal to the most positive terminal in your circuit. An excess negative voltage applied to these capacitors can cause the device to overheat and explode.

The curve tracers can apply voltages as high as 200 V to a device. There is an interlock forcing the user to cover the device when applying these voltages. Do not attempt to override this safety feature when using the curve tracer.

## Standard Component Values:

In many of the experiments you will be asked to use standard resistor or capacitor values which are closest to those you calculated. The values were chosen to fit the tolerance and eliminate overlap. Most resistors are color coded. Figure SC-1 provides the color codes for standard resistor values to help you quickly select the values you need in your experiments. Since the capacitors used in the EDC-213 experiments are for coupling or bypass purposes, values are not as critical and hence the color coding is not included.



A = first significant figure  
 B = second significant figure  
 C = decimal multiplier  
 D = tolerance

Black	= 0	decimal multiplier = $10^0 = 1$	
Brown	= 1	decimal multiplier = $10^1 = 10$	
Red	= 2	decimal multiplier = $10^2 = 100$	
Orange	= 3	decimal multiplier = $10^3 = 1000$	
Yellow	= 4	decimal multiplier = $10^4 = 10000$	
Green	= 5	decimal multiplier = $10^5 = 100000$	
Blue	= 6	decimal multiplier = $10^6 = 1000000$	
Violet	= 7	decimal multiplier = $10^7 = 10000000$	
Gray	= 8	decimal multiplier = $10^8 = 100000000$	
White	= 9	*	
Gold	= *	decimal multiplier = $10^{-1} = 0.1$	tolerance = $\pm 5\%$
Silver	= *	decimal multiplier = $10^{-2} = 0.01$	tolerance = $\pm 10\%$
No color	= *	decimal multiplier = *	tolerance = $\pm 20\%$

**Figure SC-1: Resistor color coding**

The values of carbon resistors are guaranteed by the manufacturer to be within a certain tolerance, usually 5%, 10%, or 20% of the standard value. Perhaps most common is  $\pm 10\%$ . Table SC-1 shows the standard values for the  $\pm 10\%$  tolerance.

<u>Standard value</u>	<u>Band 1</u>	<u>Band 2</u>	<u>Band 3</u>	<u>Band 4</u>
10	Brown	Black	Decade multiplier	Silver
12	Brown	Red	Decade multiplier	Silver
15	Brown	Green	Decade multiplier	Silver
18	Brown	Gray	Decade multiplier	Silver
22	Red	Red	Decade multiplier	Silver
27	Red	Violet	Decade multiplier	Silver
33	Orange	Orange	Decade multiplier	Silver
39	Orange	White	Decade multiplier	Silver
47	Yellow	Violet	Decade multiplier	Silver
56	Green	Blue	Decade multiplier	Silver
68	Blue	Gray	Decade multiplier	Silver
82	Gray	Red	Decade multiplier	Silver

**Table SC-1: Standard values for carbon resistors with ±10% tolerance**

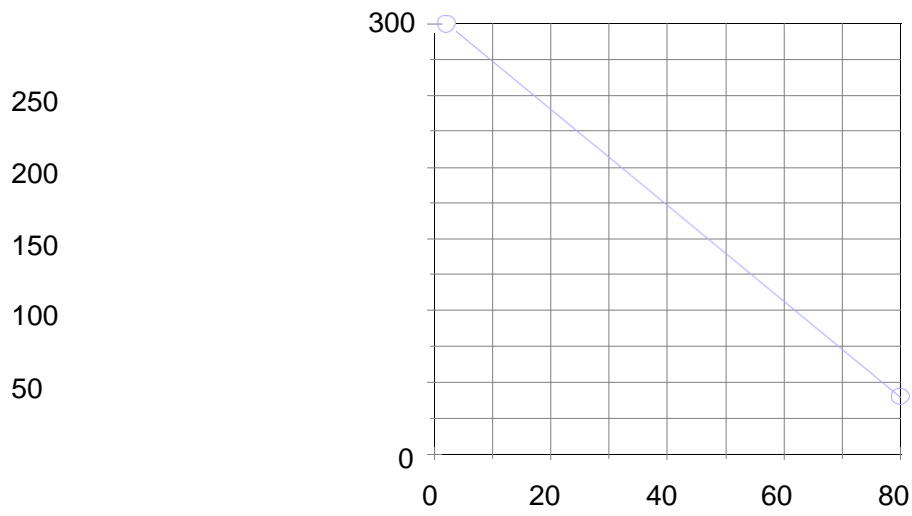
As an example of how to use this information, a 680Ω resistor with ± 10% tolerance is guaranteed to have a value between 612Ω and 748Ω. The color code is

<u>Band 1</u>	<u>Band 2</u>	<u>Band 3</u>	<u>Band 4</u>	<u>Resistor Value</u>	<u>Tolerance</u>
Blue (6)	Gray (8)	Brown ( $\times 10^1$ )	Silver (10%)	$= 68 \times 10^1 = 680$	±68

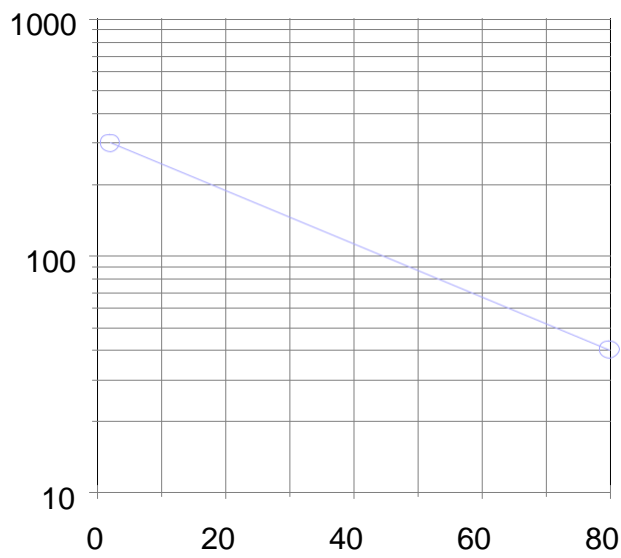
### **Graph Paper:**

Graphs of data may take many forms, whether plotted on traditional graph paper or using computer software. Three fundamental graph types to show the relationships between a dependent and an independent variable are linear, semi-log, and log-logplots.

**Linear** graph paper has uniform spacing along the horizontal (“X”) axis and uniform spacing along the vertical (“Y”) axis, although the scales along the two axes do not need to be the same.

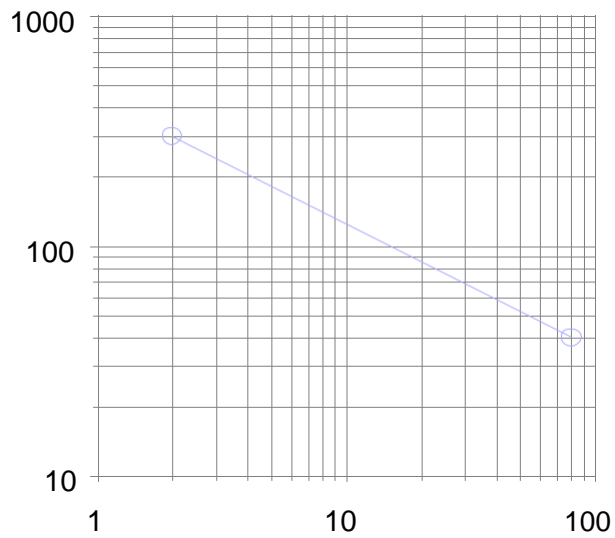


**Semi-log** graph paper is linear on one axis and logarithmic on the other axis:



**semi-log graph paper (2-cycle)**

**Log-log** graph paper has a logarithmic scale along both axes:



**log-log graph (2-cycle by 2-cycle)**

Choose the style that best reveals the relationships between the variables.

- A straight line on linear paper has the relationship  $y=mx+b$ .  
 $m = (y_1 - y_2) / (x_1 - x_2)$   $b = y$  when  $x=0$
  - A straight line on semi-log paper (if x-axis is linear) has the relationship  $\log(y)=mx+b$   $m = (\log(y_1) - \log(y_2)) / (x_1 - x_2)$   $b = \log(y)$  when  $x=0$
- A straight line on log-log paper has the relationship  $\log(y)=m \cdot \log(x)+b$   $m = (\log(y_1) - \log(y_2)) / (\log(x_1) - \log(x_2))$   $b = \log(y)$  when  $\log(x)=0$

# Lab Contents

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# Lab Session 01

## Introduction to Laboratory Equipments

### Objective:

In this lab students will learn the basics of operating a digital multimeter, function generator and an oscilloscope that are used extensively in circuits and electronics.

### Equipments required:

- Digital Multimeter
- Function Generator
- Digital Storage Oscilloscope
- Bread Board

### Theory:

#### The Function Generator (SG2120):

Function generators generate various waves, with the most useful of them (for our purposes) being sine waves. Function generators allow you to set the amplitude, frequency and shape (sine, triangular, square) of the wave. Sometimes they allow you to set the dc offset, which is simply a dc voltage added to the oscillating signal. The front panel of the function generator is shown in figure below.



**Fig 1.1 Function Generator**

The main characteristics of the function generator are:

- Shape: sine, square, or triangle waves.
- Frequency: inverse of the period of the signal; units are cycles per second (Hz)
- $V_{pp}$ : peak to peak Voltage value of the signal
- DC Offset: constant voltage added to the signal to increase or decrease its mean or average level.  
In a schematic, this would be a DC voltage source in series with the oscillating voltage source.

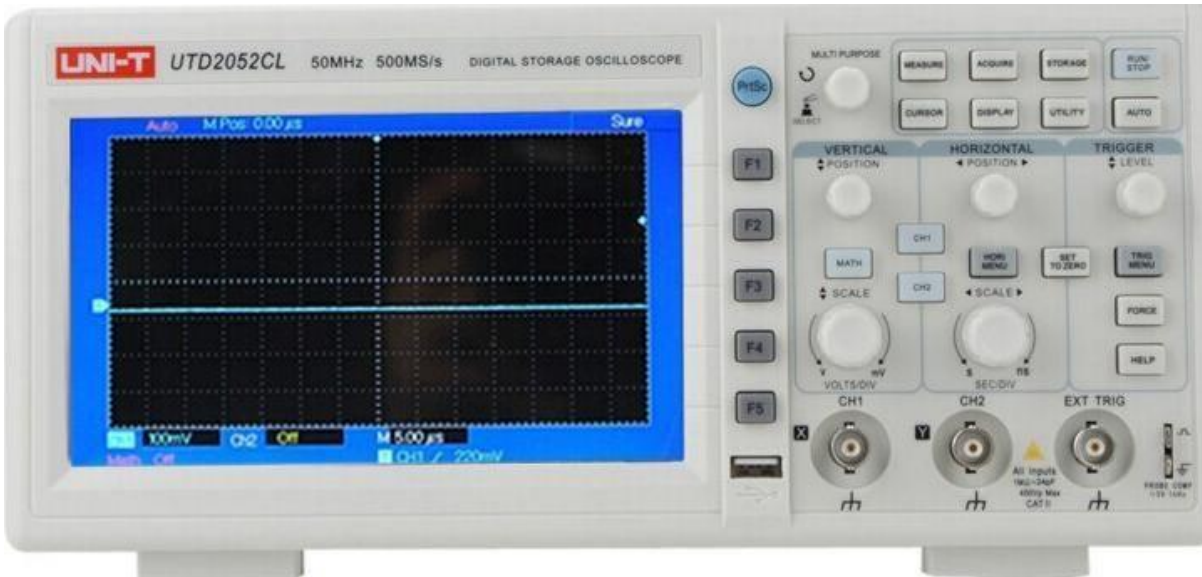
### Specifications:

Output Frequency 10mHz ~ 20MHz

Output Amplitude 10mV<sub>p-p</sub> ~ 20V<sub>p-p</sub>

## The Oscilloscope (UTD2052CL)

Oscilloscopes are very useful instruments that are used to measure and display a variety of signals. In this lab students will use the oscilloscope to measure voltage, time and frequency. Oscilloscopes vary widely depending on the manufacturer and the model but the basic operation remains the same. Most oscilloscopes will have 2 or 4 channels normally labeled either 1, 2, ... or A, B, . . . Using these channels you can input more than one signal for comparison and analysis. The front panel of the oscilloscope is shown in figure below.



**Fig 1.2 Oscilloscope**

In general an oscilloscope has the following controls:

- Position: position knobs (Vertical or Horizontal) shift the trace around the screen.
- Vertical sensitivity or V/div or V/cm: the gain that must be applied to the input to control the amount of signal displayed per division (Figure 2(c)).
- Sweep time or time/div: controls the time it takes to sweep the screen and show the signal. The higher the number is the more compact the signal will look.
- Source or Trigger Source: selects the source to trigger the sweep. Common sources are (a) internal - the input signal controls the triggering and you can choose which channel to use; (b) line - selects the 60Hz line voltage as the trigger signal; (c) Ext - an external signal is used to trigger. At this time you will always be using the internal trigger.

In addition to these controls you will have menus that allow you to measure different values of the signal such as peak or peak-to-peak voltages, phase, frequency, etc. You also have two vertical and two horizontal cursor lines that you can move. If you are using the vertical lines, the oscilloscope will display the time difference between them. On the other hand, if you are using the horizontal lines, the oscilloscope will display the voltage difference between them.

## The Digital Multimeter:

A Multimeter is an electronic device that is used to make various electrical measurements, such as AC and DC voltage, AC and DC current, and resistance. It is called a Multimeter because it combines the functions of a voltmeter, ammeter, and ohmmeter. Multimeter may also have other functions, such as diode test, continuity test, transistor test, TTL logic test and frequency test.

### Parts of Multimeter

- **Display:** The display usually has four digits and the ability to display a negative sign. A few multimeters have illuminated displays for better viewing in low light situations.
- **Selection Knob:** The selection knob allows the user to set the multimeter to read different things such as milliamps (mA) of current, voltage (V) and resistance ( $\Omega$ ).
- **Ports:** Two probes are plugged into two of the ports on the front of the unit. COM stands for common and is almost always connected to Ground or '-' of a circuit. The COM probe is conventionally black but there is no difference between the red probe and black probe other than color. 10A is the special port used when measuring large currents (greater than 200mA). mA/V/ $\Omega$  is the port that the red probe is conventionally plugged in to. This port allows the measurement of current (up to 200mA), voltage (V), and resistance ( $\Omega$ ). The probes have a banana type connector on the end that plugs into the multimeter. Any probe with a banana plug will work with this meter.



**Fig-1.3-Digital-Multimeter Input-**

### Jacks:

The black lead is always plugged into the common terminal. The red lead is plugged into the 10 A jack when measuring currents greater than 300 mA, the 300 mA jack when measuring currents less than 300 mA, and the remaining jack (V-ohms-diode) for all other measurements.



## Fig 1.4 Input Jacks

### Procedure for Measurement:

#### Voltage Measurement:

D.C. / A.C. Voltage Measurement Connect the positive (red) test lead to the 'V/mA' jack socket and the negative (black) lead to the 'COM' jack socket.

- Set the selector switch to the desired mV D.C./D.C.V/A.C.V range.
- Connect the test leads to the circuit to be measured.
- Turn on the power to the circuit to be measured; the voltage value should appear on the digital display along with the voltage polarity (if reversed only).



Fig 1.5 Voltage Measurement

#### Current Measurement:

- Connect the positive(red) test lead to the 'V/mA' jack socket and the negative(black) lead to the 'COM' jack socket(for measurements up to 200mA). For measurements between 200mA and 10A connect the red test lead to the '10mA' socket. Set the selector switch to the desired uA/mA/A range.
- Open the circuit to be measured and connect the test leads in SERIES with the load in which current is to be measured.
- To avoid blowing an input fuse, use the 10A jack until you are sure that the current is less than 300 mA. Turn off power to the circuit. Break the circuit. (For circuits of more than 10 amps, use a current clamp.) Put the meter in series with the circuit and turn power on.

#### Resistance Measurement:

- Connect the positive(red) test lead to the 'V/mA' jack socket and the negative(black) lead to the 'COM' jack socket.
- Set the selector switch to the desired 'OHM  $\Omega$ '.
- If the resistance to be measured is part of a circuit, turn off the power and discharge all capacitors before measurement.
- Connect the test leads to the circuit to be measured.
- The resistance value should now appear on the digital display.
- If the resistance to be measured is part of a circuit, turn off the power and discharge all capacitors before measurement.

## Continuity Test:

This mode is used to check if two points are electrically connected. It is often used to verify connectors. If continuity exists (resistance less than 210 ohms), the beeper sounds continuously.

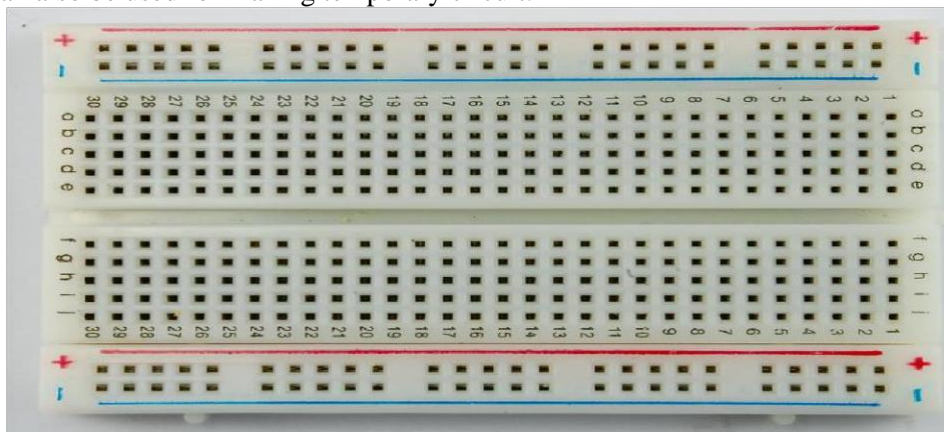
- Connect the positive (red) test lead to the 'V/mA' jack socket and the negative (black) lead to the 'COM' jack socket. □  
Set the selector switch to the position.
- Connect the test leads to two points of the circuit to be tested. If the resistance is in Ohms, the buzzer will sound.
- If the resistance to be measured is part of a circuit, turn off the power and discharge all capacitors before measurement.

## Diode Test:

- Connect the positive (red) test lead to the 'V/mA' jack socket and the negative (black) lead to the 'COM' jack socket
- Set the selector switch to the position.
- Connect the test leads to be measured.
- Turn on the power to the circuit to be measured and the voltage value should appear on the digital display.

## Bread Board:

Bread Board is an array of horizontal and vertical wires inside the body of the bread board, and upper side of it is perforated to insert wires in it. Bread board is used for checking circuit before printing it on PCB. It can also be used for making temporary circuit.



**Fig 1.6 Breadboard**

**Lab Procedure:**

- 1.Connect function generator output at the input of CRO at channel 1 or at channel 2.
- 2.Select proper channel i.e. if signal is connected to channel 1 select CH1 and if signal is connected to channel 2 select CH2.
- 3.Adjust Time/Div knob to get sufficient time period displacement of the wave on the CRO screen. With fine tuning of time/div make the waveform steady on screen.
- 4.Use triggering controls if waveform is not stable.
- 5.Keep volt/div knob such that waveform is visible on the screen without clipping. 6.Measure P-P reading along y-axis. This reading multiplied with volt/div gives peak to peak amplitude of the AC input wave.
- 7.Measure horizontal division of one complete cycle. This division multiplied by Time/Div gives time period of the input wave.
- 8.Calculate frequency using formula  $f = 1/T$ .

Note down your readings in the observation table

**Observations:**

Task 1:

Calculation of frequency on waveform basis:							
Function	Vertical Division	Vertical Sensitivity	Amplitude	Horizontal Division	Horizontal Sensitivity	Time Period	$f = \frac{1}{T}$
	(a)	V/div (b)	V <sub>P-P</sub> (axb)	(c)	Time/div (d)	sec (cxd)	Hz
Sine							
Square							
Triangular							

Table 1.1

Task-2:

Draw waveforms using Function Generator & Oscilloscope, and plot it on graph paper.

Sine Wave:

$$V_{in} = 3V (p-p), \quad f = 0.5 \text{ kHz}$$

Square Wave:

$$V_{in} = 4V (p-p), \quad f = 2.5 \text{ kHz}$$

Triangular Wave:

$$V_{in} = 5V (p-p), \quad f = 2.75 \text{ kHz}$$

# MULTISIM TUTORIAL

## Start

Click on Start → All Programs → [redacted] Instruments → Circu [redacted] gn  
Suite 10. 0 → Multisim.

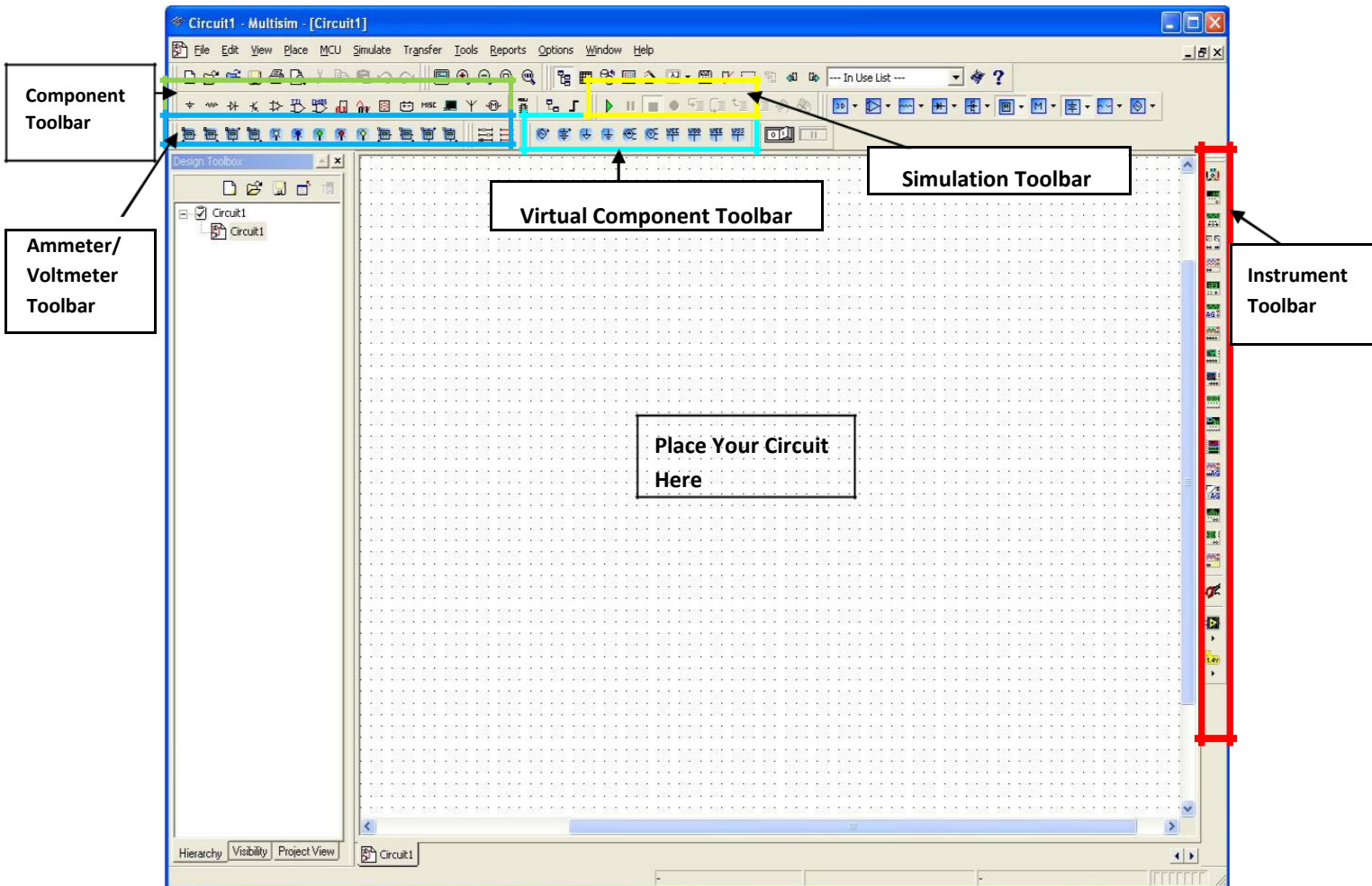


Figure 1.7

## 1. Open/Create Schematic

A blank schematic Circuit 1 is automatically created. To create a new schematic click on File – New – Schematic Capture. To save the schematic click on **File /Save As**. To open an existing file click on **File/ Open** in the toolbar.

## 2. Place Components

To Place Components click on **Place/Components**. On the Select Component Window click on **Group** to select the components needed for the circuit. Click OK to place the component on the schematic.



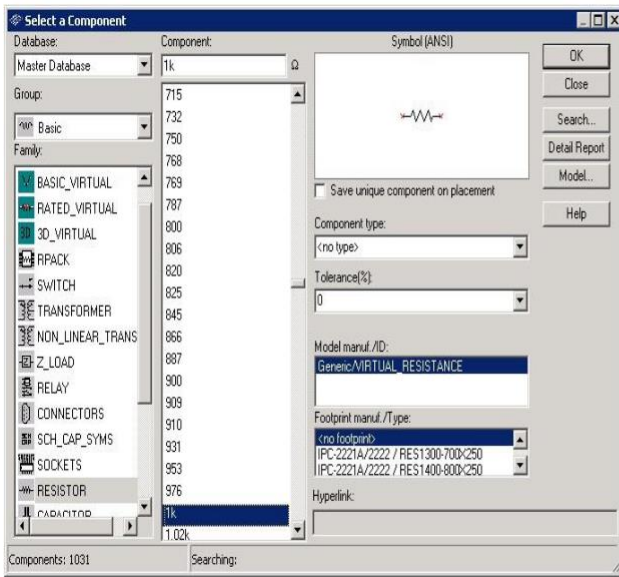


Figure 1.8: Select Resistor

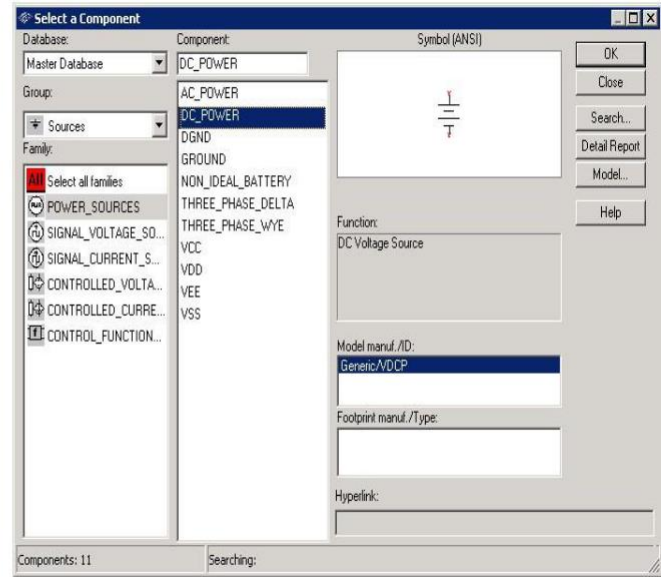


Figure 1.9: Select DC voltage

For example to select resistors and the DC source shown in Figure 3 click on **Place/ Components**. In **Group** select **Basic** scroll down to Resistors and select the value of the resistor needed to construct the circuit, for this example select 1k. To place DC source click on Sources in **Group** and select DC Source. As shown in Figure 1 and Figure 2 respectively.

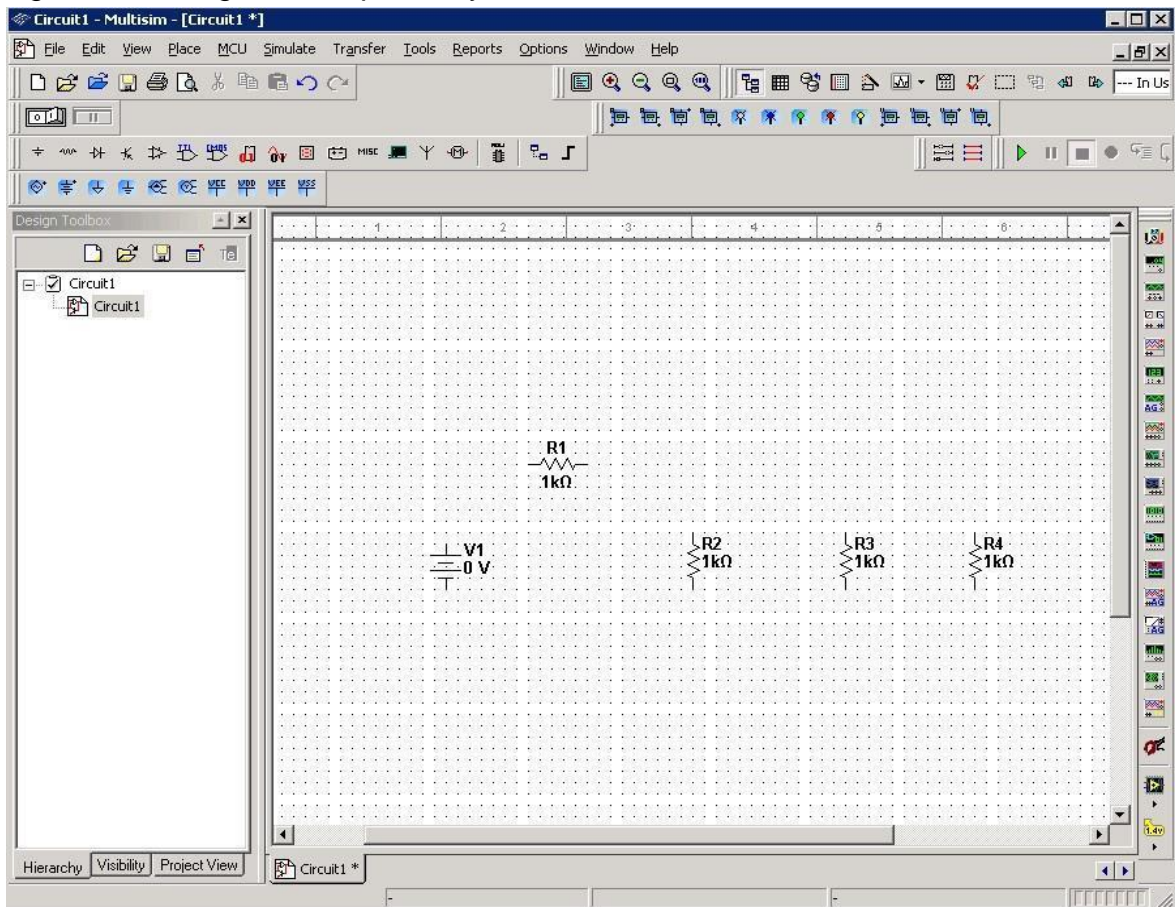


Figure 1.10: DC Source & Resistors

## Virtual Components

Components can also be placed on the circuit using **Virtual components**. Click on View – Toolbars and select the toolbar needed for the circuit.

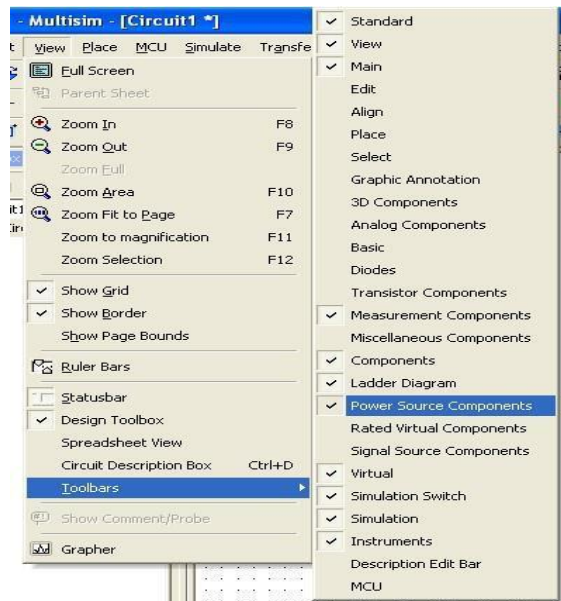


Figure 1.11: Virtual Components

## 4. Rotate Components

To rotate the components right click on the Resistor to flip the component on 90 Clockwise (Ctrl +R) and 90 Counter Clockwise (Ctrl+Shift+R).

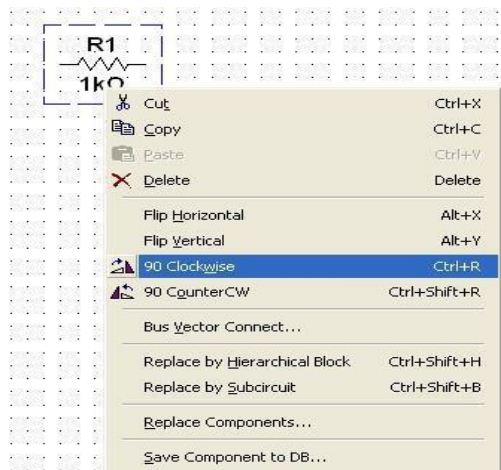


Figure 1.12: Rotate Components

## 5. Place Wire/Connect Components

To connect resistors click on **Place/Wire** drag and place the wire. Components can also be connected by clicking the mouse over the terminal edge of one component and dragging to the edge of another component. Reference Figure 6.

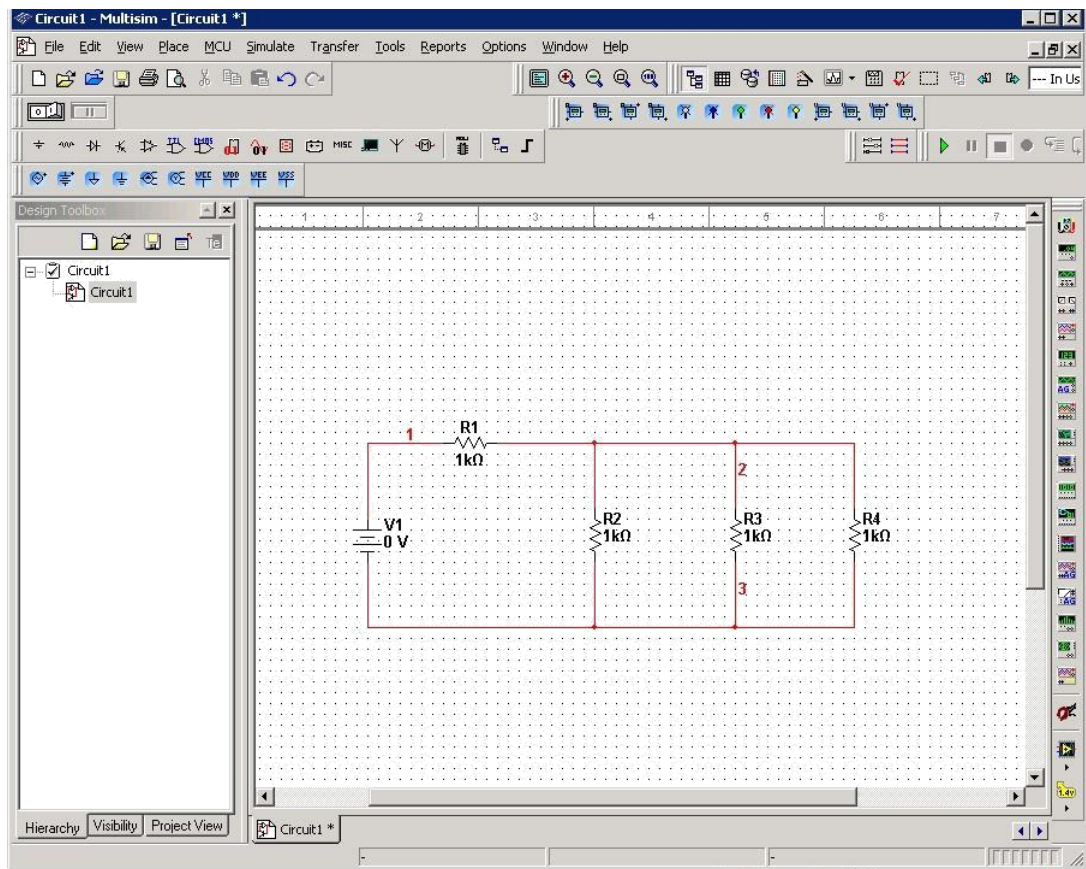


Figure 1.13: Place/ Wire

## 6. Change Component Values

To change component values double click on the component this brings up a window that display the properties of the component. Reference Figure 7. Change R1 from 1k Ohm to 10 Ohms, R2 to 20 Ohms, R3 to 30 Ohms, and R4 to 40 Ohms. Also change the DV source from 0 V to 20 V. Figure 8 shows the completed circuit

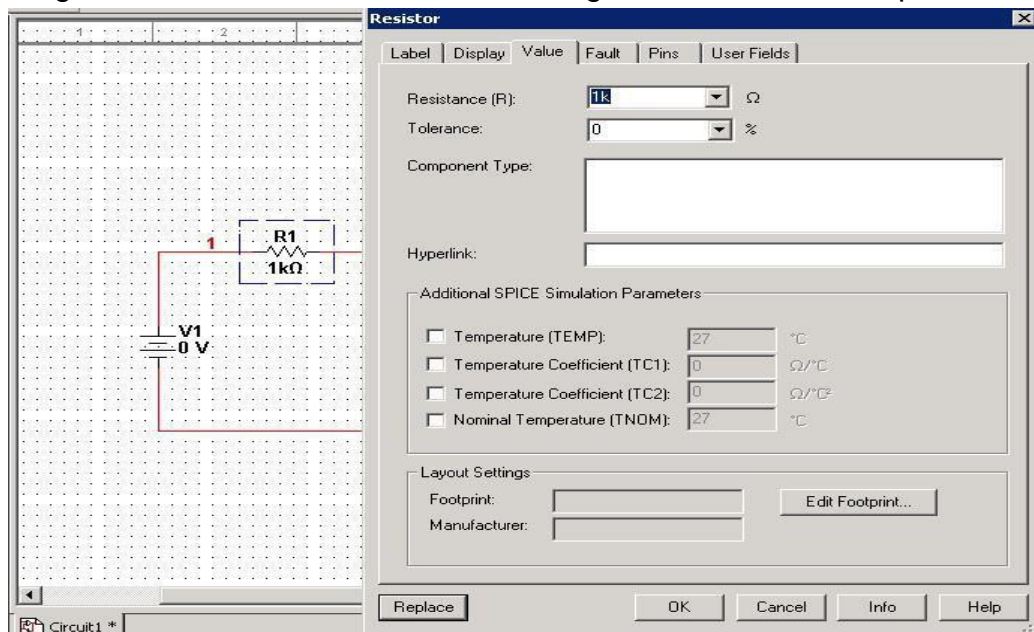
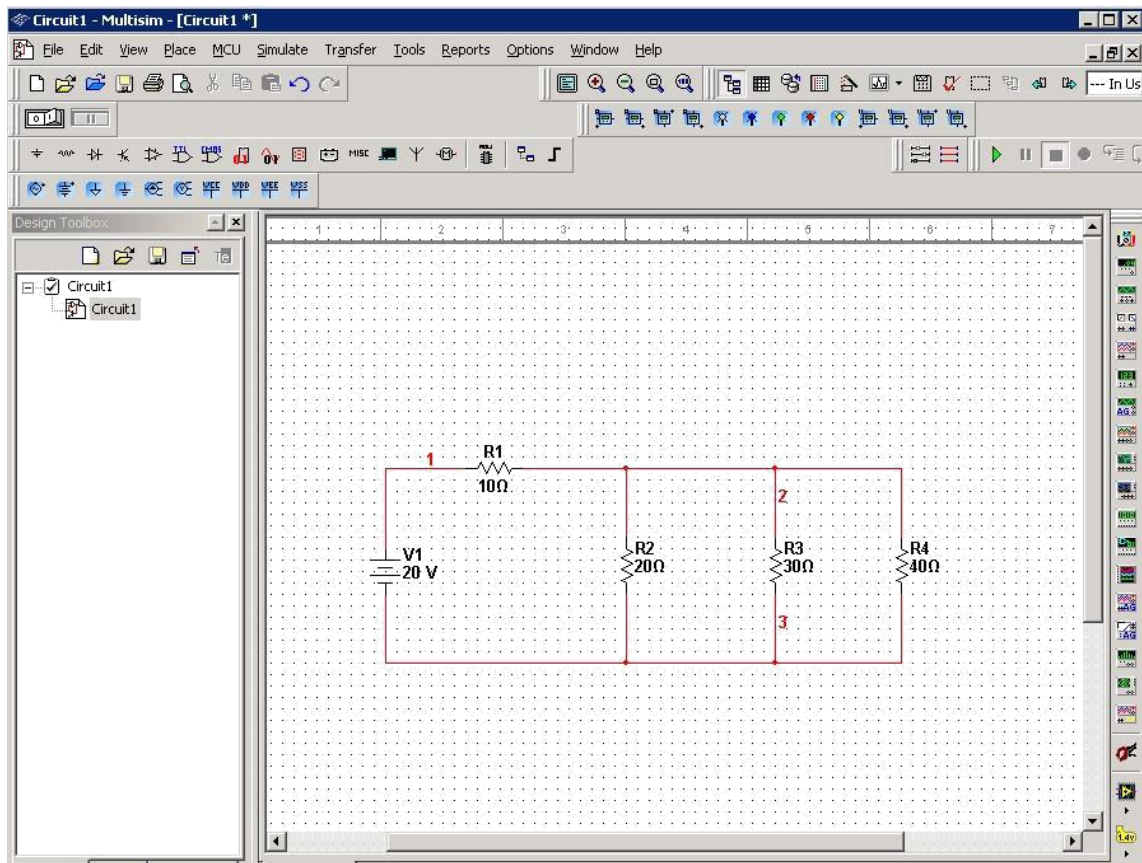


Figure 1.14: Change Component Values



**Figure 1.15: Completed Circuits**

### 7. Grounding:

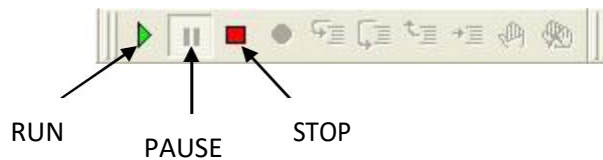
All circuits must be grounded before the circuit can be simulated. Click on Ground in the toolbar to ground the circuit. If the circuit is not grounded Multisim will not run the simulation.



**Figure 1.16: Grounding**

### 8. Simulation:

To simulate the completed circuit Click on **Simulate/Run** or **F5**. This feature can also be accessed from the toolbar as shown in the Figure 10 below.



**Figure 1.17: Simulation**

## Analyzing Components

Multisim offers multiple ways to analyze the circuit using virtual instruments. Some of the basic instruments needed for this lab are described below.

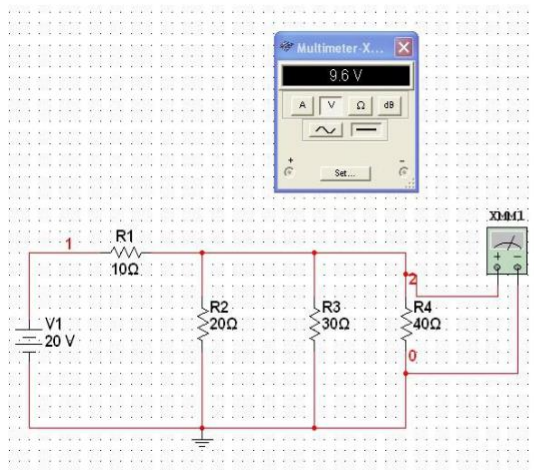
### 1) Multimeter

Use the Multimeter to measure AC or DC voltage or current, and resistance or decibel loss between two nodes in a circuit. To use the Multimeter click on the Multimeter button in the **Instruments** toolbar and click to place its icon on the workspace. Double-click on the icon to open the instrument face, which is used to enter settings and view measurements.

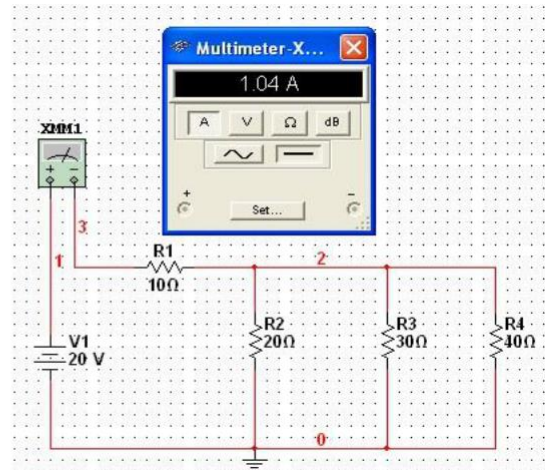


**Figure 1.18:** Multimeter

To measure Voltage place multimeter in Parallel with the component (Resistor, Voltage etc). To measure Current place the multimeter in series with the component. Reference the Figure 12 and 13.



**Figure 1.19:** Measure Voltage



**Figure 1.20:** Measure Current

## 5) Voltmeter

The Voltmeter offers advantages over the multimeter for measuring voltage in a circuit. Always connect the voltmeter in parallel with the load. The voltmeter can be found in the measurement toolbar.

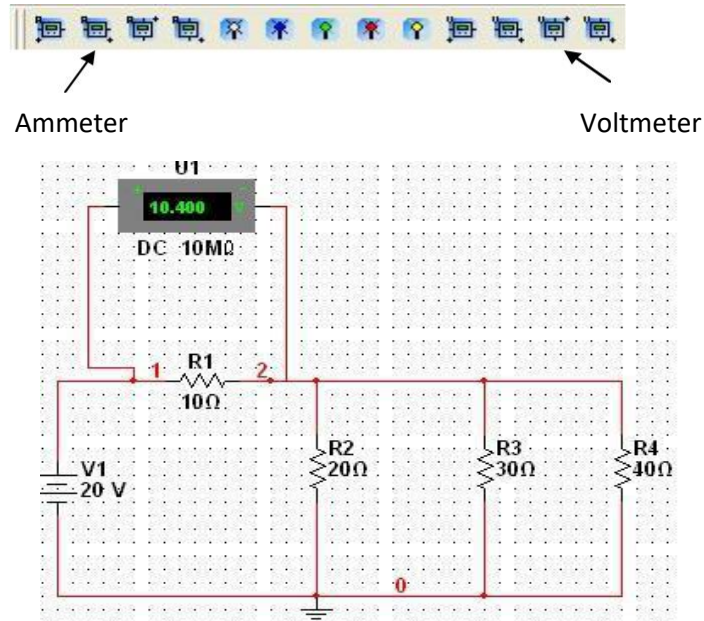


Figure 1.21: Voltmeter

### Precautions:

#### For Digital multimeter

- Voltage should always be measured in *parallel*.
- Current should always be measured in *series*.
- Switch off circuit supply before measuring resistance of a resistor connected in circuit, and take out the resistor from circuit.

#### For Breadboard

- Before implementing circuit on it determine its continuity.

For Function generator do not exceed the values provided in the specifications.

Remember to calibrate Oscilloscope probe.



## Lab Session 02

### Characteristics of Diode, half wave and full wave rectification

#### Objectives:

Observe and plot Forward and Reverse Biased V-I Characteristics of a diode.

Implement half-wave and full-wave rectification.

#### Equipments and Components Required:

- Digital Multi meter
- Resistors  $1k\Omega$
- Diode
- Oscilloscope
- Breadboard
- Resistor ( $1k\Omega$ )
- Connecting wires
- Function Generator
- DC Power supply

#### Theory:

Diodes are semiconductor devices which have conductivity between conductors and insulators. By the process of doping, P type and N type semiconductors are formed. By doping with penta valent and trivalent element, P-N junction diode is form.

Application of voltage across a diode, transistor etc is called Biasing. A diode can be in three states. It can be in an unbiased, forward biased or reverse biased condition. In forward biased condition, positive terminal of diode is connected to positive terminal of battery while in reverse biased condition, they are connected in reverse polarities.

#### Procedure:

##### Forward Biased:

- 1.First of all check diode terminals with Digital Multi meter.
- 2.Connect power supply with the diode as shown in the Fig 2.1.
- 3.Increase voltage from the power supply from 0.1V to 1V in given steps as shown in the table 2.1 and measure voltage across diode and current through diode. Note down readings in the table.
- 4.Plot VI characteristics for forward bias.

##### Reverse Biased:

- 1.Reverse diode position for reverse bias as shown in Fig 2.1.
- 2.Increase voltage from the power supply from 20V to 200V in given steps as shown in the table 2.2 and measure voltage across diode and current through diode. Note down readings in the table.
- 3.Plot VI characteristics for reverse bias

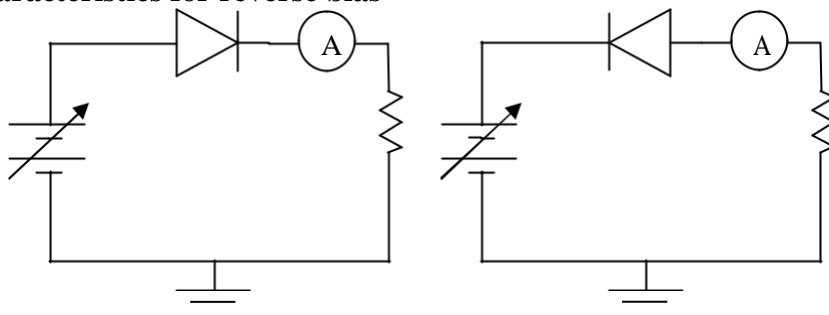
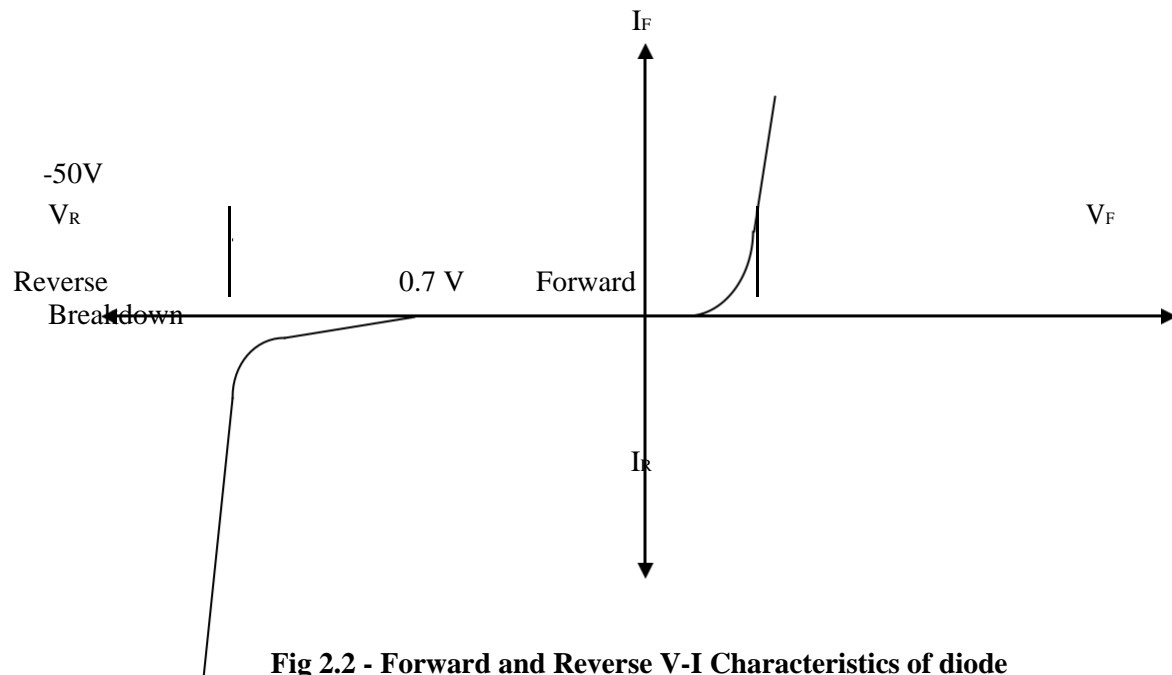


Fig 2.1 Forward Biased diode and Reverse Biased diode





**Fig 2.2 - Forward and Reverse V-I Characteristics of diode**

Observations:

Task-1:

Forward Biased Results:

$V_S$ (V)	$V_F$ (V)	$I_F$ (A)
0.1		
0.2		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1.0		

**Table 2.1 Forward Biased diode**

Task-2:

Reverse Biased Results:

$V_S$ (V)	$V_R$ (V)	$I_R$ (A)
20		
40		
60		
80		
100		
120		
140		
160		
180		
200		

**Table 2.2 Reverse Biased diode**

Graph:

Forward V-I-Characteristics:

Reverse V-I-Characteristics:

## Half Wave Rectification

### Theory:

The primary objective of rectification is to establish a DC level from a sinusoidal input signal that has zero average (DC) level. Most of the electronic equipment requires DC voltage for their operation. Yet our electrical distribution system is an AC system. Therefore it must be changed to DC before the electronic equipment can be operated. The diode, because of its one-way conduction characteristic, is the basic element for rectification process.

### Single Phase Half-Wave Rectification:

A half wave rectifier is a special case of a clipper. In half wave rectification, either the positive or negative half of the AC wave is passed easily, while the other half is blocked, depending on the polarity of the rectifier. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode in a single phase supply.

### Average Value of Half Wave-Rectified Output:

The average value of half -wave rectified output is: —

### Capacitor Input Filter:

The output from the rectifier circuit is a pulsating DC. This pulsating DC cannot be utilized in most electronic circuits because of the fluctuation of the output voltage. To make this output voltage useable; it must be smoothed out to a steady DC output with very little fluctuation. To perform this, a filter circuit is utilized. The filter circuit is placed between the rectifier and the output load; it uses capacitors, resistors and inductors to smooth or decrease the ripple voltage.

### Procedure:

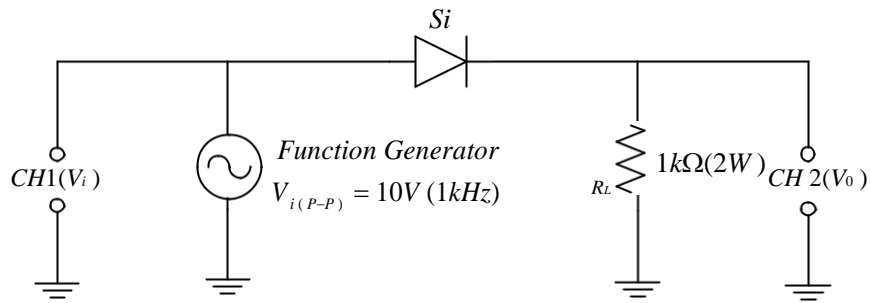
1. Connect the circuit on breadboard as shown in Fig 2.3. Adjust the function generator as required.  
2. Use the dual mode operation of the oscilloscope to display both waveforms simultaneously. Measure the frequencies of input signal (CH1) and output signal (CH2). Note these frequencies:

3. Plot both waveforms on the graph.

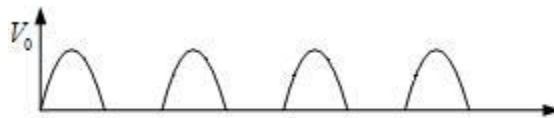
4. Measure the peak voltage of the output for Fig 2.4 as shown by CH2 of Oscilloscope. Now calculate the following value:

5. Now use DMM to measure

$$V_{DC} =$$



**Fig 2.3 half wave rectifier**



**Fig 2.4 Output of half wave rectifier**

### **Full-Wave Rectifier Without Filters**

#### **Theory:**

The primary objective of rectification is to establish a DC level from a sinusoidal input signal that has zero average (DC) level. Most of the electronic equipment requires DC voltage for their operation. Yet our electrical distribution system is an AC system. Therefore it must be changed to DC before the electronic equipment can be operated. The diode, because of its one-way conduction characteristic, is the basic element for rectification process.

#### **Single Phase Full-Wave Rectification:**

Full-wave rectification converts both polarities of the input waveform to DC (direct current), and is more efficient. A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative (or positive) portions of the alternating current waveform. The positive (or negative) portions thus combine with the reversed negative (or positive) portions to produce an entirely positive (or negative) voltage waveform.

#### **Average Value of Full Wave-Rectified Output:**

The average value of full -wave rectified output is: \_\_\_\_\_

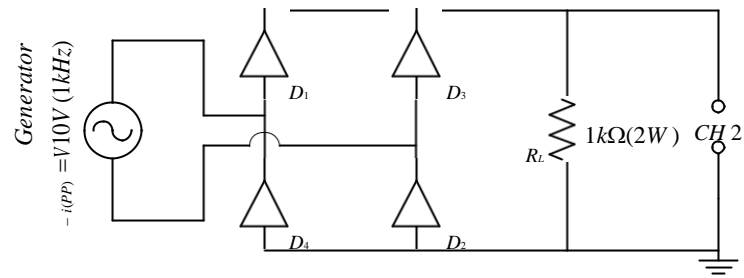
#### **Procedure:**

1. Connect the circuit as shown in Fig 2.5. Adjust function generator as required before connecting it to the circuit.
2. Measure the frequencies of the input and output signals. Note these frequencies:
3. Measure the peak voltage of the output \_\_\_\_\_ by Oscilloscope. Now calculate the following values:

\_\_\_\_\_

4. Now use DMM to measure

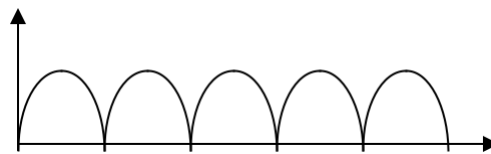
$V_{DC} =$



**Fig 2.5 Full wave rectifier**

$V_{out}$

t



**Fig 2.6 Output of full wave rectifier**

5. Now connect the circuit as shown in Fig 4.3 and place capacitors as required by table 4.1.

6. Measure the average value by CRO using Coupling difference.

7. Now use DMM to measure

$V_{DC} =$

### Precautions:

- While disassembling circuit first remove source of power
- Check continuity of wires
- Test diode before making circuit
- Check continuity of breadboard
- Check continuity of DMM
- Connection should be proper and tight
- DC Supply should be increase slowly in steps
- Always connect voltmeter in parallel and ammeter in series



## Lab Session 03

# BJTs Common Emitter Input/Output Characteristics and Operating Regions.

### Objectives:

Determine output characteristics of BJTs and plot it on graph.

### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- Transistors
- Resistors
- Potentiometer:
- Connecting wires

### Theory:

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" or "amplification".

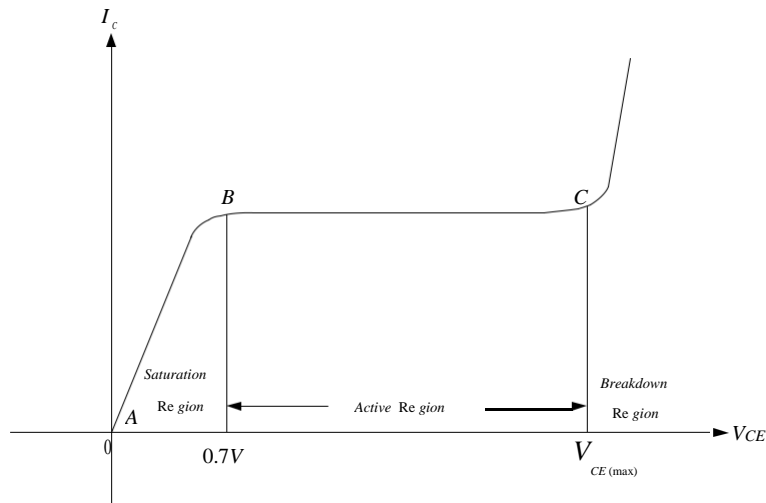
There are two basic types of bipolar transistor construction, PNP and NPN, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made.

Bipolar transistor basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are emitter, base and collector.

Bipolar transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current controlled switch. The principle of operation of the two transistor types PNP and NPN, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

### Output Characteristics and Operating Regions of BJTs:

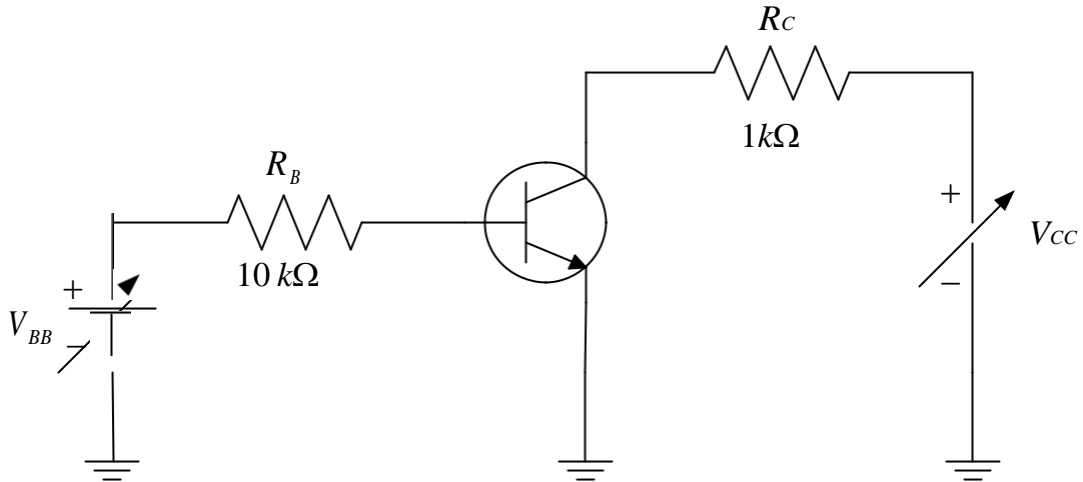
The output characteristics and operating regions for common emitter configuration of transistor are shown in Fig 3.1



**Fig 3.1 Operating characteristics BJT**

**Procedure:**

1. Connect circuit as shown in Fig 3.2 Set
2. Now adjust the base current by changing
3. Now for measurements of values of table 3.1 at base current obtain the values of (as indicated in Table 3.1) by changing
4. Plot the output characteristics between and for



**Fig 3.2 Circuit Diagram**

5. Now plot output characteristics.

**Observations:**

**Task: 1**

**Input characteristics of BJTs:**

	NPN Transistor V <sub>c</sub> =4v	NPN Transistor V <sub>c</sub> =8v
	I <sub>b</sub> (uA)	I <sub>b</sub> (uA)
0.1		
0.2		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1		

**Table 3.1 (A) Input characteristics of BJTs**



**Task:2****Output characteristics of BJTs:**

	<u>NPN Transistor</u>	<u>NPN Transistor</u>
	Ic(mA)	Ic(mA)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

**Table 3.1 (B) Output Characteristics of BJT****Graph for NPN:****Precautions:**

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch ON the power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



## Lab Session 04

### BJTs Common Base Input/Output Characteristics

#### Objectives:

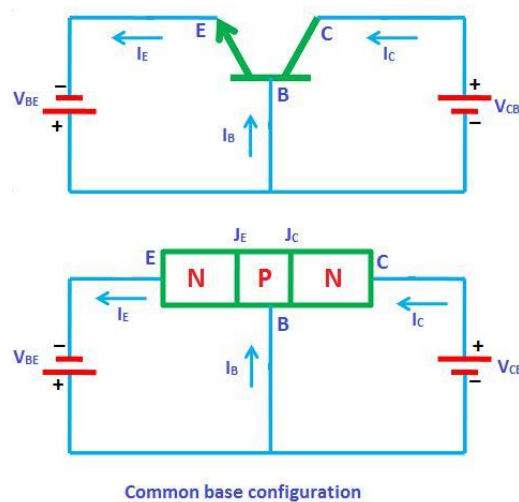
Determine output characteristics of BJTs and plot it on graph.

#### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- Transistors
- Resistors
- Potentiometer:
- Connecting wires

#### Theory:

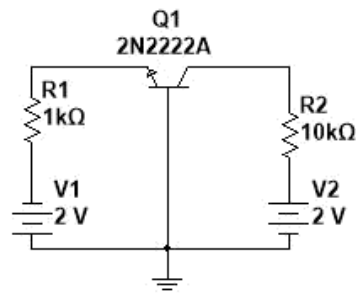
The common-base configuration is unique in that the applied signal is connected to the emitter terminal and the base is at, or just above, ground potential. It is a fairly popular configuration because in the ac domain it has a very low input impedance, high output impedance, and good gain. A typical common-base configuration appears in Fig. 4.1 . Note that two supplies are used in this configuration and the base is the common terminal between the input emitter terminal and output collector terminal.



**Fig.4.1 Common Base Configuration**

#### Procedure:

1. Connect circuit as shown in Fig 4.2 Set .
2. Now adjust the emitter current by changing .
3. Now for measurements of values of table 4.2 at emitter current , obtain the values of (as indicated in Table 4.2) by changing .
4. Plot the output characteristics between and for .



**Fig.4.2 Circuit Diagram**

5. Now plot output characteristics.

**Observations:**

**Task: 1**

**Input characteristics of BJTs:**

	<u>NPN Transistor</u> $V_{CB} = 4v$	<u>NPN Transistor</u> $V_{CB} = 8v$
	$I_E$ (uA)	$I_E$ (uA)
1		
3		
5		
7		
9		

**Table 4.1 Input characteristics of BJTs**

**Task:2**

**Output characteristics of BJTs:**

	<u>NPN Transistor</u>	<u>NPN Transistor</u>
	$I_c$ (mA)	$I_c$ (mA)
1		
3		
5		
7		
9		

**Table 4.2 Output Characteristics of BJT**

## **Graph for NPN:**

### **Precautions:**

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch ON the power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



## Lab Session 05

# BJTs Common Collector Input/Output Characteristics

### Objectives:

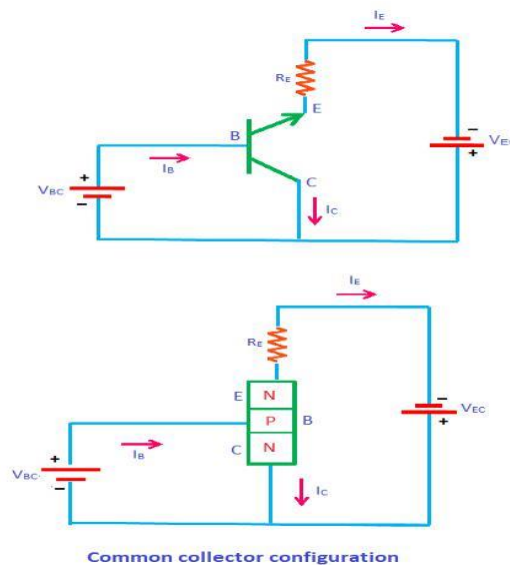
Determine output characteristics of BJTs and plot it on graph.

### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- Transistors
- Resistors
- Potentiometer:
- Connecting wires

### Theory:

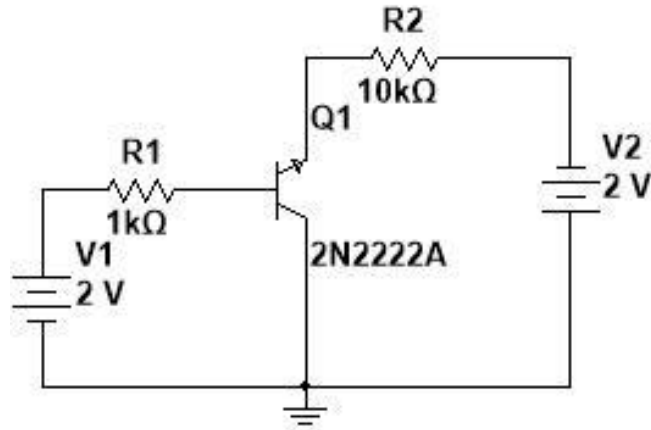
The configuration in which the collector is common between emitter and base is known as CC configuration. In CC configuration, the input circuit is connected between emitter and base and the output is taken from the collector and emitter. The collector is common to both the input and output circuit and hence the name common collector connection or common collector configuration. In common collector, input voltage  $V_{CB}$  is largely determined by output voltage  $V_{CE}$ . Input characteristics are the curve between base current,  $I_B$  and collector to base voltage,  $V_{CB}$  at constant collector to emitter voltage,  $V_{CE}$ . Base to emitter voltage,  $V_{BE}$  decreases and hence  $I_B$  decreases.



**Fig.5.1 Common Collector Configuration**

**Procedure:**

1. Connect circuit as shown in Fig 5.2 Set
2. Now adjust the base current by changing
3. Now for measurements of values of table 5.2 at base current obtain the values of (as indicated in Table 5.2) by changing
4. Plot the output characteristics between and for



**Fig5.2 Circuit Diagram**

5. Now plot output characteristics.

**Observations:**

**Task: 1**

**Input characteristics of BJTs:**

	<u>NPN Transistor</u> $V_{EC} = 5v$	<u>NPN Transistor</u> $V_{EC} = 10v$
	$I_B$ (uA)	$I_B$ (uA)
1		
3		
5		
7		
9		

**Table 5.1 Input characteristics of BJTs**



**Task:2****Output characteristics of BJTs:**

	<u>NPN Transistor</u>	<u>NPN Transistor</u>
	$I_E(\text{mA})$	$I_E(\text{mA})$
1		
3		
5		
7		
9		

**Table 5.2 Output Characteristics of BJT****Graph for NPN:****Precautions:**

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch ON the power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



## Lab Session 06

### BJT Voltage Divider & Emitter Feedback Configuration

#### Objectives:

- To design a voltage divider biased configuration.
- To design emitter feedback biased configuration.
- And to comparison between both voltage divider and emitter feedback biased configuration.

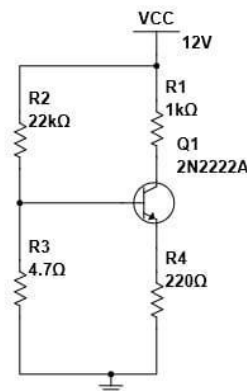
#### Equipments:

- BJT 2N2222A
- Resistors
- Power Supply
- DMM
- DC Power Supply

#### Theory:

##### Voltage Divider:

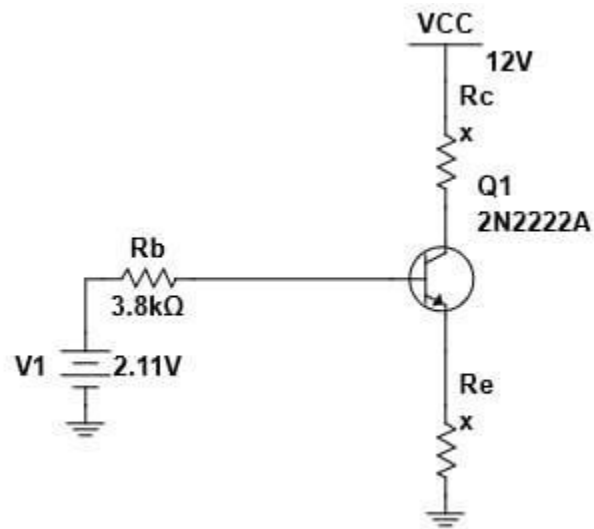
Voltage-divider bias is the most widely used type of bias circuit. Only one power supply is needed and voltage-divider bias is more stable ( $\beta$  independent) than other bias types. For this reason it will be the primary focus for study. In the case where base to ground resistance (input resistance) is low enough to consider, we can determine it by the simplified equation  $R_{in}(\text{base}) = \beta DC R_e$ . We can view the voltage at point A of the circuit in two ways, with or without the input resistance (point A to ground) considered.



**Fig 6.1 Circuit Diagram**

### Procedure:(Voltage Divider)

- Patch Circuit according to circuit diagram as shown in fig 6.1
- Simplify Resistances R1 and R2 with the help of thevenin theorem.
- $R_{Th} = \text{---}$
- $V_{TH} = \text{---} \times V_{CC}$



**Fig. 6.2 Thevinizing Circuit**

- Now apply KVL at input loop to find base current and collector current.
- Now find Collector to emitter voltage (VCE).
- Put all values in a Table.

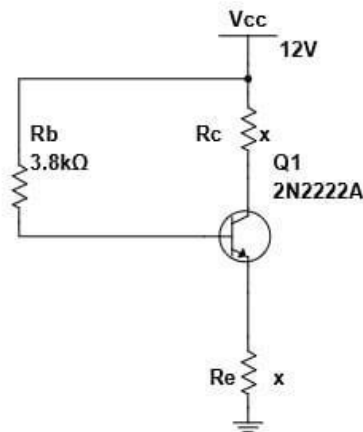
## Observations:

Theoretical Values			Practical Values					
$I_B$	$I_C$	$V_{CE}$	$I_B$	$I_C$	$V_{CE}$	$V_{RC}$	$V_{RE}$	$V_{RB}$

**Table 6.1 Voltage Divider**

## Emitter Feedback:

If an emitter resistor is added to the base-bias circuit, the result is emitter-feedback bias, as shown in Figure 6.3. The idea is to help make base bias more predictable with negative feedback, which negates any attempted change in collector current with an opposing change in base voltage. If the collector current tries to increase, the emitter voltage increases, causing an increase in base voltage because  $V_B = V_E + V_{BE}$ .



**Fig.6.3 Circuit Diagram**

This increase in base voltage reduces the voltage across  $R_B$ , thus reducing the base current and keeping the collector current from increasing. A similar action occurs if the collector current tries to decrease. While this is better for linear circuits than base bias, it is still dependent on  $\beta_{DC}$  and is not as predictable as voltage-divider bias. To calculate  $I_E$ , you can write Kirchhoff's voltage law (KVL) around the base circuit.

### Procedure: (Emitter Feedback)

- Patch Circuit according to circuit diagram as shown in fig 6.3
- Now apply KVL at input loop to find base current and collector current.
- $I_B = \text{—————}$
- $I_C = \beta I_B$
- Now find Collector to emitter voltage ( $V_{CE}$ ).
- $V_{CE} = V_{CC} - I_C(R_C + R_E)$
- Put all values in a Table.

### Observations:

Theoretical Values			Practical Values					
$I_B$	$I_C$	$V_{CE}$	$I_B$	$I_C$	$V_{CE}$	$V_{RC}$	$V_{RE}$	$V_{RB}$

**Table 6.2 Emitter Feedback biased Configuration**

### Precautions:

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



## Lab Session 07

# FET input/output Characteristics

### Objectives:

- Determine drain and transfer characteristics of FET and plot it on graph.

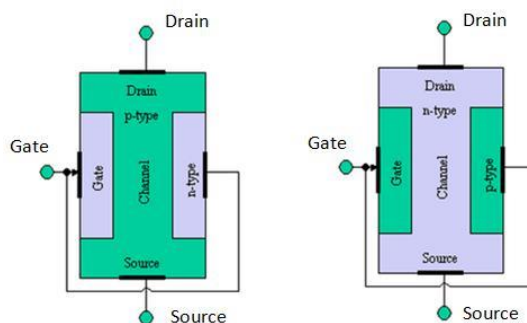
### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- JFET
- Resistors
- Potentiometer:
- Connecting wires

### Theory:

JFET is a three-terminal device with one terminal capable of controlling the current between the other two.

The basic construction of the n -channel JFET is shown in Fig.7.1 . Note that the major part of the structure is the n -type material, which forms the channel between the embedded layers of p -type material. The top of the n -type channel is connected through an ohmic contact to a terminal referred to as the drain (D) , whereas the lower end of the same material is connected through an ohmic contact to a terminal referred to as the source (S). The two p -type materials are connected together and to the gate (G) terminal. In essence, therefore, the drain and the source are connected to the ends of the n -type channel and the gate to the two layers of p -type material. In the absence of any applied potentials the JFET has two p – n junctions under no-bias conditions. The result is a depletion region at each junction, that resembles the same region of a diode under no-bias conditions. Recall also that a depletion region is void of free carriers and is therefore unable to support conduction.

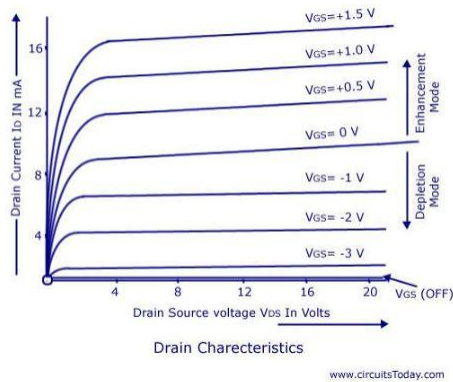


**Fig.7.1 JFET**

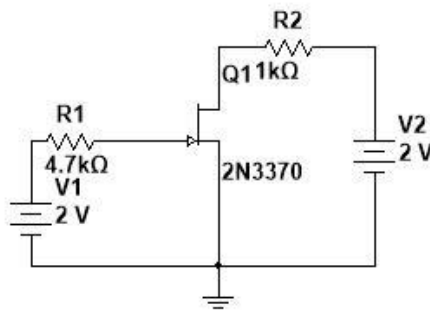


## Procedure:

- Connect the circuit as per given diagram properly.
- Keep  $V_{GS} = 0V$  by varying  $V_{GG}$
- Vary  $V_{DS}$  in step of  $1V$  up to  $10$  volts and measure the drain current  $I_D$ . Tabulate all the readings.
- Repeat the above procedure for  $V_{GS}$  as  $-0.5, -1V, -1.5V, -2V, -2.5V, -3V, -3.5V$  etc
- Now Set the voltage  $V_{DS}$  constant at  $5 V$ .
- Vary  $V_{GS}$  by varying  $V_{GG}$  in the step of  $0$  up to  $5V$  and note down value of drain current  $I_D$ .
- Tabulate all the readings.



**Fig. 7.2 Graphic Representation**



**Fig.7.3 Circuit Diagram**

**Observations:**

<b>V<sub>DD</sub> (V)</b>	<b>I<sub>D</sub> (mA)</b>	<b>V<sub>GS</sub>(V)</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>

**Table 7.1**

<b>V<sub>GS</sub>(V)</b>	<b>I<sub>D</sub>(mA)</b>	<b>V<sub>DS</sub>(V)</b>
<b>-1</b>		<b>5</b>
<b>-2</b>		<b>5</b>
<b>-3</b>		<b>5</b>
<b>-4</b>		<b>5</b>

**Table 7.2**

**Plot I<sub>D</sub> Vs V<sub>DD</sub>:**

## **Plot $I_D$ Vs $-V_{GS}$ :**

### **Precautions:**

- While performing the experiment do not exceed the ratings of the FET. This may lead to damage of FET
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Gate, Drain and Source terminals of the transistor



## Lab Session 08

### Characteristics of MOSFET in Enhancement Mode.

#### Objectives:

- To determine MOSFET Enhancement mode Characteristics.

#### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- MOSFET
- Resistors
- Potentiometer:
- Connecting wires

#### Theory:

Although there are some similarities in construction and mode of operation between depletion type and enhancement-type MOSFETs, the characteristics of the enhancement-type MOSFET are quite different from anything obtained thus far. The transfer curve is not defined by Shockley's equation, and the drain current is now cut off until the gate-to source voltage reaches a specific magnitude. In particular, current control in an n-channel device is now effected by a positive gate-to-source voltage rather than the range of negative voltages encountered for n-channel JFETs and n-channel depletion-type MOSFETs.

The basic construction of the n-channel enhancement-type MOSFET is provided in Fig. 8.1. A slab of p-type material is formed from a silicon base and is again referred to as the substrate. As with the depletion-type MOSFET, the substrate is sometimes internally connected to the source terminal, whereas in other cases a fourth lead (labeled SS) is made available for external control of its potential level. The source and drain terminals are again connected through metallic contacts to n-doped regions, but in the absence of a channel between the two n-doped regions. This is the primary difference between the construction of depletion-type and enhancement-type MOSFETs—the absence of a channel as a constructed component of the device. The SiO<sub>2</sub> layer is still present to isolate the gate metallic platform from the region between the drain and source, but now it is simply separated from a section of the p-type material. In summary, therefore, the construction of an enhancement-type MOSFET is quite similar to that of the depletion-type MOSFET, except for the absence of a channel between the drain and source terminals.

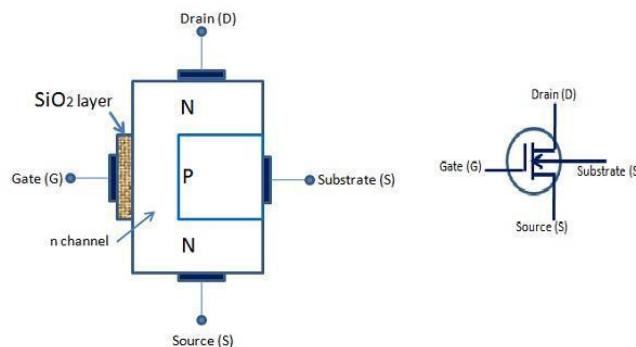
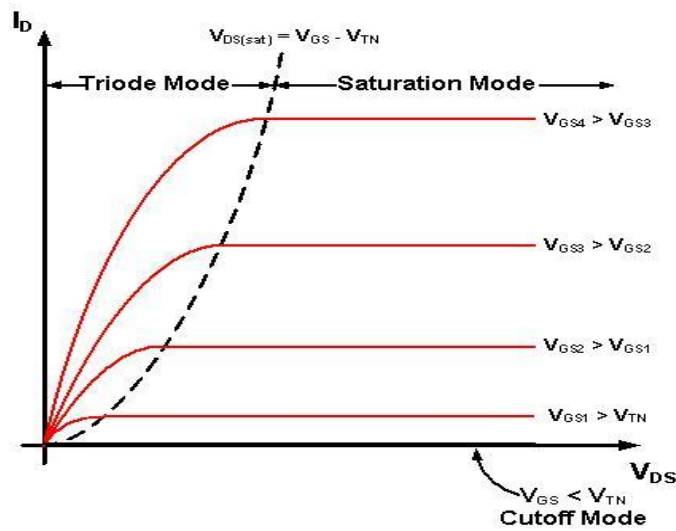


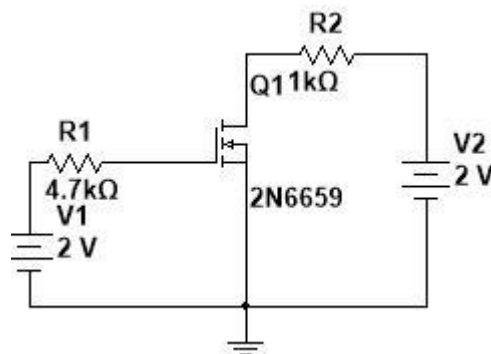
Fig.8.1 MOSFET

## Procedure:

- Connect the circuit as per given diagram properly.
- Keep  $V_{GS} = 0V$  by varying  $V_{GG}$
- Vary  $V_{DS}$  in step of  $1V$  up to  $10$  volts and measure the drain current  $I_D$ . Tabulate all the readings.
- Repeat the above procedure for  $V_{GS}$  as  $+0.5, +1V, +1.5V, +2V, +2.5V, +3V, +3.5V$  etc
- Now Set the voltage  $V_{DS}$  constant at  $5V$ .
- Vary  $V_{GS}$  by varying  $V_{GG}$  in the step of  $0$  up to  $5V$  and note down value of drain current  $I_D$ .
- Tabulate all the readings.



**Fig. 8.2 Graphic Representation**



**Fig.8.3 Circuit Diagram**

**Observations:**

<b>V<sub>DD</sub> (V)</b>	<b>I<sub>D</sub> (mA)</b>	<b>V<sub>GS</sub>(V)</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>

**Table 8.1**

<b>V<sub>GS</sub>(V)</b>	<b>I<sub>D</sub>(mA)</b>	<b>V<sub>DS</sub>(V)</b>
<b>+1</b>		<b>5</b>
<b>+2</b>		<b>5</b>
<b>+3</b>		<b>5</b>
<b>+4</b>		<b>5</b>

**Table 8.2**

**Plot I<sub>D</sub> Vs V<sub>DD</sub>:**

## Plot $I_D$ Vs $+V_{GS}$ :

### Precautions:

- While performing the experiment do not exceed the ratings of the MOSFET. This may lead to damage of MOSFET
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Gate, Drain and Source terminals of the transistor





## Lab Session 09

### Characteristics of MOSFET in Depletion Mode.

#### Objectives:

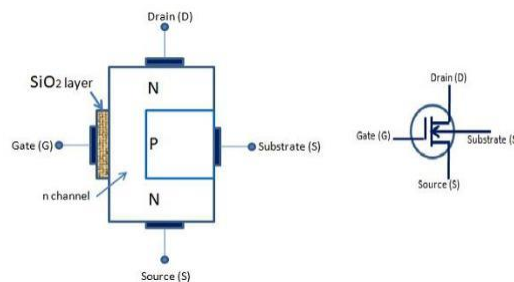
- To determine MOSFET Depletion mode Characteristics.

#### Equipments Required:

- DC Power Supply
- Digital Multimeter
- Breadboard
- MOSFET
- Resistors
- Potentiometer:
- Connecting wires

#### Theory:

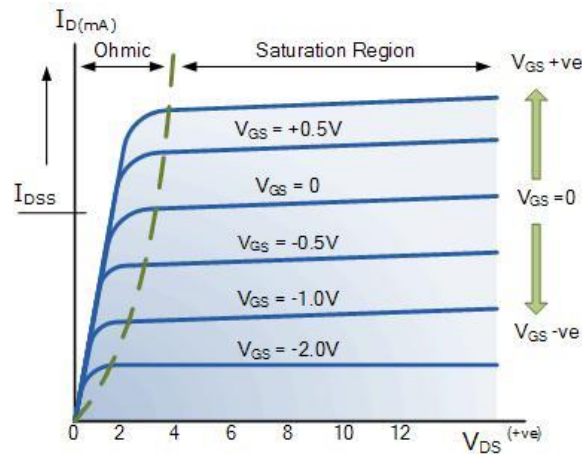
As noted in the introduction, there are two types of MOSFETS depletion type and enhancement type. The terms depletion and enhancement define their basic mode of operation; the name MOSFET stands for metal –oxide– semiconductor field effect transistor. Since there are differences in the characteristics and operation of different types of MOSFET, they are covered in separate sections. In this section we examine the depletion-type MOSFET, which has characteristics similar to those of a JFET between cutoff and saturation at  $IDSS$ , and also has the added feature of characteristics that extend into the region of opposite polarity for  $V_{GS}$ . The basic construction of the n -channel depletion-type MOSFET is provided in Fig.9.1 A slab of p -type material is formed from a silicon base and is referred to as the substrate. It is the foundation on which the device is constructed. In some cases the substrate is internally connected to the source terminal. However, many discrete devices provide an additional terminal labeled SS , resulting in a four-terminal device. The source and drain terminals are connected through metallic contacts to n -doped regions linked by an n -channel. The gate is also connected to a metal contact surface but remains insulated from the n -channel by a very thin silicon dioxide ( $SiO_2$ ) layer.  $SiO_2$  is a type of insulator referred to as a dielectric , which sets up opposing (as indicated by the prefix di -) electric fields within the dielectric when exposed to an externally applied field. The fact that the  $SiO_2$  layer is an insulating layer means that: There is no direct electrical connection between the gate terminal and the channel of a MOSFET.



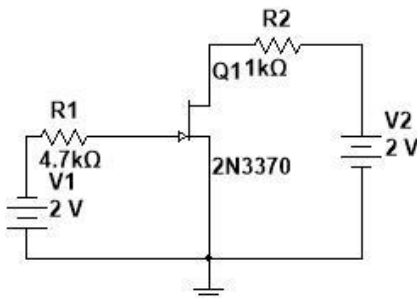
**Fig.9.1 MOSFET**

## Procedure:

- Connect the circuit as per given diagram properly.
- Keep  $V_{GS} = 0V$  by varying  $V_{GG}$
- Vary  $V_{DS}$  in step of  $1V$  up to  $10$  volts and measure the drain current  $I_D$ . Tabulate all the readings.
- Repeat the above procedure for  $V_{GS}$  as  $-0.5V, -1V, -1.5V, -2V, -2.5V, -3V, -3.5V$  etc
- Now Set the voltage  $V_{DS}$  constant at  $5V$ .
- Vary  $V_{GS}$  by varying  $V_{GG}$  in the step of  $0$  up to  $5V$  and note down value of drain current  $I_D$ .
- Tabulate all the readings.



**Fig. 9.2 Graphic Representation**



**Fig. 9.3 Circuit Diagram**

**Observations:**

<b>V<sub>DD</sub> (V)</b>	<b>I<sub>D</sub> (mA)</b>	<b>V<sub>GS</sub>(V)</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>
		<b>0</b>

**Table 9.1**

<b>V<sub>GS</sub>(V)</b>	<b>I<sub>D</sub>(mA)</b>	<b>V<sub>DS</sub>(V)</b>
<b>-1</b>		<b>5</b>
<b>-2</b>		<b>5</b>
<b>-3</b>		<b>5</b>
<b>-4</b>		<b>5</b>

**Table 9.2**

**Plot I<sub>D</sub> Vs V<sub>DD</sub>:**

## **Plot $I_D$ Vs $-V_{GS}$ :**

### **Precautions:**

- While performing the experiment do not exceed the ratings of the MOSFET. This may lead to damage of MOSFET
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Gate, Drain and Source terminals of the transistor.



# Lab Session 10

## MOSFET Digital-Gates Circuit

### Objective:

Implement digital gates logic through MOSFET.

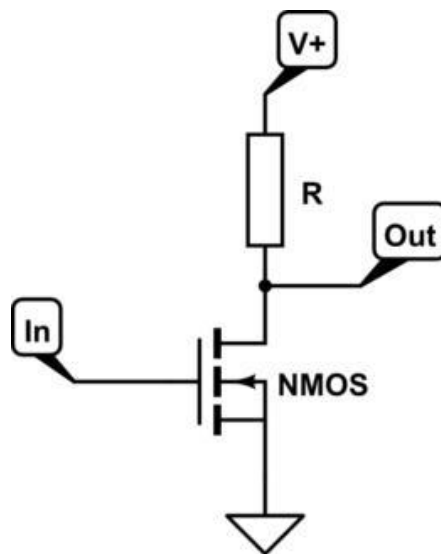
### Equipments:

- DMM
- MOSFET
- D.C Supply
- Probs
- Bread Board
- Connecting Wires

### Theory:

#### Theory:

N-type metal-oxide-semiconductor logic uses n-type (-) MOSFETs (metal-oxide-semiconductor field-effect transistors) to implement logic gates and other digital circuits. These nMOS transistors operate by creating an inversion layer in a p-type transistor body. This inversion layer, called the n-channel, can conduct electrons between n-type "source" and "drain" terminals. The n-channel is created by applying voltage to the third terminal, called the gate. Like other MOSFETs, nMOS transistors have four modes of operation: cut-off (or subthreshold), triode, saturation (sometimes called active), and velocity saturation.

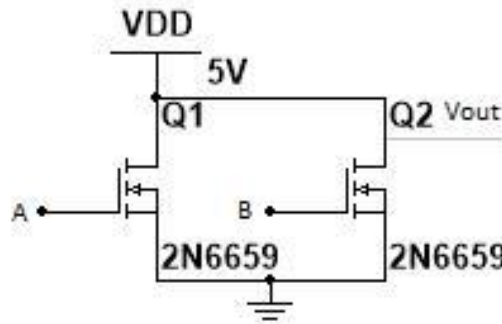


**Fig. 10.1 NMOS**

### Procedure:(NOR Gate)

- Here is a NOR gate implemented in schematic NMOS shown in figure 10.2.
- If either input A or input B is high (logic 1, = True), the respective MOS transistor acts as a very low resistance between the output and the negative supply, forcing the output to be low (logic 0, = False).

- When both A and B are high, both transistors are conductive, creating an even lower resistance path to ground. The only case where the output is high is when both transistors are off, which occurs only when both A and B are low, thus satisfying the truth table of a NOR gate



**Fig.10.2 NMOS NOR Gate**

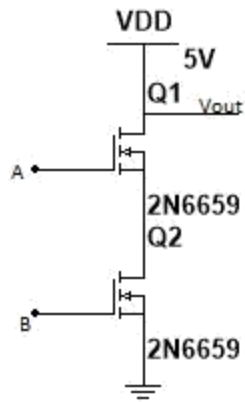
A	B	V <sub>OUT</sub>
0	0	1
0	1	0
1	0	0
1	1	0

**Table 10.1 Truth Table for NOR Gate**

**Procedure:(NAND Gate)**

- Here is a NAND gate implemented in schematic NMOS shown in figure 10.3.
- If either input A or input B is low (logic 0, = False), forcing the output to be high (logic 1, = True).
- When both A and B are high, both transistors are conductive, creating an even lower resistance path to ground. The only case where the output is low is when both transistors are ON, which occurs only when both A and B are high, thus satisfying the truth table of a NAND gate.





**Fig 10.3 NMOS NAND Gate**

A	B	V <sub>OUT</sub>
0	0	1
0	1	1
1	0	1
1	1	0

**Table 10.2 Truth Table for NAND Gate**

**Precautions:**

- While performing the experiment do not exceed the ratings of the MOSFET. This may lead to damage of MOSFET
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Gate, Drain and Source terminals of the transistor.



## Lab Session 11

# Inverting and Non-Inverting Amplifiers behavior of Operational Amplifier

### Objective

In this lab, Inverting and Non-Inverting Operational Amplifier circuits will be investigated.

### Material and Equipment

- Resistor 1 k $\Omega$
- Resistor 3.3 k $\Omega$
- Resistor 1.5 k $\Omega$
- Operational Amplifier LM 741
- 2 DC power supply, 0...15 V
- 1 Oscilloscope

### Theory

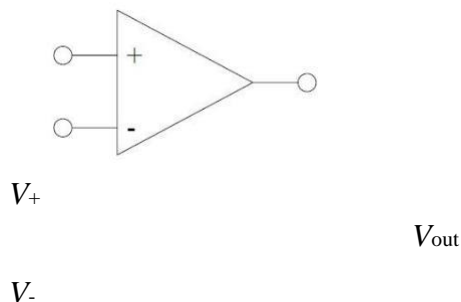
#### 1) Op-Amp Basics

The operational amplifier is one of the most useful and important components of analog electronics.

They are widely used in popular electronics. Their primary limitation is that they are not especially fast: The typical performance degrades rapidly for frequencies greater than about 1 MHz, although some models are designed specifically to handle higher frequencies. The primary use of op-amps in amplifier and related circuits is closely connected to the concept of negative feedback. Feedback represents a vast and interesting topic in itself. However, it is possible to get a feeling for the two primary types of amplifier circuits, inverting and noninverting, by simply postulating a few simple rules (the "golden rules").

#### 2) The Golden Rules

The other important fact about op-amps is that their *open-loop gain* is huge, in which there is no feedback loop from output back to input. A typical open-loop voltage gain is  $\sim 10^4 - 10^5$ . By using negative feedback, we throw most of that away!



**Figure 11.1: Operational amplifier.**

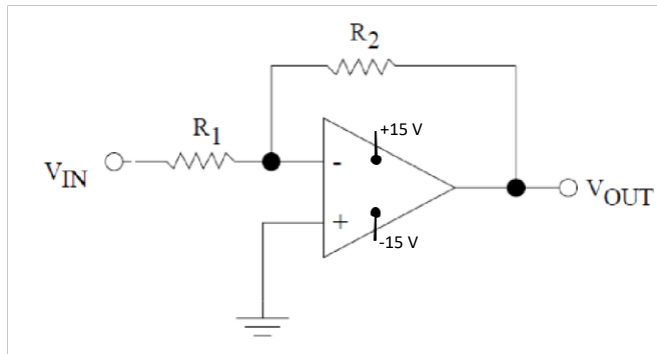
The golden rules are idealizations of op-amp behavior, but are nevertheless very useful for describing overall performance. They are applicable whenever op-amps are configured with

negative feedback, as in the two amplifier circuits discussed below. These rules consist of the following two statements:

1. The voltage difference between the inputs,  $V_+ - V_-$ , is zero. (Negative feedback will ensure that this is the case.)  $\Rightarrow V_+ = V_-$ .
  2. The inputs draw no current. (This is true in the approximation that the  $Z_{in}$  of the op-amp is much larger than any other current path available to the inputs.)
- When we assume ideal op-amp behavior, it means that we consider the golden rules to be exact. We now use these rules to analyze the two most common op-amp configurations.  $\Rightarrow I_+ = I_- = 0$ .

### 3) Inverting Amplifier

The inverting amplifier configuration is shown in Fig. 11.2. It is "inverting" because our signal input comes to the "-" input, and therefore has the opposite sign to the output. The negative feedback is provided by the resistor  $R_2$  connecting output to input.



**Figure 11.2: Inverting amplifier configuration.**

We can use our rules to analyze this circuit. Since input + is connected to ground, then by rule 1, input - is also at ground. For this reason, the input - is said to be at *virtual ground*. Therefore, the voltage drop across  $R_1$  is  $v_{in} - v_- = v_{in}$ , and the voltage drop across  $R_2$  is  $v_{out} - v_- = v_{out}$ . So, applying Kirchoff's first law to the node at input -, we have, using golden rule 2:

$$i_- = 0 = i_{in} + i_{out} = v_{in}/R_1 + v_{out}/R_2 \text{ or}$$

$$G = v_{out}/v_{in} = -R_2/R_1$$

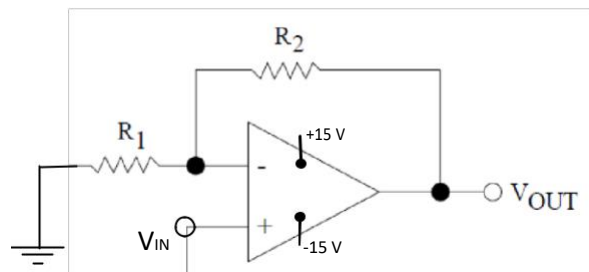
### 4) Non-inverting Amplifier

This configuration is given in Fig. 3. Again, its basic properties are easy to analyze in terms of the golden rules.

$$v_{in} = v_+ = v_- = v_{out} \left[ \frac{R_1}{R_1 + R_2} \right]$$

Where the last expression is from our voltage divider result. Therefore, rearranging gives

$$G = v_{out}/v_{in} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$



**Figure 11.3: Non-inverting amplifier configuration.**

## Procedure

### A. Inverting Amplifier

- 1) Set up the circuit of the figure.2, where  $R_1=1\text{ k}\Omega$ ,  $R_2=1.5\text{ k}\Omega$  and  $V_{IN}$  is a sinusoidal signal having a frequency  $f = 1\text{ kHz}$
- 2) Vary the input amplitude  $V_{inMax}$  and measure the output amplitude  $V_{outMAX}$ , using the oscilloscope, to fill the table below.

$V_{inMax}$ (V)	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2
$V_{outMax}$ (V)											

**Table11.1**

### B. Non-Inverting Amplifier

- 1) Set up the circuit of the figure.3, where  $R_1=1.5\text{ k}\Omega$ ,  $R_2=3.3\text{ k}\Omega$  and  $V_{IN}$  is a sinusoidal signal having a frequency  $f = 1\text{ kHz}$ .
- 2) Vary the input amplitude  $V_{inMax}$  and measure the output amplitude  $V_{outMAX}$ , using the oscilloscope, to fill the table below.

$V_{inMax}$ (V)	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2
$V_{outMax}$ (V)											

**Table 11.2**



## Lab Session 12

### **BJT Common Emitter Amplifier Configuration**

#### **Objectives:**

- To design a common emitter transistor (NPN) amplifier circuit.

#### **Equipments:**

- DC power supply.
- Function generator.
- DMM
- Oscilloscope.
- Transistor
- Resistor
- Capacitor
- Connecting Wires

#### **Theory:**

Transistors are utilized for three main purposes: amplification, oscillation, and switching. Amplification is commonly accomplished by electronic circuits called amplifiers, which are used to increase signal power by increasing the voltage or current of the given signal. One important requirement during amplification is that only magnitude of signal should increase and there should be no change in signal shape. Common Emitter (CE) Amplifier operation:

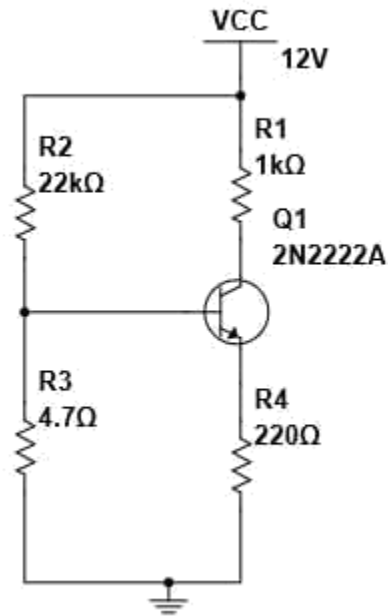
When capacitors are regarded as short circuits, it is seen that circuit input terminals are transistors base and emitter and output terminal are collector and emitter, so called Common emitter configuration. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal is "out-of-phase" with the input voltage signal.

#### **DC Voltage measurement:**

For DC Voltage measurements disconnect all capacitors from circuit. The EB should be forward biased. The  $V_{CB}$  may range from approximately half the supply voltage.

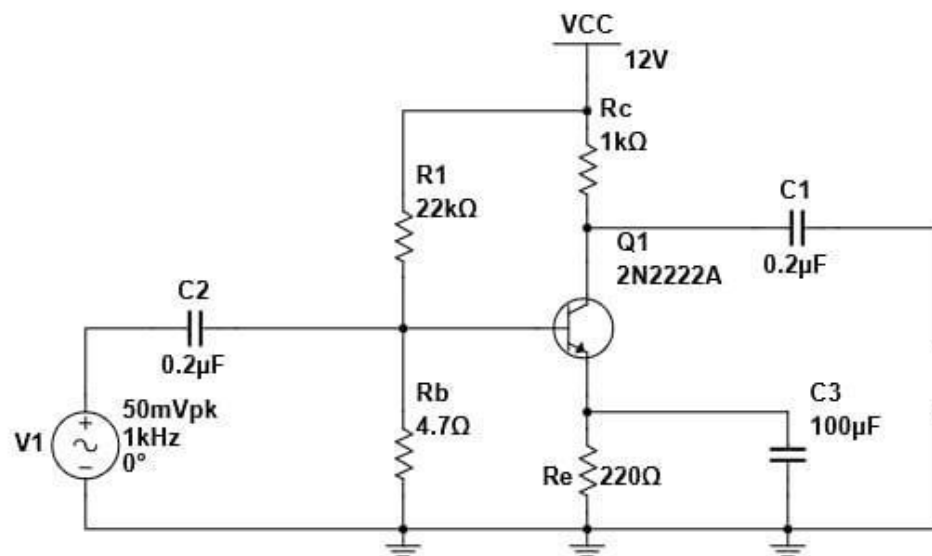
#### **Procedure:**

1. Connect the circuit components as shown in Fig 12.2. After connecting the circuit components apply and then set .
2. Now measure the Q-point values.



**Fig 12.1 Circuit diagram**

3. Connect circuit as shown in Fig 12.1. disconnect all capacitors and measure DC Voltages
4. For frequency measurement feed 100mV and apply frequency 1kHz.
5. Now increase frequency from 1kHz to 1MHz and measure voltage gain of amplifier at each frequency.
6. Plot Gain versus Frequency.



**Fig 12.2 Common Emitter Amplifier Circuit**



**Observations:**

**DC Measurements:**

Quantities	Measured	Calculated
$I_C(\text{sat})$		
$V_{CE}=V_{CC}$		

**Table 12.1 DC Measurements**

**Amplification of of CE:**

Frequency	$V_O$	Gain( $A_V$ )
10k		

**Table 12.2 Amplification of of CE:**

**Plot Gain versus frequency:**

**Precautions:**

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



## Lab Session 13

### **BJT Common Base Amplifier Configuration**

#### **Objectives:**

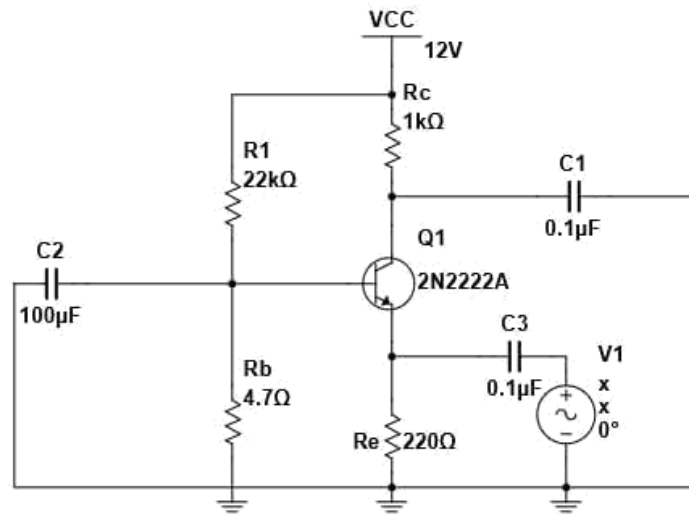
- To design a common base transistor (NPN) amplifier circuit.

#### **Equipments:**

- DC power supply.
- Function generator.
- DMM
- Oscilloscope.
- Transistor
- Resistor
- Capacitor
- Connecting Wires

#### **Theory:**

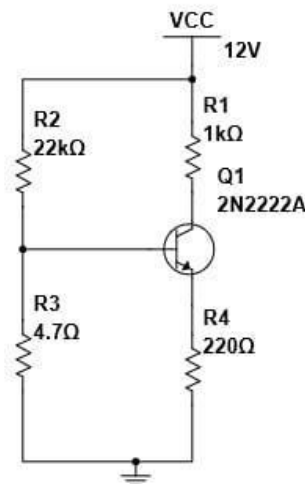
The common base amplifier is the least widely used of the three transistor amplifier configurations. The common emitter and common collector (emitter follower) configurations are far more widely used because their characteristics are generally more useful. The common base amplifier configuration comes into its own at high frequencies where stability can be an issue. For both NPN and PNP circuits, it can be seen that for the common base amplifier circuit, the input is applied to the emitter, and the output is taken from the collector. The common terminal for both circuits is the base. The base is grounded for the signal and for this reason the circuit may sometimes be called a grounded base circuit. The common base amplifier configuration is not used as widely as transistor amplifier configurations. However it does find uses with amplifiers that require low input impedance levels. One application is for moving-coil microphones preamplifiers - these microphones have very low impedance levels. Another application is within VHF and UHF RF amplifiers where the low input impedance allows accurate matching to the feeder impedance which is typically  $50\Omega$  or  $75\Omega$ . The configuration also improves stability which is a key issue. It is worth noting that the current gain of a common-base amplifier is always less than unity. However the voltage gain is more, but it is a function of input and output resistances (and also the internal resistance of the emitter-base junction). As a result, the voltage gain of a common-base amplifier can be very high.



**Fig. 13.1 Common Base Amplifier Circuit**

**Procedure:**

1. Connect the circuit components as shown in Fig 13.1. After connecting the circuit components apply and then set .
2. Now measure the Q-point values.
3. Connect circuit as shown in Fig 13.2 disconnect all capacitors and measure DC Voltages
4. For frequency measurement feed 100mV and apply frequency 1kHz.
5. Now increase frequency from 1kHz to 1MHz and measure voltage gain of amplifier at each frequency.
6. Plot Gain versus Frequency.



**Fig.13.2 Circuit Diagram**

**Observations:**

**DC Measurements:**

Quantities	Measured	Calculated
$I_C(\text{sat})$		
$V_{CE}=V_{CC}$		

**Table 13.1 DC Measurements**

**Amplification of CB:**

Frequency	$V_O$	Gain( $A_V$ )
10k		

**Table 13.2 Amplification of CB:**

**Plot Gain versus frequency:**

**Precautions:**

- While performing the experiment do not exceed the ratings of the BJT. This may lead to damage of BJT
- Connect voltmeter and ammeter with correct polarities as shown in the circuit diagram
- Do not switch on power supply unless the circuit connections are checked as per the circuit diagram
- Properly identify the Base, Emitter and Collector terminals of the transistor



**Lab Session 14**  
**Design Project**