LABORATORY MANUAL

Name of the Laboratory

Basic Electronics Lab

PREPARED BY

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LIST OF EXPERIMENTS

1. Familiarization of electronics measuring instrument and components.
2. Measure the voltage and frequency using a CRO.
3. Study and verification of the truth table for logic gates.
4. To design and verify the truth table for logic gates using NOR gate.
5. To design and verify the truth table for logic gates using NAND gate.
6. Study V-I characteristics of PN junction diode and determine the static and dynamic resistance from the characteristic curve.
7. Study of a Half wave rectifier circuit with and without capacitor filter.
8. Study of a Full wave rectifier circuit with and without capacitor filter.
9. Study V-I characteristics of Zener diode and determine its voltage regulation.
10. Study the input and output characteristics of common base (CB) transistor.
11. Study the input and output characteristics of common emitter (CE) transistor.
12. Design and verification of Inverting and non-inverting amplifier using Op-Amp IC.

INNOVATIVE EXPERIMENTS

13. Design and verification of summer and subtractor circuit using Op-Amp IC
14. Study and verification of the truth table for half adder using logic gates.
15. As suggested by the concerned faculty/lab in charge.

EXPERIMENT NO: 01

<u>Aim</u>: Familiarization of electronic measuring instruments and components.

<u>Objective</u>:

i. To get brief idea of different electronic passive components such as resistors, capacitors and inductors.
ii. To understand different electronic active components e.g. p-n junction diode, zener diode, light emitting diodes (LEDs) and bipolar junction transistors (BJTs).
iii. Understanding of integrated circuits (ICs) and breadboard.
iv. To get brief idea of different electronic measuring instruments such as cathode ray oscilloscope (CRO) and multimeter.

<u>Apparatus required</u>: Resistors, capacitors, inductors, p-n junction diode, LED, zener diode, BJTs, ICs, bread board, multimeter, CRO and connecting cables.

<u>Theory</u>: Electronic components can be categorized into two groups: discrete components and integrated circuits (ICs). further discrete components can be classified as passive and active components.

I. Passive components: These components are not capable of amplifying or processing an electrical signal. resistors, capacitors and inductors are basic passive components used in electronics.

a. Resistor: Resistor is a two-terminal electronic component whose function is to limit the current flow in an electric circuit. The symbol for resistor in an electronic circuit is shown in Fig. 1.1.

Figure 1.1: Symbol of resistor

These are available in different values, shapes and sizes. most axial resistors use a pattern of colored stripes to indicate resistance. Four band identification is the most commonly used color coding scheme on all resistors. It consists of four colored bands that are painted around the body of the resistor as shown in Fig. 1.2. resistor values are always coded in ohms (Ω).

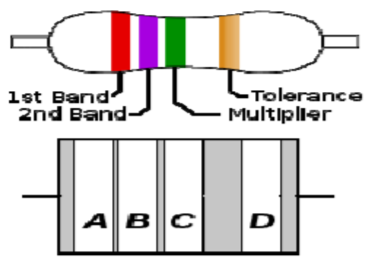


Figure 1.2: Color coding scheme for resistor

- Band A is first significant figure of component value
- Band B is the second significant figure
- Band C is the decimal multiplier
- Band D if present, indicates tolerance of value in percent (no color means 20%)

The color codes are given in the following table in table 1.1.

Table 1.1: Color codes for resistor

Band Color	1st Band	2nd Band	3rd Band	Multiplier x	Tolerances ± %
Black	0	0	0	1	
Brown	1	1	1	10	± 1
Red	2	2	2	100	± 2
Orange	3	3	3	1000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	± 0.5
Blue	6	6	6	1,000,000	± 0.25
Violet	7	7	7	10,000,000	± 0.10
Grey	8	8	8	100,000,000	± 0.05
White	9	9	9	1,000,000,000	
Gold				0.1	± 5
Silver				0.01	± 10
None					± 20

Tight tolerance resistors may have three bands for significant figures rather than two, and/or an additional band indicating temperature coefficient, in units of ppm/k. for large power resistors and potentiometers, the value is usually written out implicitly as "10 kΩ", for instance.

Two main characteristics of resistors are its resistance R (ohms) & power rating W (watts). these are not polarity sensitive devices.

The relative sizes of resistors change with the wattage (power) rating as shown in Fig. 1.3. the size increases for increased wattage rating in order to withstand the higher currents and dissipation losses. however, the resistance value is not related to physical size.

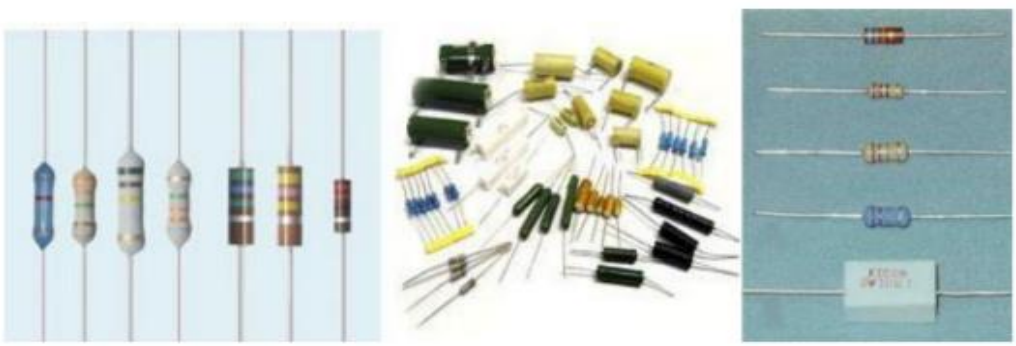


Figure 1.3: Resistor with different sizes

Applications: In electronic circuits, resistors are used

- ✓ to limit current flow,
- ✓ to adjust signal levels,
- ✓ bias active elements, and
- ✓ terminate transmission lines among other uses.

b. Capacitor: A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store energy electrostatically in an electric field. It contains two electrical conductors separated by a dielectric (insulator) as shown in Fig. 1.4. for example, one common construction consists of metal foils separated by a thin layer of insulating film. the unit for capacitance is farad (F).

Figure 1.4: Symbol of capacitor

A lot have their values printed on them, some are marked with 3-digit codes, and a few are color coded as shown in Fig. 1.5. the same resources listed above for resistors can also help you identify capacitor values. they are typically marked with a “C” on a circuit board.

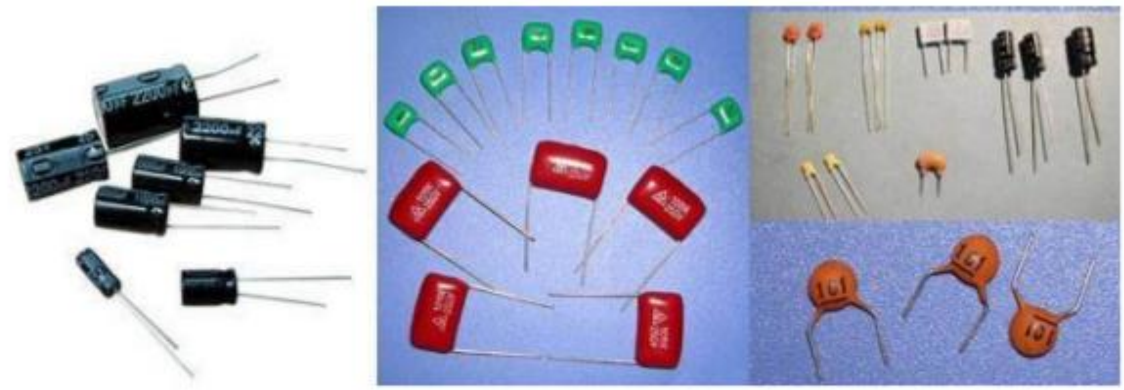


Figure 1.5: Different types of capacitors

Mostly used capacitors are electrolytic and ceramic capacitors.

- **Electrolytic Capacitors:** An electrolytic capacitor uses an electrolyte, an ionic conducting liquid, as one of its plates, to achieve a larger capacitance per unit volume than other types. they are used in relatively high-current and low frequency electrical circuits. however, the voltage applied to these capacitors must be polarized ; one specified terminal must always have positive potential with respect to the other. these are of two types, axial and radial capacitors as shown in Fig. 1.6. the arrowed stripe indicates the polarity, with the arrows pointing towards the negative pin.

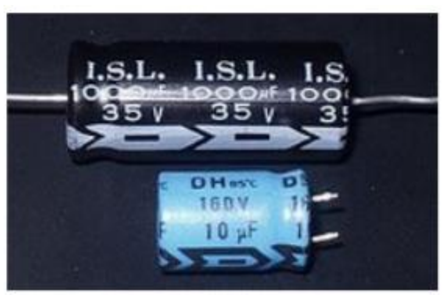


Figure 1.6: Axial and radial electrolytic capacitors

- **Ceramic Capacitor:** Ceramic capacitors are generally non-polarized and almost as common as radial electrolytic capacitors. generally, they use an alphanumeric marking system as shown in Fig. 1.7. the number part is the same as for SMT resistors, except that the value represented is in pF. they may also be written out directly, for instance, 2n2 = 2.2 nF.

SMT

Figure 1.7: Ceramic capacitors

Capacitor has ability to block a steady D.C. voltage while passing a.c. signals, higher the frequency, less the opposition to a.c. voltage.

Applications:

- In tuned circuits.
- As bypass capacitors to bypass ac through it.
- Blocking capacitor to block dc components.

c. **Inductor:** An inductor, also called a coil or reactor, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil.

When current flows through it, energy is stored in a magnetic field in the coil. as the current flowing through an inductor changes, the time varying magnetic field induces a voltage in the conductor, according to faraday's law of electromagnetic induction, which by lenz's law opposes the change in current that created it.

Inductors, also called coils, can be a bit harder to figure out their values. if they are color coded, the resources listed for resistors can help; otherwise, a good meter that can measure inductance will be needed. they are typically marked with an "L" on a circuit board. the unit for inductance is henry (H).

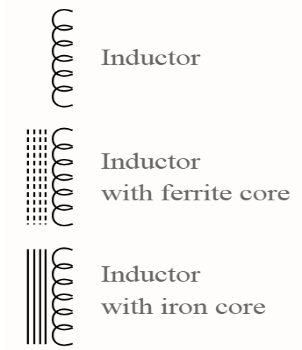


Figure 1.8: Symbol for inductor

Applications:

- Filter chokes for smoothing and pulsating currents produced by rectifiers.
- Audio frequency chokes, to provide high impedance at audio frequencies.

II. Active Components: These components are capable of amplifying or processing an electrical signal. diodes and transistors are some active components used in electronics engineering.

a. P-N Junction Diode: A popular semiconductor device called a diode is made by combining P & N type semiconductor materials. the doped regions meet to form a P-N junction. diode is unidirectional device that allow current to flow through them in one direction only. the schematic symbol for a semiconductor diode is shown in fig.1.9. the P-side of the diode is called the anode (A), while the N-side of the diode is called the cathode (K).

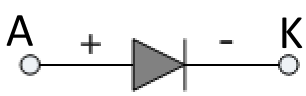


Figure 1.9: Symbol for p-n junction diode

Fig. 1.10 Shows how to identify the cathode of a diode.

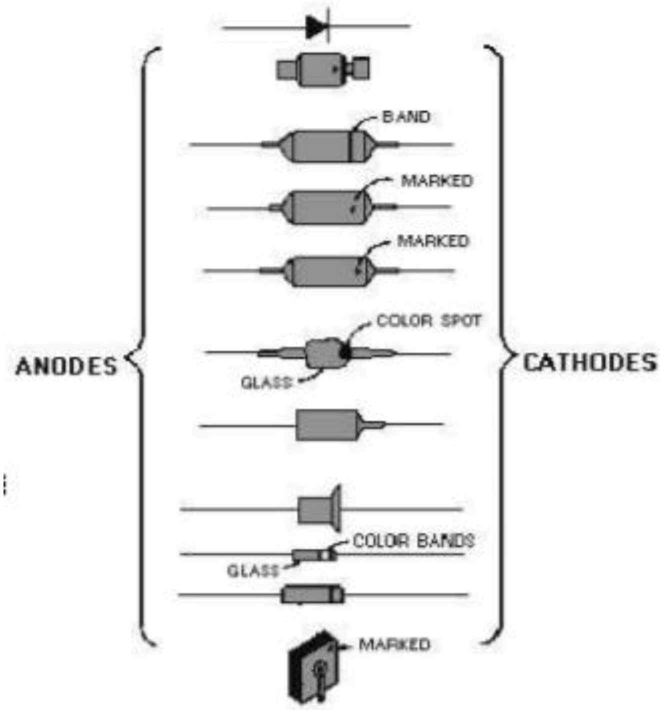


Figure 1.10: Identification of diode cathode end

Applications:

- As switches.
- In rectifiers, clipper and clamper circuits.

b. Zener Diode: It is a diode which allows current to flow in the forward direction in the same manner as an ideal diode. It also permits the current to flow in the reverse direction when the voltage is above a certain value known as the break down voltage/ "Zener knee voltage"/ "Zener voltage"/"avalanche point"/"peak inverse voltage" denoted by V_Z. The symbol for Zener diode is shown in Fig. 1.11.

The device consists of a reverse biased, highly doped, p-n junction diode operating in the breakdown region. conventional diodes and rectifiers never operate in the breakdown region, but the Zener diode can safely be operated at this point.

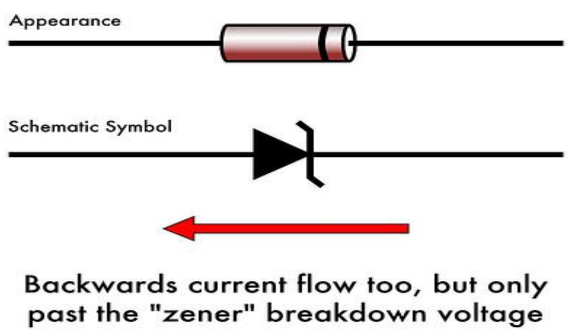


Figure 1.11: Symbol of Zener diode

Applications: Zener diodes are used as voltage regulators and as voltage reference standards.

c. Light Emitting Diode: As opposed to other diodes that give off heat when conducting, LEDs emit light. In the latter, the recombination of charge carriers across the PN junction releases optical energy when the electrons fall from the conduction to the valence band. The heat emission is negligible in light emitting materials like gallium arsenic phosphide and gallium phosphide.

LEDs must be covered in a transparent or translucent material. the wavelength of the radiation for a given colour is given by the relation $\lambda = 1.24/E_g$. here E_g is the energy gap between conduction and valence bands. Its value is 1.45 eV for GaAs, 3eV for GaAsP and 2.25 eV for GaP. the colors obtained from these materials are red, yellow and green respectively. the symbol for LED is given in Fig. 1.12.

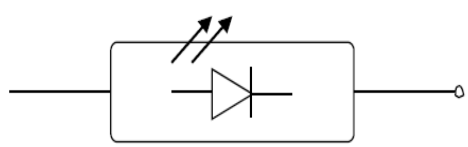


Figure 1.12: Symbol of LED

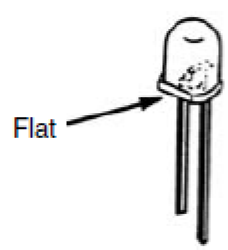


Figure 1.13: Physical appearance of LED

In Fig. 1.13, longer terminal is cathode and the other is anode.

d. **Bipolar Junction Transistor:** A BJT is a three terminal device having three doped regions called emitter, base and collector. there are two types of transistors: NPN and PNP as shown in Fig. 1.14. notice that for both types, the base is narrow region sandwiched between the larger collector and moderate emitter regions.

In NPN transistors, the majority current carriers are free electrons in the emitter and collector, while the majority current carriers are holes in the base. the opposite is true in the PNP transistor where the majority current carriers are holes in the emitter and collector, and the majority current carriers are free electrons in the base.

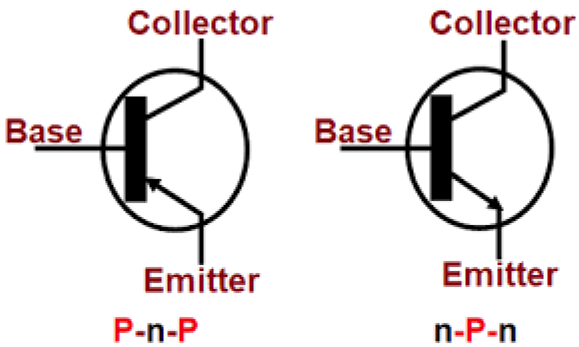


Figure 1.14: Schematic symbols for BJTs (a) PNP transistor (b) NPN transistor.

For a transistor to function properly as an amplifier, the emitter-base junction must be forward biased and the collector base junctions must be reverse biased.

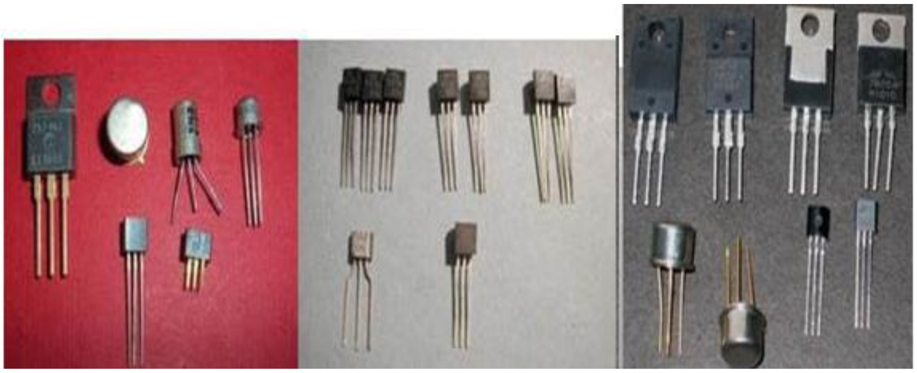


Figure 1.15: Physical appearance of BJTs

Testing a Transistor: To determine whether a transistor is PNP or NPN, there assistance between the three different leads, emitter, base and collector is measured.

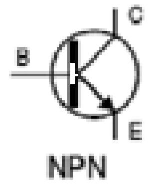


Figure 1.16: Testing a NPN transistor

The diagram shows how the junctions behave in an NPN transistor. the diodes are reversed in a PNP transistor but the same test procedure can be used as shown in Table 1.2.

Table 1.2: Transistor Resistance Values for the PNP and NPN transistor types

Between Transistor Terminals		PNP	NPN
Collector	Emitter	R_{HIGH}	R_{HIGH}
Collector	Base	R_{LOW}	R_{HIGH}
Emitter	Collector	R_{HIGH}	R_{HIGH}
Emitter	Base	R_{LOW}	R_{HIGH}
Base	Collector	R_{HIGH}	R_{LOW}
Base	Emitter	R_{HIGH}	R_{LOW}

III. Integrated Circuits: An integrated circuit (more often called as an IC/microchip/silicon chip) is a piece of specially prepared silicon (or another semiconductor) into which a very complex electronic circuit is etched using photographic techniques. silicon chips can contain computer processors, memory and special devices. the chip is very fragile and so is normally surrounded by a tough plastic package, and electrical contact with the chip is provided through metal legs sticking out of the package as shown in fig. 1.17.

There are two main advantages of ICs over discrete circuits: cost and performance. cost is low because millions of transistors are printed as a complete unit by photolithography and not constructed as one transistor at a time. performance is better since the components have high switching speed, consuming little power.

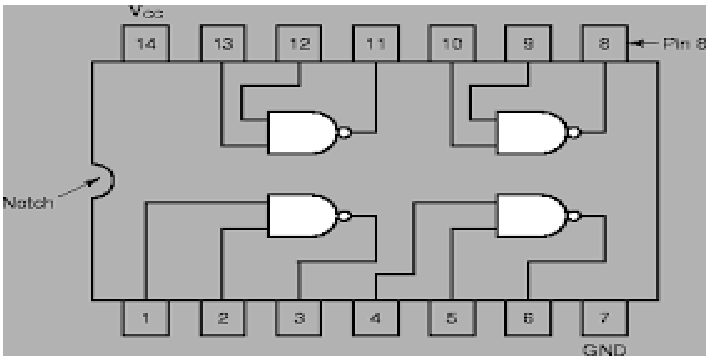


Figure 1.17: 2 D view of NAND gate IC

IV. Breadboard: This is the platform (or chassis) on which any circuit can be ringed up to provide inter connections between electronics components and devices. the advantage of bread board is that the components can be connected (or) disconnected easily.

A picture of breadboard is shown in Fig. 1.18(a) and the connection details on its rear side are shown in Fig. 1.18(b). It has holes both horizontally and vertically. the horizontal holes at the top and bottom are having internal shorts where as in the remaining part vertical holes are shorted internally.

The five holes in each individual column on either side of the central groove are electrically connected to each other, but remain insulated from all other sets of holes. In addition to the main columns of holes, however, you'll note four sets or groups of holes along the top and bottom.

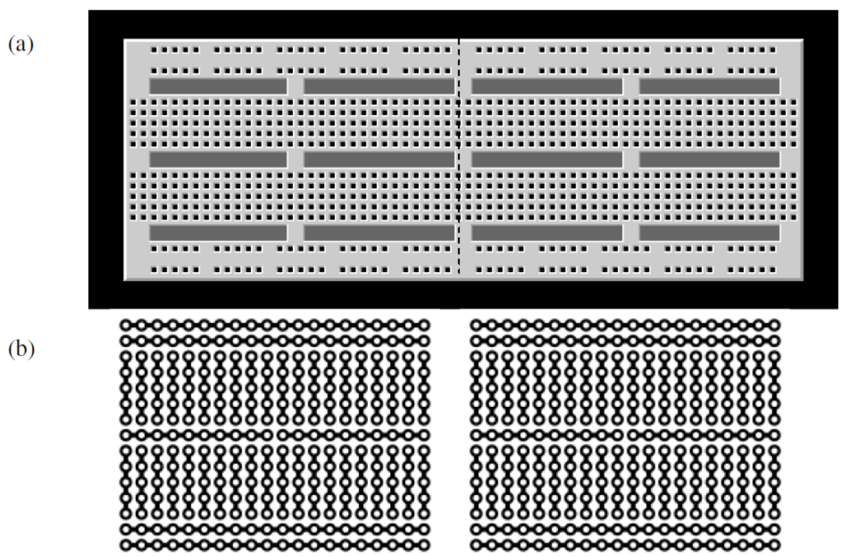


Figure 1.18: (a) A typical Breadboard and (b) its connection details

Each of these consists of five separate sets of five holes each, for a total of 25 holes. These groups of 25 holes are all connected together on either side of the dotted line indicated on Fig.1.18 (a) and needs an external connection if one wishes the entire row to be connected. This makes them ideal for distributing power to multiple ICs or other circuits.

V. Measuring Instruments: Various measuring instruments are used in electronic circuits like multimeter and CRO.

a. 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, and transistor test.

Parts of Multimeter: A multimeter has three parts:

- Display
- Selection Knob
- Ports

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. the selection knob allows the user to set the multimeter to read different things such as milliamps (mA) of current, voltage (V) and resistance (Ω).

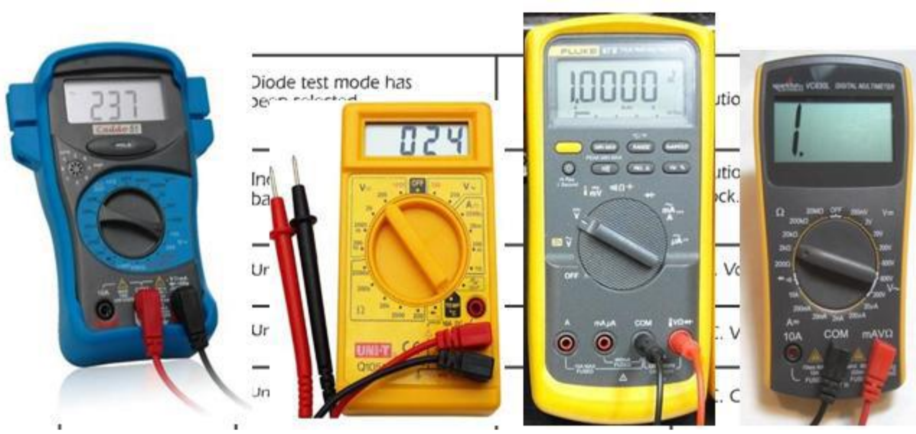


Figure 1.19: Digital Multimeters

Two probes are plugged into two of the ports on the front of the unit as shown in Fig. 1.19. 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). MAVΩ 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 (Ω).

The probes have a banana type connector at the end that plugs into the multimeter. any probe with a banana plug will work with this meter.

b. **Cathode Ray Oscilloscope (CRO):** The device consists of a vacuum tube which contains a cathode; anode, grid, X&Y-plates and a fluorescent screen (Fig. 1.20 below). when the cathode is heated (by applying a small potential difference across its terminals), it emits electrons. having a potential difference between the cathode and the anode (electrodes), accelerate the emitted electrons towards the anode, forming an electron beam, which passes to fall on the screen. when the fast electron beam strikes the fluorescent screen, a bright visible spot is produced.

The grid, which is situated between the electrodes, controls the amount of electrons passing through it thereby controlling the intensity of the electron beam. the X&Y-plates are responsible for deflecting the electron beam horizontally and vertically. a sweep generator is connected to the X-plates, which moves the bright spot horizontally across the screen and repeats that at a certain frequency as the source of the signal. the voltage to be studied is applied to the Y-plates. the combined sweep and Y voltages produce a graph showing the variation of voltage with time.

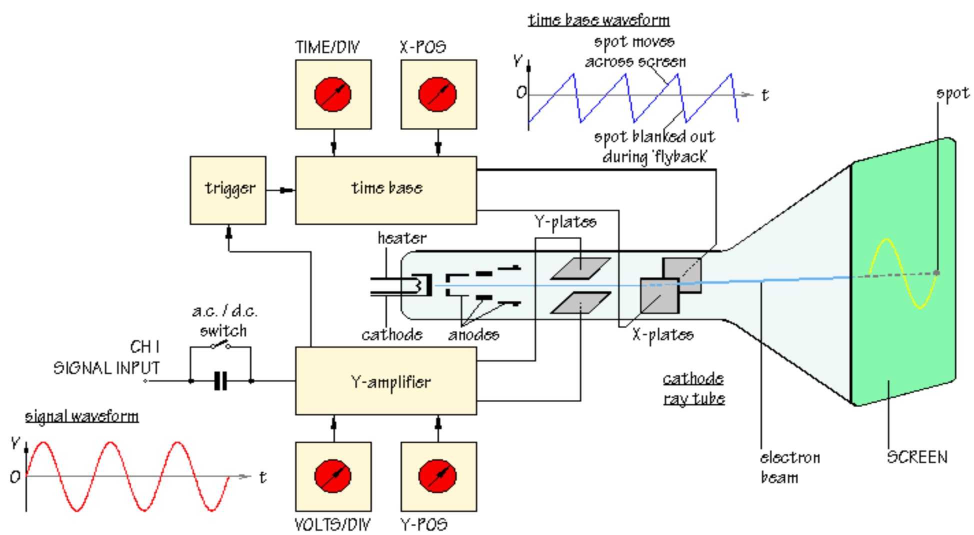


Figure 1.20: Cathode Ray Oscilloscope

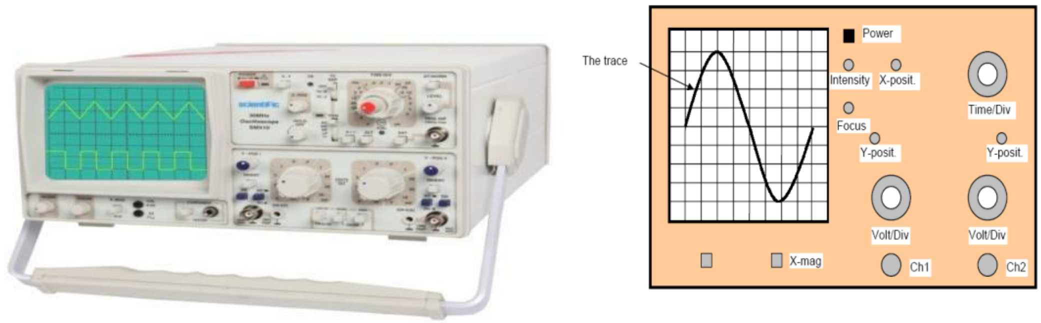


Figure 1.21: Cathode Ray Oscilloscope (Experimental View)

Result: Study of various electronic measuring instruments and components has been completed.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Precautions:

1. Connecting electrolytic capacitors in reverse polarity can easily damage or destroy the capacitor.
2. Breadboard sockets are sturdy and rugged, and can take quite a bit of handling.
3. Be sure the test leads and rotary switch are in the correct position for the desired measurement using multimeter.

EXPERIMENT NO: 02

Aim: Measurement of voltage and frequency using a CRO.

Objective:

i. Detailed study of CRO and its functions.
ii. Measurement of amplitude and frequency of a given function.

Apparatus Required: Function generator (Signal source), CRO, BNC connecting probes.

Theory:

a. Function Generator:

A function generator is electronic test equipment used to generate different types of waveforms over a wide range of frequencies. function generators are capable of producing a variety of repetitive waveforms, some of which are listed below.

Sine Wave: A function generator will normally have the capability to produce a standard sine wave output. this is the standard waveform that oscillates between two levels with a standard sinusoidal shape as shown in Fig. 2.1.

Figure 2.1: Sine Wave

Square Wave: A square wave is normally relatively easy for a function generator to produce. it consists of a signal moving directly between high and low levels as shown in Fig. 2.2.

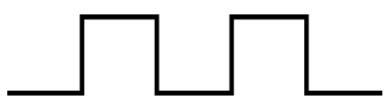


Figure 2.2: Square Wave

Pulse: A pulse waveform is another type that can be produced by a function generator. it is effectively the same as a square wave, but with the mark space ratio very different to 1:1 as shown in Fig. 2.3.

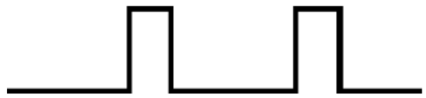


Figure 2.3: Pulse

Triangular Wave: This form of signal produced by the function generator linearly moves between a high and low point as shown in Fig. 2.4.

Figure 2.4: Triangular Wave

Saw Tooth Wave: Again, this is a triangular waveform, but with the rise edge of the waveform faster or slower than the fall, making a form of shape similar to a saw tooth as shown in Fig. 2.5.

Figure 2.5: Sawtooth Wave

These waveforms can be either repetitive or single-shot. function generators are used in the development, test and repair of electronic equipment. Fig. 2.6 shows front view of a function generator.

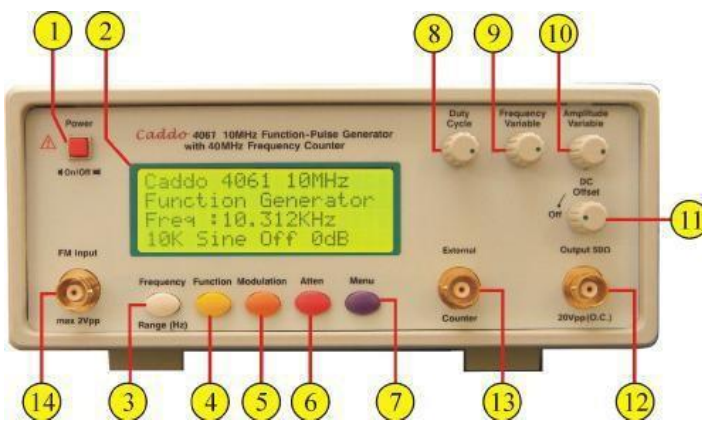


Figure 2.6: Front View of Function Generator

Table 2.1: Function Generator Control Knobs

Knob No.	Control Name	Functions
1	Power	Push button switch to power ON the instrument.
2	LCD Display	20 x 4 Character bright back lit Liquid Crystal Display.
3	Frequency	Used for selection of frequency range step by step.
4	Function	Used for selection of Particular waveform. A total number of 6 different waveforms: ➢ Sine ➢ Square ➢ Triangular ➢ Ramp ➢ Pulse
5	Modulation	Used for selection of Frequency Modulation.
6	Attenuation	Used for Selection of 20dB or 40dB attenuation
7	Menu	Used for selection of Function Generator/Frequency counter mode.
8	Duty Cycle	When pulse output function is selected, this controls the pulse duty cycle from 15% to 85%.
9	Frequency Variable	In conjunction with frequency range, selected by frequency key on front Panel.
10	Amplitude Variable	In conjunction with attenuators (6), this varies the level of output.
11	DC Offset	This control provides DC offset. Approximately ±5VDC is superimposed on the output. Keep the control off if DC offset is not required.
12	Output (BNC Connector)	Output of 10 MHz function generator i.e. 20Vpp (Open Circuit)
13	External Counter (BNC Connector)	Input BNC connector for measuring the frequency of external signal when External Counter mode is selected

		by Menu key on the LCD display.
14	Modulation Input	Maximum modulation Input i.e. 2Vpp.

b. Cathode Ray Oscilloscope (CRO):

It is primarily used for visual indication of signal waveform. it is basically a very fast X – Y plotter. the heart of CRO is a vacuum tube called Cathode Ray Tube (CRT).

CRT consists of 3 basic components as shown in Fig. 2.7:

1. **Electron gun,** which produces sharply focused beam of electron accelerated to a very high velocity. It consists of cathode, anode and grid.
2. **Deflection system,** which deflects electrons, both in horizontal & vertical planes. It consists of X &Y-plates
3. **Fluorescent screen,** upon which beam of electrons impinges to produce a spot of visible light.

When the cathode is heated (by applying a small potential difference across its terminals), it emits electrons. Potential difference between the cathode and the anode (electrodes) accelerate the emitted electrons towards the anode, forming an electron beam which passes to fall on the screen. when the fast electron beam strikes the fluorescent screen, a bright visible spot is produced.

The grid, which is situated between the electrodes, controls the amount of electrons passing through it thereby controlling the intensity of the electron beam. the X&Y- plates are responsible for deflecting the electron beam horizontally and vertically. a sweep generator is connected to the X-plates, which moves the bright spot horizontally across the screen and repeats that at a certain frequency as the source of the signal. the voltage to be studied is applied on Y-plates. the combined sweep and Y voltages produce a graph showing the variation of voltage with time.

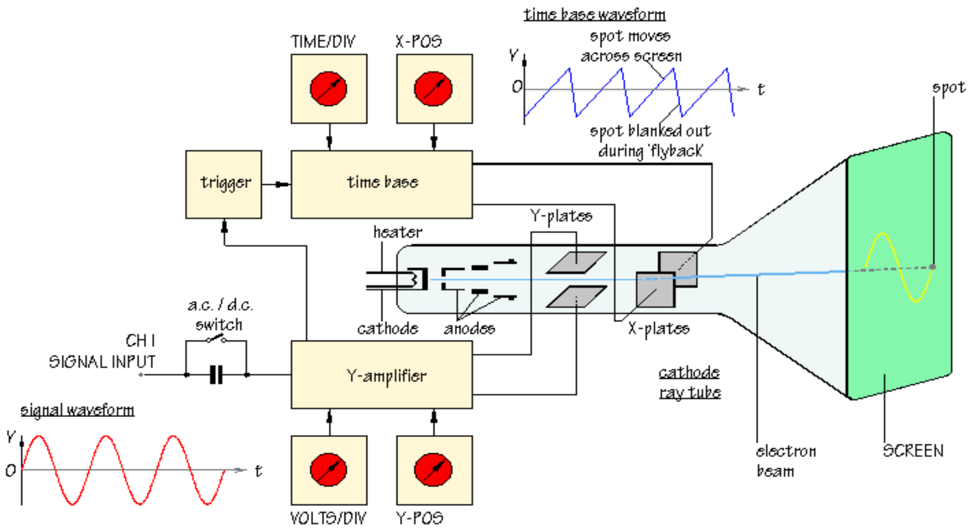


Figure 2.7: Cathode Ray Oscilloscope

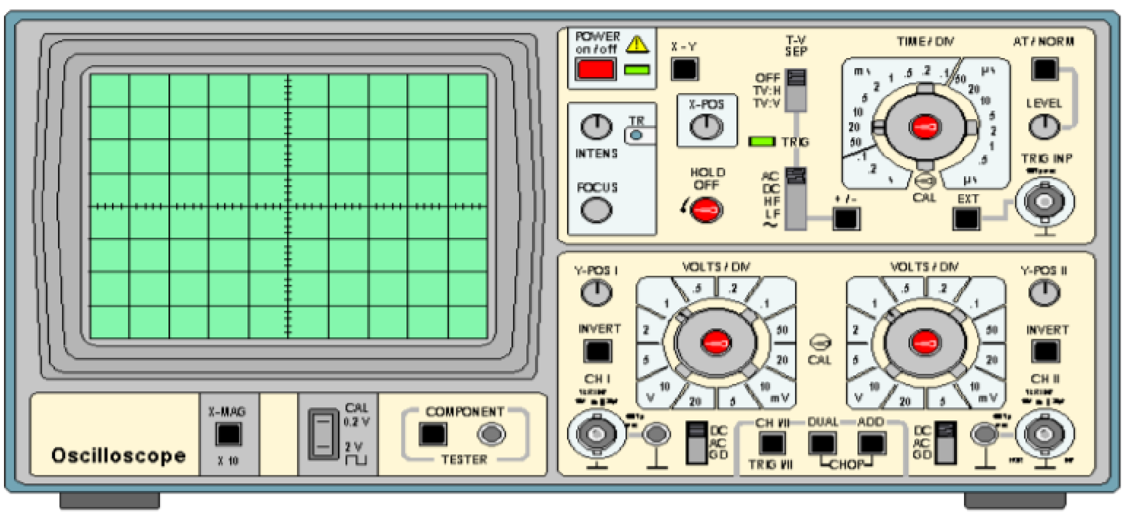


Figure 2.8: View of Oscilloscope

Fig. 2.8 shows 2-D view of CRO. it consists of:

Screen: Usually displays a V/t graph, with voltage V on the vertical axis and time T on the horizontal axis. the scales of both axes can be changed to display a huge variety of signals.

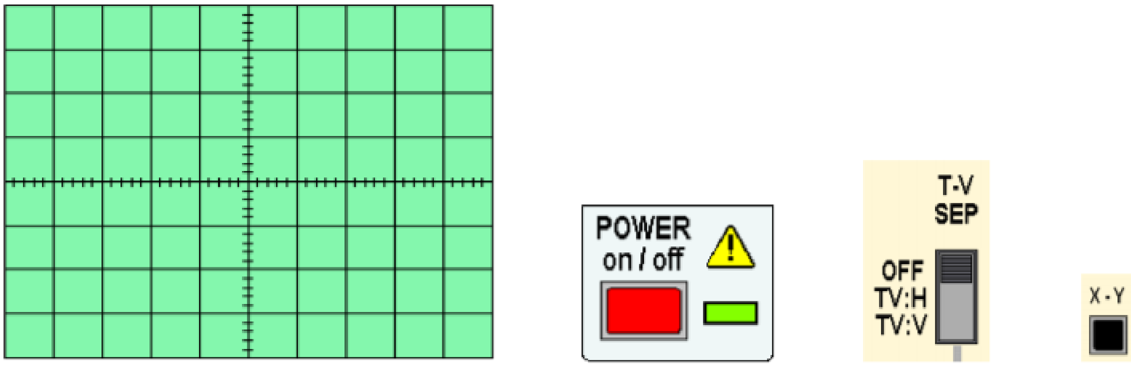


Figure 2.9: Front View of Oscilloscope

Power On/Off switch Pushed in to switch the oscilloscope on. the LED illuminates.

X-Y Control: Normally in the OUT position.

When the X-Y button is pressed IN, the oscilloscope does not display a *V*/*t* graph. Instead, the vertical axis is controlled by the input signal to CH II. this allows the oscilloscope to be used to display a *V*/*V* voltage/voltage graph.

The X-Y control is used when you want to display component characteristic curves.

TV-Separation: Oscilloscopes are often used to investigate waveforms inside television systems. this control allows the display to be synchronized with the television system so that the signals from different points can be compared.

Time / Div: Allows the horizontal scale of the *V*/*t* graph to be changed.

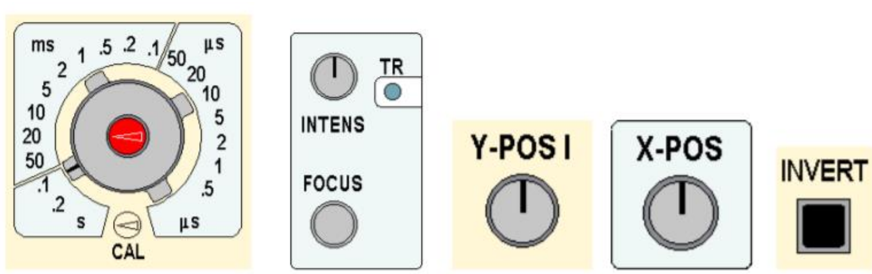


Figure 2.10: Time division, Intensity, focus, X-Y mode knobs

Intensity and Focus: Adjusting the INTENSITY control changes the brightness of the oscilloscope display. the FOCUS should be set to produce a bright clear trace.

If required, TR can be adjusted using a small screwdriver so that the oscilloscope trace is exactly horizontal when no signal is connected.

X-POS: Allows the whole *V*/*t* graph to be moved from side to side on the oscilloscope screen.

This is useful when you want to use the grid in front of the screen to make measurements, for example, to measure the period of a waveform.

Y-POS I and Y-POS II: These controls allow the corresponding trace to be moved up or down, changing the position representing 0 V on the oscilloscope screen.

To investigate an alternating signal, adjust Y-POS so that the 0 V level is close to the centre of the screen. For a pulse waveform, it is more useful to have 0 V close to the bottom of the screen. Y-POS I and Y-POS II allow the 0 V levels of the two traces to be adjusted independently.

Invert: When the INVERT button is pressed IN, the corresponding signal is turned upside down, or inverted, on the oscilloscope screen. this feature is sometimes useful when comparing signals.

CH I And CH II Inputs: Signals are connected to the BNC input sockets using BNC plugs.

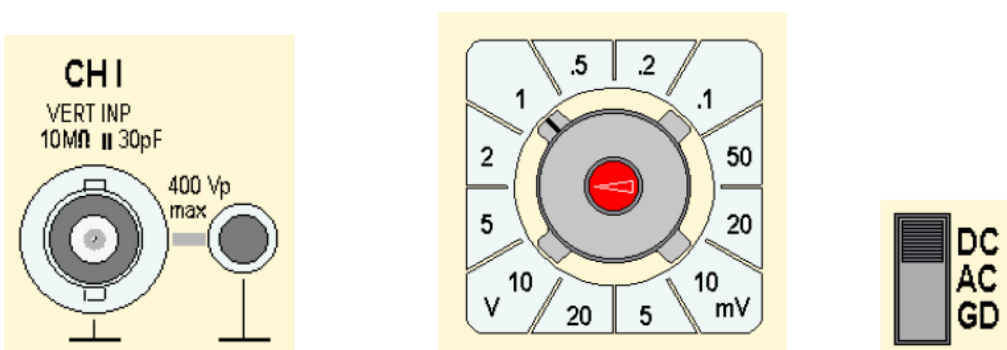


Figure 2.11: Voltage division, Channels, AC, DC and GND knobs

The smaller socket next to the BNC input socket provides an additional 0 V, GROUND or EARTH connection.

Volts / Div: Adjust the vertical scale of the *V*/*t* graph. the vertical scales for CH I and CH II can be adjusted independently.

DC/AC/GND Slide Switches: In the DC position, the signal input is connected directly to the Y-amplifier of the corresponding channel, CH I or CH II. In the AC position, a capacitor is connected into the signal pathway so that DC voltages are blocked and only changing AC signals are displayed.

In the GND position, the input of the Y-amplifier is connected to 0 V. this allows you to check the position of 0 V on the oscilloscope screen. the DC position of these switches is correct for most signals.

Trace Selection Switches: The settings of these switches control which traces appear on the oscilloscope screen.

<u>Experimental Procedure</u>:

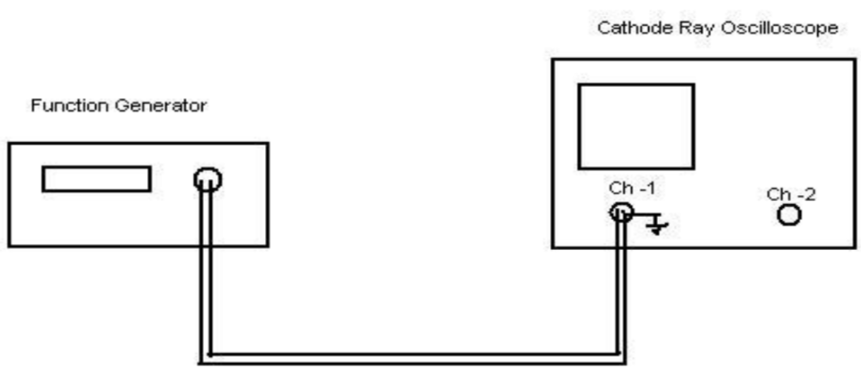
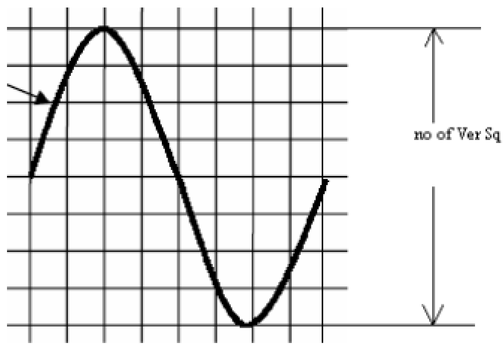


Figure 2.12: Set up for measurement of Voltage& Frequency

1. Turn on the Oscilloscope
2. Adjust the intensity and the focus of the trace.
3. Use the X & Y knobs to center the trace horizontally and vertically.
4. Connect the cable from Ch1 of the CRO to Function generator.
5. A signal will appear on the screen.

6. Make sure that the inner red knobs of the Volt/Div and the Time/Div are locked clockwise.
7. Set the frequency of the generator to 100 Hz.
8. Adjust the Volt/Div and the Time/Div knobs so that you get a suitable size signal
9. **For voltage measurement:** Count the number of vertical squares lying within the signal, then calculate the peak to peak value as:



$V_{p\text{-}p}$= (no. of vertical divisions or units noted) × ($\frac{Volts}{Divisions}$)

10. **For frequency measurement:** Count the number of horizontal squares lying within the one Duty Cycle, then calculate time value as:

Waveform is displayed on screen & one complete cycle is visible on screen. thus accuracy increases if a single cycle occupies as much as horizontal distance on screen.

T = No. of horizontal divisions occupied by one cycle × ($\frac{Time}{Division}$)

Frequency can be calculated as Frequency (f) = $\frac{1}{T}$

Observations:

(1) Measurement of Voltage:

S.No.	Waveform	No. of vertical divisions (A) (div)	Amplitude multiplier position (B) (volt/div)	Peak-to-Peak Voltage (V_{p-p}) A*B	Maximum amplitude (V_m=V_{p-p}/2)
1.	Sine				
2.	Square				
3.	Triangular				
4.					
5.					
6.					

(2) Measurement of Frequency:

S.No.	Waveform	Applied Frequency	Horizontal division X (div)	Time multiplier Y (ms/div)	Time period *T* (X*Y) (ms)	Observed Frequency (*F=1/T*) (Hz)	Error %
1.	Sine						
2.	Square						
3.	Triangular						
4.							
5.							
6.							

Result: Detailed study of CRO has been completed and the voltage and frequency values of the given function have been observed on CRO and calculated.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Knowledge of different functions of CRO.
2. Knowledge of different waveform patterns
3. Knowledge of measurement of amplitude and frequency for any unknown waveform.

Applications:

1. To examine waveforms.
2. In measurement of voltage and current.
3. In measurement of phase and frequency.

Precautions:

1. Check the power supply before turning on CRO.
2. Take the readings carefully.
3. Make calculations for voltage and current carefully.

EXPERIMENT NO: 03

Aim: Study of logic gates

Objectives:

i. Study of all gates and their pin description.
ii. Use of universal gate.

Apparatus Required: IC 7408 (AND Gate), IC 7432 (OR Gate), IC 7404 (NOT Gate), IC 7400 (NAND Gate), IC 7402 (NOR Gate), IC 7486(XOR Gate), Bread Board, Power Supply, Connecting Wires, LED.

Theory:

Objective: To verify truth table of all logic gates

Logic Gates: A logic gate is an elementary building block of a digital circuit. most logic gates have two inputs and one output. at any given moment, every terminal is in one of the two binary conditions: LOW (0) or HIGH (1), represented by different voltage levels. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

AND, OR and NOT are basic gates. XOR and XNOR are derived gates. NAND and NOR gate are universal gatesas any logic can be implemented using only NAND or only NOR.

a) **AND Gate** gives logic 1 as output only if all of its inputs are at logic 1.

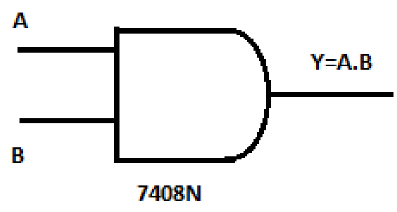


Figure 3.1: Symbol of AND gate

Truth Table of AND Gate:

A	B	A•B
0	0	0
0	1	0
1	0	0
1	1	1

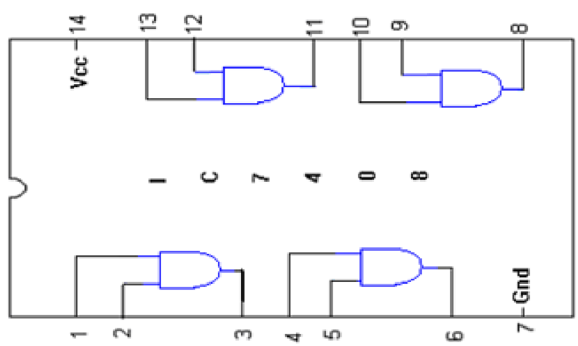


Figure 3.2: Pin Diagram of AND gate

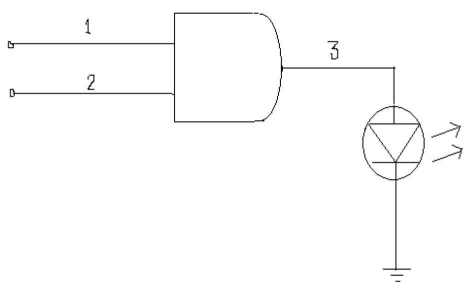


Figure 3.3: AND gate with LED as load

b) **OR Gate** gives logic 0 as output only if all of its inputs are at logic 0.

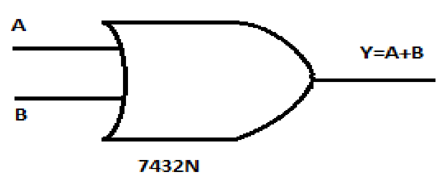


Figure 3.4: Symbol of OR gate

Truth Table of OR Gate:

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

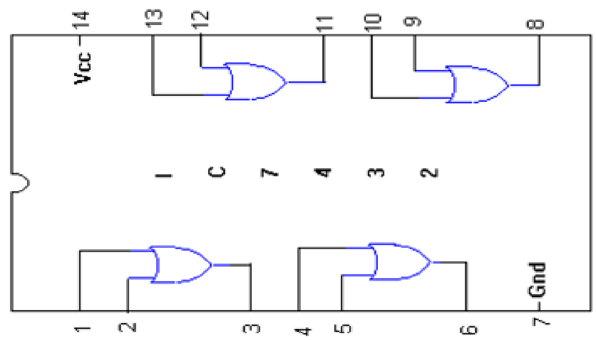


Figure 3.5: Pin Diagram of OR gate

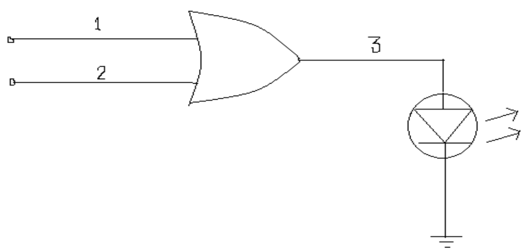


Figure 3.6: OR gate with LED as load

c) **NOT Gate** complements the input.

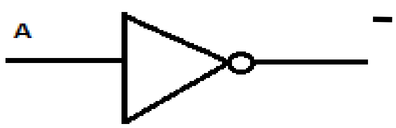


Figure 3.7: Symbol of NOT gate

Truth Table of NOT Gate:

A	Y
0	1
1	0

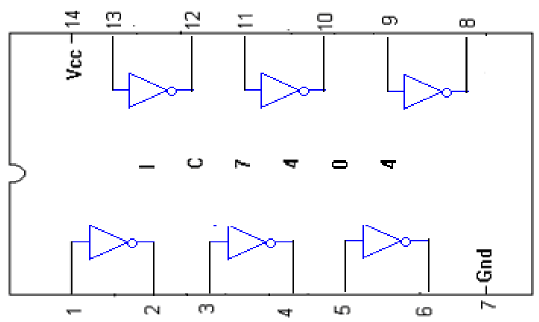


Figure 3.8: Pin Diagram of NOT gate

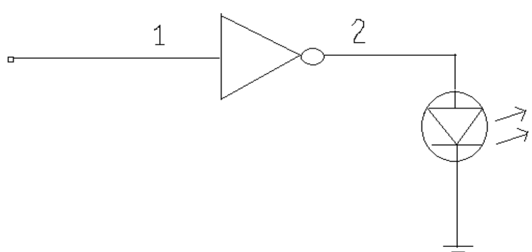


Figure 3.9: NOT gate with LED as load

d) XOR Gate gives logic 1 output if the two inputs are dissimilar.

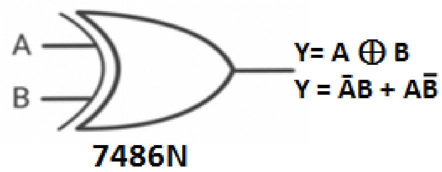


Figure 3.10: Symbol of XOR gate

Truth Table of XOR Gate:

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

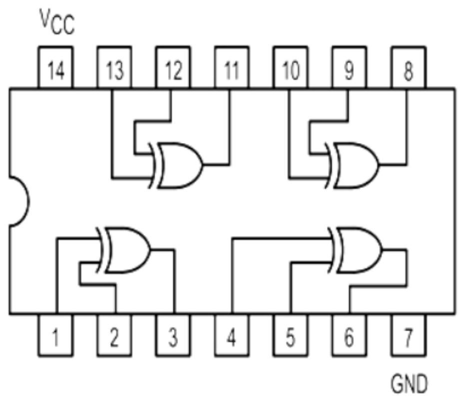


Figure 3.11: Pin Diagram of XOR gate (7486N)

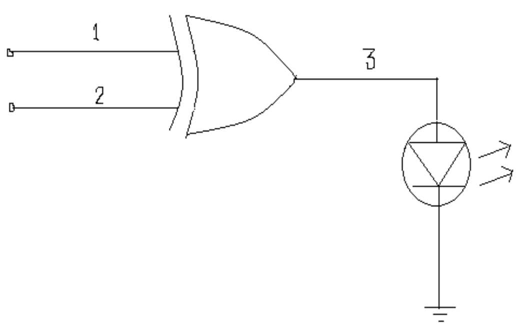


Figure 3.12: XOR gate with LED as load

e) **XNOR Gate** gives high output (logic 1) only if both inputs are same.

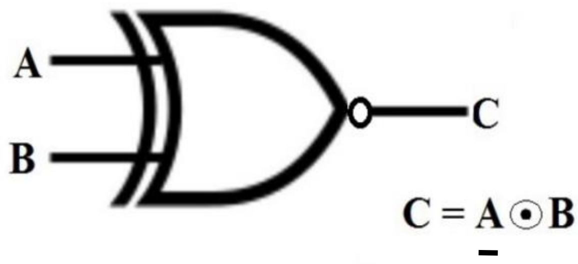


Figure 3.13: Symbol of XNORgate

Truth Table of XNOR Gate:

A	B	C
0	0	1
0	1	0
1	0	0
1	1	1

f) **NAND Gate** gives logic 0 as output only if all of its inputs are at logic 1.NAND gate is a contraction of AND-NOT.

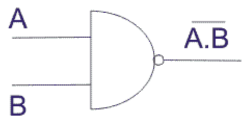


Figure 3.14: Symbol of NAND gate

Truth Table of NAND Gate:

A	B	Y
0	0	1

0	1	1
1	0	1
1	1	0

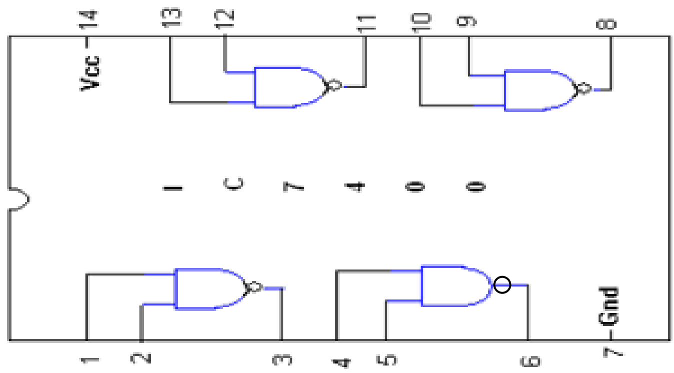


Figure 3.15: Pin Diagram of NAND gate

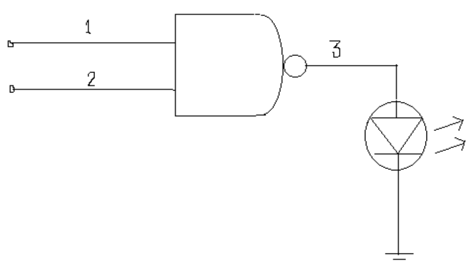


Figure 3.16: NAND gate with LED as load

g) **NOR Gate** gives logic 1 as output only if all of its inputs are at logic 0.NOR gate is a contraction of OR-NOT.

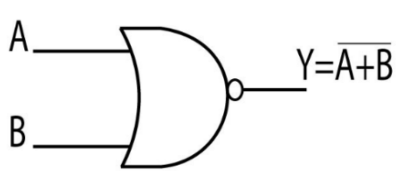


Figure 3.17: Symbol of NOR gate

Truth Table of NOR Gate:

A	B	Y
0	0	1

0	1	0
1	0	0
1	1	0

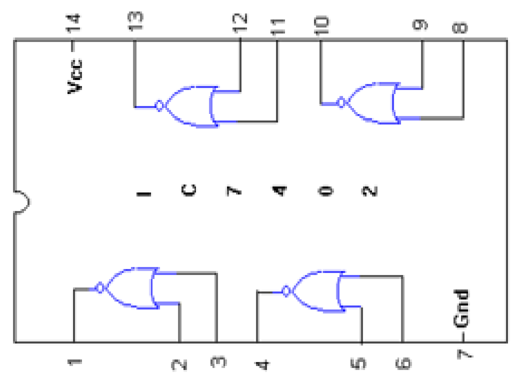


Figure 3.18: Pin Diagram of NOR gate

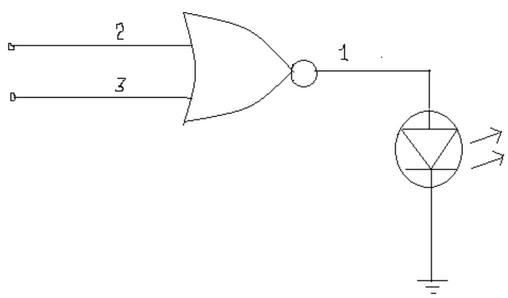


Figure 3.19: NOR gate with LED as load

<u>Experimental Procedure</u>:

1. Turn the power (Trainer Kit) off during circuit implementation.
2. Connect the +5V and ground (GND) leads of the power supply to the power and ground bus strips on your breadboard.
3. Point all the chips in the same direction with pin 1 at the upper-left corner on breadboard. (Pin 1 is often identified by a dot or a notch next to it on the chip package).

4. Select a connection and place a piece of hook-up wire between corresponding pins of the chips on breadboard. It is better to make the short connections before the longer ones. Mark each connection of schematic in steps, so as not to try to make the same connection again at a larger stage.
5. If an error is made and not spotted before you turn the power on, turn the power off immediately before reconstructing the circuit.
6. Verify the truth table of given circuit.

Result: The truth tables of all gates AND, OR, NOT, XOR, XNOR, NAND and NOR gates have been verified. all gates have been realized by universal gates (NAND and NOR).

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Depth knowledge of basic gates ICs.
2. Learning the pin description of ICs.

Applications:

1. NOT gates are used in oscillators to generate clock signals.
2. AND gate is used in the measurement of frequency of a pulsed waveform.
3. EX-OR gates are used in parity generation, checking units and comparators.

Precautions:

1. Turn the power off before making any connection.
2. Make connections carefully.

EXPERIMENT NO: 04

Aim: To design and verify the truth table for logic gates using NOR gate.

Objectives:

i. Use of universal gate.
ii. Realization of various gates using NOR gate

Apparatus Required: IC 7402 (NOR Gate), Bread Board, Power Supply, Connecting Wires, LED.

Theory:

Logic Gates: A logic gate is an elementary building block of a digital circuit. most logic gates have two inputs and one output. at any given moment, every terminal is in one of the two binary conditions: LOW (0) or HIGH (1), represented by different voltage levels. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

AND, OR and NOT are basic gates. XOR and XNOR are derived gates. NAND and NOR gate are universal gatesas any logic can be implemented using only NAND or only NOR.

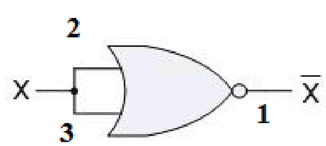


Figure 4.1: NOT Gate using NOR Gate

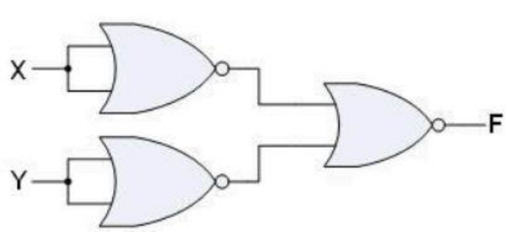


Figure 4.2: AND Gate using NOR Gate

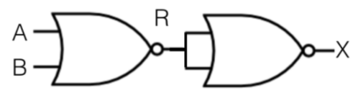


Figure 4.3: OR Gate using NOR Gate

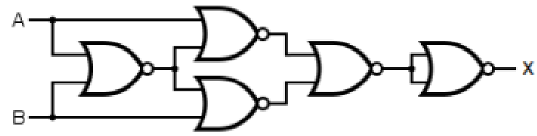


Figure 4.4: XOR Gate using NOR Gate

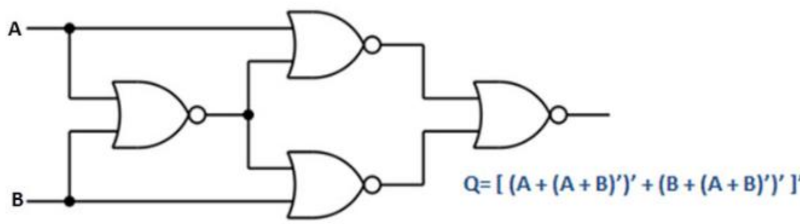


Figure 4.5: XNOR Gate using NOR Gate

Experimental Procedure:

7. Turn the power (Trainer Kit) off during circuit implementation.
8. Connect the +5V and ground (GND) leads of the power supply to the power and ground bus strips on your breadboard.
9. Point all the chips in the same direction with pin 1 at the upper-left corner on breadboard. (Pin 1 is often identified by a dot or a notch next to it on the chip package).
10. Select a connection and place a piece of hook-up wire between corresponding pins of the chips on breadboard. It is better to make the short connections before the longer ones. Mark each connection of schematic in steps, so as not to try to make the same connection again at a larger stage.
11. If an error is made and not spotted before you turn the power on, turn the power off immediately before reconstructing the circuit.
12. Verify the truth table of given circuit.

Result: The truth tables of all gates AND, OR, NOT, XOR, XNOR, NAND and NOR gates have been verified. all gates have been realized by universal gates (NAND and NOR).

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

3. Depth knowledge of basic gates ICs.
4. Learning the pin description of ICs.

Applications:

4. NOT gates are used in oscillators to generate clock signals.
5. AND gate is used in the measurement of frequency of a pulsed waveform.
6. EX-OR gates are used in parity generation, checking units and comparators.

Precautions:

3. Turn the power off before making any connection.
4. Make connections carefully.

EXPERIMENT NO: 05

Aim: To design and verify the truth table for logic gates using NAND gate.

Objectives:

iii. Use of universal gate.

iv. Realization of various gates using NAND gate

Apparatus Required: IC 7400 (NAND Gate), Bread Board, Power Supply, Connecting Wires, LED.

Theory:

Logic Gates: A logic gate is an elementary building block of a digital circuit. most logic gates have two inputs and one output. at any given moment, every terminal is in one of the two binary conditions: LOW (0) or HIGH (1), represented by different voltage levels. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

AND, OR and NOT are basic gates. XOR and XNOR are derived gates. NAND and NOR gate are universal gatesas any logic can be implemented using only NAND or only NOR.

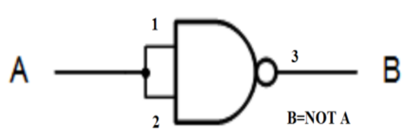


Figure 5.1: NOT Gate using NAND Gate

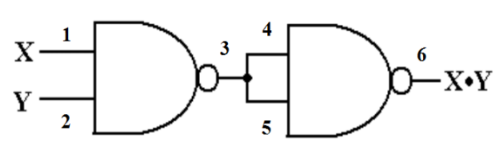


Figure 5.2: AND Gate using NAND Gate

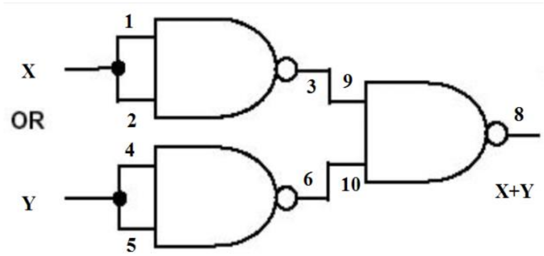


Figure 5.3: OR Gate using NAND Gate

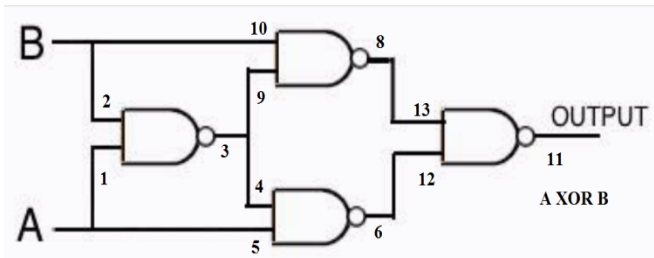


Figure 5.3: XOR Gate using NAND Gate

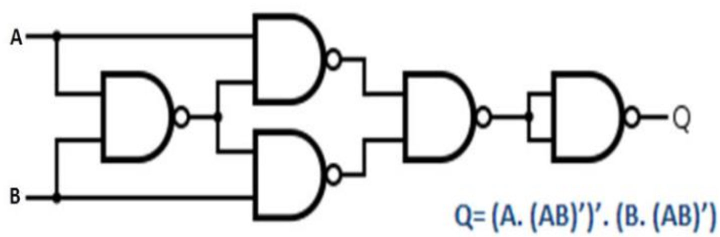


FIGURE 5.4: XNOR GATE USING NAND GATE

<u>Experimental Procedure</u>:

13. Turn the power (Trainer Kit) off during circuit implementation.
14. Connect the +5V and ground (GND) leads of the power supply to the power and ground bus strips on your breadboard.
15. Point all the chips in the same direction with pin 1 at the upper-left corner on breadboard. (Pin 1 is often identified by a dot or a notch next to it on the chip package).

16. Select a connection and place a piece of hook-up wire between corresponding pins of the chips on breadboard. It is better to make the short connections before the longer ones. Mark each connection of schematic in steps, so as not to try to make the same connection again at a larger stage.
17. If an error is made and not spotted before you turn the power on, turn the power off immediately before reconstructing the circuit.
18. Verify the truth table of given circuit.

Result: The truth tables of all gates AND, OR, NOT, XOR, XNOR, NAND and NOR gates have been verified. all gates have been realized by universal gates (NAND and NOR).

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

5. Depth knowledge of basic gates ICs.
6. Learning the pin description of ICs.

Applications:

7. NOT gates are used in oscillators to generate clock signals.
8. AND gate is used in the measurement of frequency of a pulsed waveform.
9. EX-OR gates are used in parity generation, checking units and comparators.

Precautions:

5. Turn the power off before making any connection.
6. Make connections carefully.

EXPERIMENT NO: 06

Aim: Study of V-I characteristics of PN junction diode and determine the static and dynamic resistance from the characteristic curve.

Objective:

i. Study of PN junction diode.
ii. Understanding the working of PN junction diode in forward and reverse bias.
iii. Observe V-I characteristics of PN junction diode.
iv. Determine the static and dynamic resistance from the V-I characteristic curve.

Apparatus Required: P-N diode IN4007, regulated power supply, resistor 1kΩ, ammeter (0-20mA), voltmeter (0-20V), breadboard, connecting wires.

Theory: A diode is a nonlinear device. donor impurities (pentavalent) are introduced into one-side and acceptor impurities into the other side of a single crystal of an intrinsic semiconductor to form a p-n diode shown in Fig. 6.1.

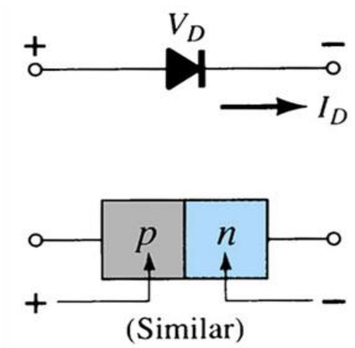


Figure 6.1: Symbol for PN Diode

A p-n junction diode conducts only in one direction. the V-I characteristics of the diode is a curve between voltage across the diode and current through the diode. when external voltage is zero, circuit is open and the potential barrier does not allow the current to flow. therefore, the circuit current is zero.

When p-type (Anode) is connected to +ve terminal and n-type (cathode) is connected to –ve terminal of the supply voltage, diode is **forward biased**. the potential barrier is reduced when diode is in the forward biased condition. at some forward voltage, the potential barrier altogether eliminated and current starts flowing through the diode and also in the circuit. the diode is said to be in ON state. the current increases with increasing forward voltage.

When n-type (cathode) is connected to +ve terminal and p-type (Anode) is connected –ve terminal of the supply voltage, diode is **reverse biased.** Potential barrier across the junction increases, therefore, the junction resistance becomes very high and a very small current (reverse saturation current) flows in the circuit. the diode is said to be in OFF state. the reverse bias current is due to minority charge carriers.

The volt-ampere characteristics of a diode explained by the following equations

$$I=I_O\,(e^{V_D/\eta V_T}-1)$$

Where I = current flowing in the diode, I_0= reverse saturation current V_D = Voltage applied to the diode

V_T= volt- equivalent of temperature = $k\,T/q$ = $T/$ 11,600 = 26mV (@ room temp) and

η= 1(for Ge) and 2 (for Si)

It is observed that **Ge** diodes has smaller cut-in-voltage (0.3V) when compared to **Si** diode(0.7V). The reverse saturation current in **Ge** diode is larger in magnitude when compared to silicon diode.

Static and Dynamic Resistance:

At a given operating point, the static and dynamic resistance ofa diode can be determined from its characteristics as shown in Fig. 6.2.

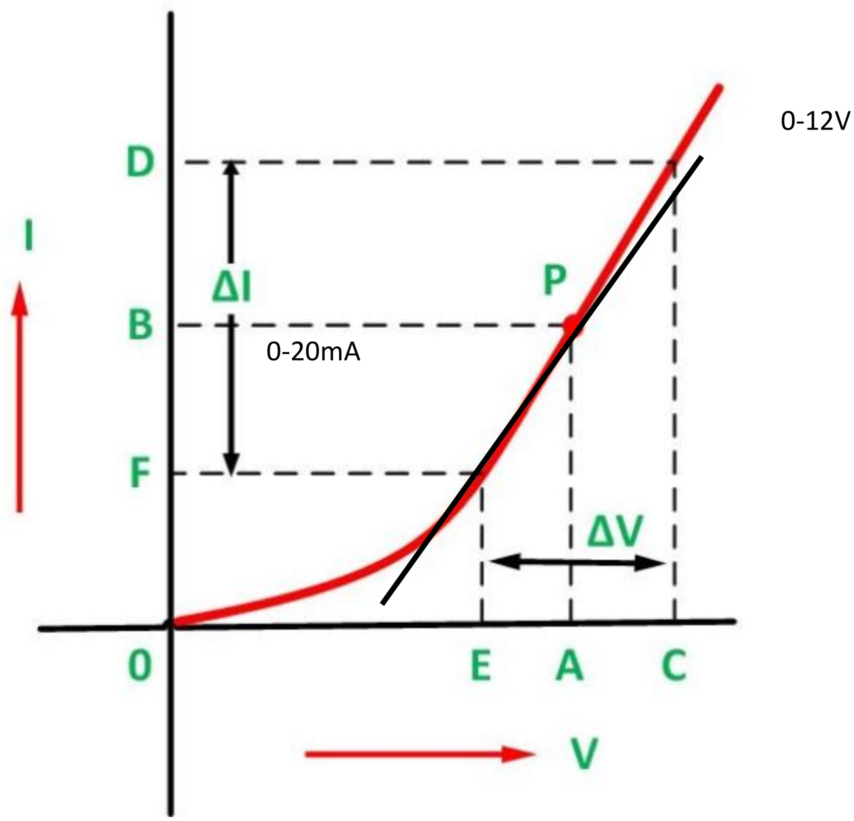


Figure 6.2: Static & Dynamic resistance determination

using V-I Characteristics of PN junction Diode

The *static or dc resistance*, R_D, of the diode at the operating point P (the point where the load line intersects the diode characteristics), is ratio of the corresponding levels of V_D and I_D. the dc resistance levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section of the characteristics.

$$R_D = V_D/I_D$$

The diode circuits generally operate with varying inputs, which will shift the instantaneous operating point, resulting in a specific change in current and voltage.

Dynamic or ac Resistance, r_d, is defined as the ratio of change in voltage to change in current around the dc operating point.

$$r_d = \Delta V_D / \Delta I_D$$

Theoretically the dynamic resistance of a diode is determined using the following equation:

Dynamic Resistance: $r_d = \eta V_T / I$

Schematic Diagram:

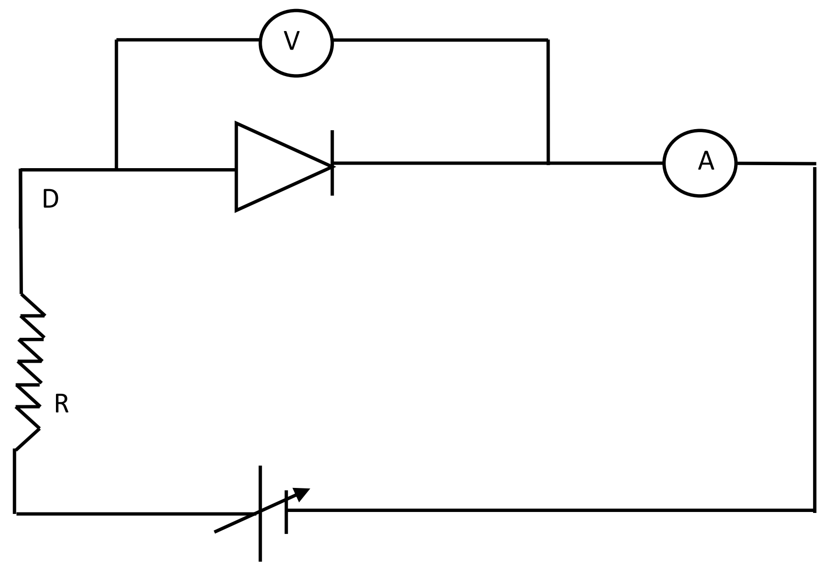


Figure 6.3: Forward Biasing of PN Junction Diode

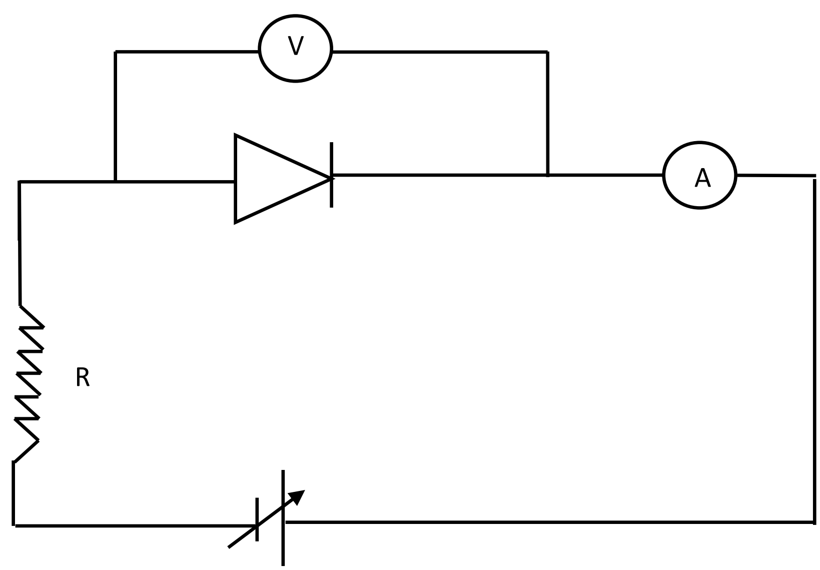


Figure 6.4: Reverse Biasing of PN Junction Diode

<u>Experimental Procedure</u>:

Forward Bias Condition:

1. Connect the components as shown in the Fig.6.3.

2. Vary the supply voltage such that the voltage across the Silicon diode varies from 0 to 0.6 V in steps of 0.1 V and in steps of 0.02 V from 0.6 to 0.76 V. In each step record the current flowing through the diode as I_F.

3. Repeat the above steps for Germanium diode with the exception that the voltage across the diode should be varied in steps of 0.01V from 0.1 to 0.3V in step-2.

4. Plot a graph between the voltage across the diode and the current flowing through the diode in forward bias for Silicon and Germanium diodes on separate graph sheets.

Reverse Bias Condition:

1. Connect the diode in the reverse bias as shown in the Fig.6.4.

2. Vary the supply voltage such that the voltage across the diode varies from 0 to 10V in steps of 1 V. Record the current flowing through the diode in each step as I_R.

3. Repeat the above steps for Germanium diode too and record the current in each step.

4. Plot a graph between the voltage across the diode and the current flowing through the diode in reverse bias for Silicon and Germanium diodes on separate graph sheets.

Calculate the static and dynamic resistance of each diode in forward and reverse bias using the following formulae.

Static resistance, $R_D = V_F/I_F$

Dynamic resistance, $r_d = \Delta V_F/\Delta I_F$

Observations:

Obs. No.	**Forward Biasing**			**Reverse Biasing**		
	Voltage Applied (V)	**Voltage V_F (V)**	**Current I_F (mA)**	**Voltage Applied (V)**	**Voltage V_R (V)**	**Current I_R (µA)**
1.						
2.						
3.						
4.						
5.						

Graph:

V-I Characteristics of diode: (To be plotted using readings) similar to Fig. 6.2.

Calculations:

Forward Bias

Static resistance at particular point: V_F / I_F =
Dynamic resistance: $\Delta V_F / \Delta I_F$ =

Reverse Bias

Static resistance at P: V_R / I_R=

Dynamic resistance: $\Delta V_R / \Delta I_R$ =

Result: The graph has been plotted between voltage and current, and corresponding V-I characteristic of p-n junction diode has been studied.

Threshold voltage for normal diode is ______V (What type of a diode it is,Si/Ge?)

Static resistance = ------, Dynamic resistance = ------ at operating point P.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Knowledge about proper connection of diode in forward and reverse bias in practical applications.
2. Understanding the concept of potential barrier and correspondingly knee voltage.
3. Knowledge about magnitude of current in forward and reverse bias in p-n junction diode.

Applications:

1. P-N junction diode is used in clipping circuits as wave shaping circuits in computers, radio, radars etc.
2. It is used as switches in digital logic designs.
3. It is used in detector and demodulator circuits.
4. It is used in clamping circuits in TV receivers as well as voltage multipliers.
5. It is used as rectifiers in DC power supply manufacturing.

Precautions:

1. Select proper multi-meter range during forward bias and reverse bias.
2. Connect diode with correct polarity for forward and reverse bias operation.
3. Make all connections tight.
4. Get the connections checked according to the circuit diagram before switching on the supply.

EXPERIMENT NO: 07

Aim: Study of V - I characteristics of Zener diode and determine its voltage regulation.

Objective:

i. Study of zener diode.
ii. Understanding the operation and working of zener diode in forward and reverse bias mode.
iii. Draw V-I characteristics of zener diode in forward and reverse bias mode.
iv. Study of voltage regulation property of zener diode and calculate percentage of regulation.

Apparatus Required: Zener diode, regulated power supply (0-30V), voltmeter (0-20V), ammeter (0-20mA),resistor (1kΩ),current limiting resistor, load resistors, breadboard and connecting wires.

Theory:

A Zener diode is heavily doped p-n junction diode, specially made to operate in the reverse break down region. the symbol of a Zener diode is shown in Fig. 7.1.if both p-side and n-side of the diode are heavily doped, depletion region at the junction reduces. this leads to the development of strong electric field and application of a small voltage at the junction may rupture covalent bond which generates large number of charge carriers. this sudden increase in the number of charge carriers results in Zener breakdown. once the diode starts conducting, it maintains almost constant voltage across the terminals even though the current through it increases. thus, it is used in voltage regulators. a Zener diode when forward biased behaves like an ordinary p-n junction diode.

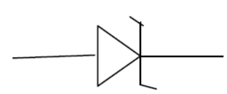


Figure 7.1: Symbol of Zener Diode

Voltage Regulation in Zener Diode:

Zener diodes are generally used in the reverse bias mode. Zener diode has a region of almost a constant voltage in it servers bias characteristics, regardless of the current flowing through the diode. this voltage across the diode (Zener voltage, V_z) remains nearly constant even with large changes in current through the diode caused by variations in the supply voltage or load.

This effect is used to regulate or stabilize a voltage source against supply or load variations. The Zener diode maintains a constant output voltage until the diode current falls below the minimum Zener current (I_z) value in the reverse breakdown region. It means the supply voltage (V_S) must be greater than V_z for a successful breakdown operation.

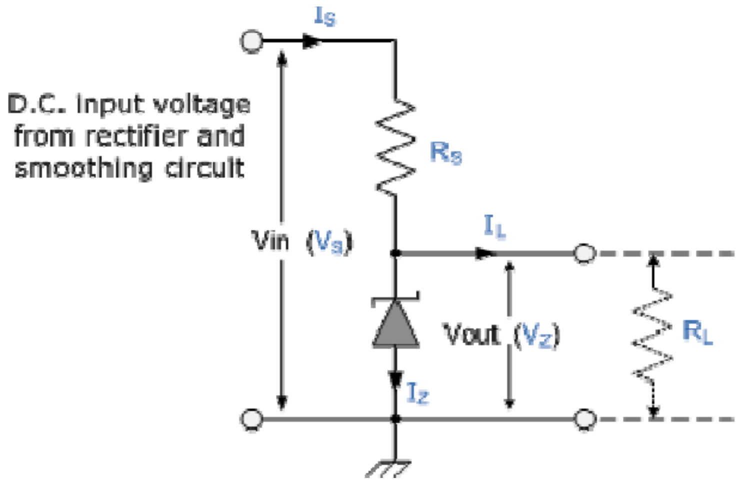


Figure 7.2: Voltage Regulation in Zener Diode

When load resistance (R_L) is not connected to the circuit, the load current (I_L) will be equal to zero. therefore, Zener diode dissipates its maximum power .hence, a suitable current limiting resistor (R_S) is always used in series to limit the Zener current.

The d.c. output voltage from the half or full-wave rectifiers contains ripples superimposed on the d.c. voltage and that the average output voltage changes with load. as shown in the circuit diagram Fig. 7.2, a more stable reference voltage can be produced by connecting a simple Zener regulator circuit across the output of the rectifier. the breakdown condition of the Zener can be validated by calculating the Thevenin voltage, V_{TH}, facing the diode is given as:

$$V_{TH} = \frac{R_L}{R_S + R_L} V_S$$

This is the voltage that exists when the Zener is disconnected from the circuit. thus, V_{TH} has to be greater than the Zener voltage to facilitate breakdown. Now, under this breakdown condition, the current through the current limiting resistor (I_S) is given by

$$I_S = \frac{V_S - V_Z}{R_S}$$

The output voltage across the load resistor (V_L) is ideally equal to the Zener voltage and the load current (I_L) is calculated using Ohm's law:

$$V_L = V_Z \text{ and } I_L = \frac{V_L}{R_L}$$

Thus the Zener current (I_Z) is $I_Z = I_S - I_L$

The parameters used for voltage regulation are:

Load Regulation: It indicates how much the load voltage varies when the load current changes. Quantitatively, it is defined as:

$$Load\ Regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\ \%\ ;$$

Where V_{FL}=load voltage with no load current (I_L = 0) and V_{FL} = load voltage with full load current. The smaller the regulation, the better is the power supply.

Line Regulation: It indicates how much the load voltage varies when the input line voltage changes. Quantitatively, it is defined as:

$$Line\ Regulation = \frac{V_{HL} - V_{LL}}{V_{LL}} \times 100\ \%;$$

Where V_{HL}=load voltage with high input line voltage and V_{LL} = load voltage with low input line voltage. as with load regulation, the smaller the regulation, the better is the power supply.

<u>Schematic Diagrams</u>:

(A) Forward Bias:

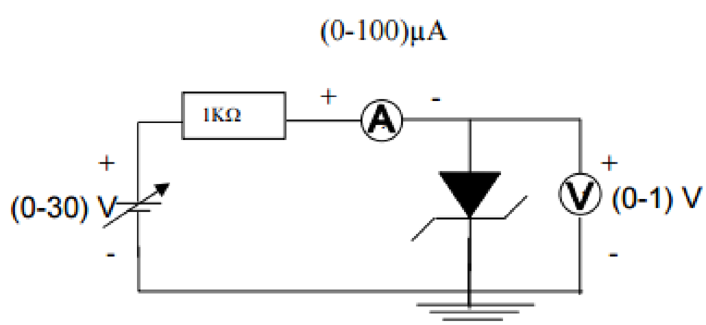


Figure 7.3: Zener Diode in Forward Bias

(B) Reverse Bias:

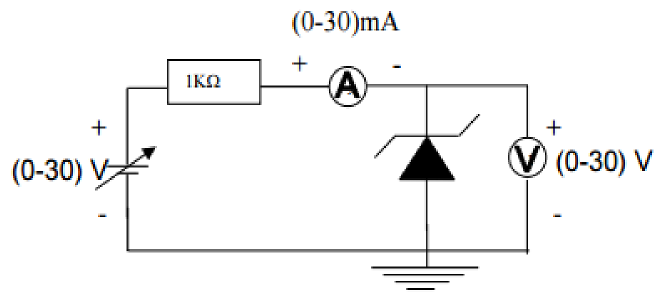


Figure 7.4: Zener Diode in Reverse Bias

(C) Zener Diode as Voltage Regulator:

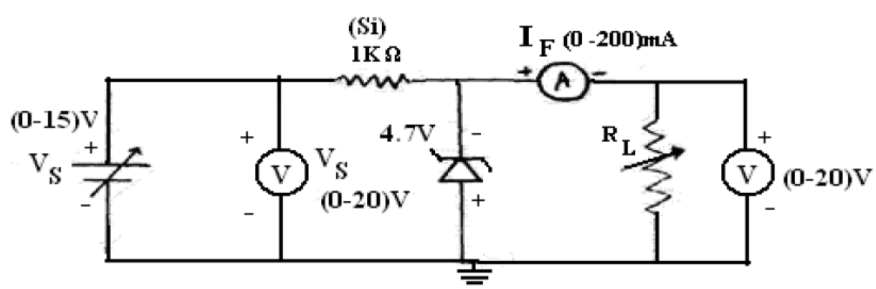


Figure 7.5: Zener Diode as Voltage Regulator

<u>Experimental Procedure</u>:

For V-I characteristics:

Forward Bias characteristics:

1. Assemble the circuit on the breadboard as shown in Fig. 7.3. connect to the 0-30V dc power supply.
2. Switch on the power supply. slowly increase the supply voltage in steps of 0.1V using the fine adjustment knob and note down the corresponding readings of diode current. when the

change in current is larger (which indicates that current has crossed the threshold point), increase the supply voltage in steps of 0.5 V and note down current.

3. Using multimeters in appropriate modes, measure voltage drop across the diode and the current in the circuit. switch off the supply after taking sufficient readings.
4. Plot the I~V characteristics and estimate the threshold voltage.

Reverse Bias characteristics:

1. Assemble the circuit on breadboard with the Zener diode, as shown in Fig. 7.4. keep in mind that initially the magnitude of current flowing in the circuit will be very small.
2. Switch on the power supply. Increase the supply voltage in steps of 0.5 V and note down the corresponding readings of diode current. when the change in current is larger (which indicates that current has crossed the threshold point), increase the supply voltage in steps of 0.1 V and note down current.
3. Plot the I~V characteristics on the same graph sheet and estimate the threshold and break-down voltages.

For voltage regulation:

1. The unregulated power supply from the source will be supplied across the terminals of Zener diode.
2. Complete the rest part of the circuit as shown in the circuit diagram. note down all the values of the components being used including the Zener breakdown voltage.
3. Keeping input voltage suitably fixed, use different values of R_L and measure both the output d.c. voltage and current using multimeter (in d.c. mode). measure input unregulated d.c. voltage. calculate V_{TH} before each measurement and ensure that the Zener is operating in breakdown region.
4. Similarly, keeping R_L fixed, vary the input voltage and measure again the output d.c voltage, current and input unregulated d.c. voltage. Calculate V_{TH} before each measurement.
5. Tabulate all your data and calculate percentage regulation in each case.

Observations:

Table (i) For V-I Characteristics of Zener Diode

S.No.	Forward Biasing			Reverse Biasing		
	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (mA)	Voltage Applied (V)	Voltage, V_D (V)	Current, I_D (µA)
1.						
2.						
3.						
4.						
5.						
6.						

Specifications of zener diode: breakdown voltage = ________ V

R_S= _________kΩ

Graph:

V-I Characteristic of Zener Diode:

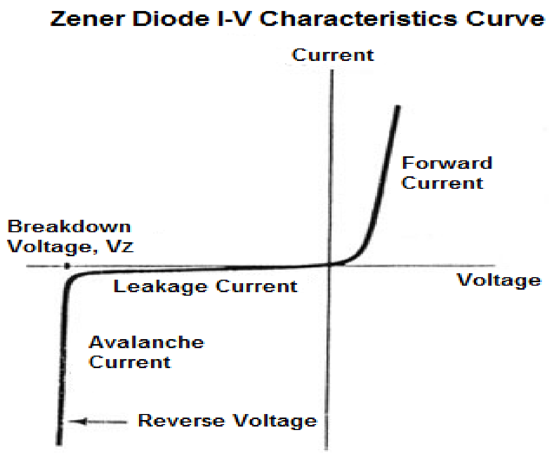


Figure 7.6: V-I characteristics of Zener Diode in Forward and Reverse Bias

For voltage regulation:

Plot graphs R_L (X-axis) vs. V_L (Y-axis) and V_i(X-axis) vs. V_L(Y-axis) using data of tables (ii) and (iii), respectively. Also plot I_L (X-axis) vs. V_L (Y-axis) for each set of observations.

Result: V-I characteristic of the zener diode and its voltage regulation operation was studied.

Threshold voltage for zener diode = -------- V

Zener break-down voltage = ------- V

% Regulation (load regulation) =_____ %

% Regulation (line regulation) =_____ %

Result Analysis & Discussion: This section should be written individually by each student.

Inferences &Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Understanding the concept of zener diode as a voltage regulator.
2. Knowledge of order of magnitude of current in forward and reverse bias in zener diode.
3. Knowledge of breakdown voltage in zener diode.

Applications:

1. Zener diodes are used in voltage stabilizers (or) shunt regulators.
2. Zener diodes are used in over voltage protection circuits.
3. Zener diodes are used in clipping and clamping circuits especially peak clippers.
4. They are used in switching applications.

Precautions:

1. Select proper multi-meter range during forward bias and reverse bias.
2. Connect diode with correct polarity for forward and reverse bias operation.
3. Make all connections tight.
4. Get the connections checked according to the circuit diagram before switching on the supply.
5. Increase the voltage slowly with the help of pot meter provided.

EXPERIMENT NO: 08

Aim: Study of a half wave rectifier circuit with and without capacitor filter.

Objective:

i. Study the working of half wave rectifier.
ii. Study the operation of half wave rectifier with and without capacitor filter.
iii. Analyze the effect of capacitor filter.

Apparatus Required: Diode, multimeter, power supply, transformer, CRO, resistor, capacitor, connecting wires and breadboard.

Theory:

The process of converting an alternating current into direct current is known as rectification. The unidirectional conduction property of semiconductor diodes (junction diodes) is used for rectification. rectifiers are of two types: (a) half wave rectifier and (b) full wave rectifier.

Half Wave Rectifier:

In a half-wave rectifier circuit (Fig. 8.1), during the positive half-cycle of the input, the diode is forward biased and conducts. Current flows through the load R and voltage (V_{OUT})is developed across it.

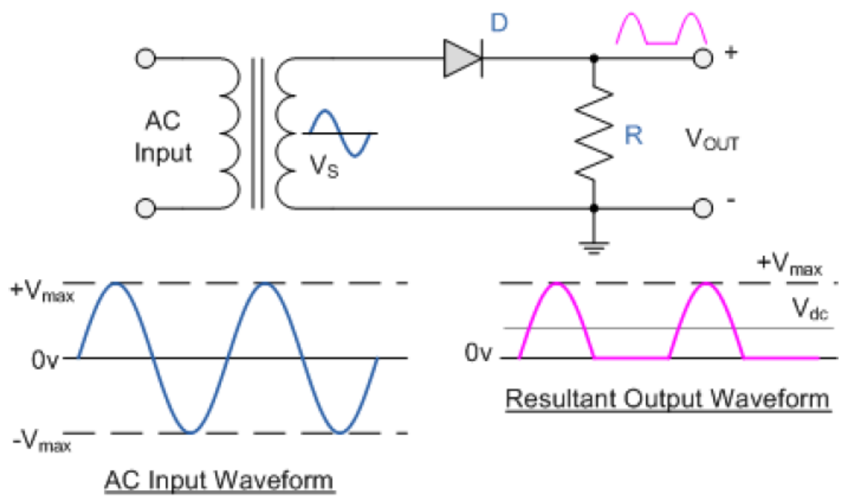


Figure 8.1: Half-Wave Rectifier Circuit without Filter

During the negative half-cycle, diode D is in reverse bias and does not conduct. therefore, in the negative half cycle of the supply, no current flows in the load resistor R as no voltage appears across it. Thus, the dc voltage across the load is sinusoidal for the first half cycle only and a pure a.c. input signal is converted into a unidirectional puls sating output signal.

For practical circuits, transformer coupling is usually provided for two reasons:

1. The voltage can be stepped-up or stepped-down, as needed.

2. The ac source is electrically isolated from the rectifier. thus preventing shock hazards in the secondary circuit.

Since the diode conducts only in one half-cycle (0-π), it can be verified that the d.c. component in the output is V_{max}/π, where V_{max} is the peak value of the voltage. thus,

$$\text{Average (dc) load voltage } (\boldsymbol{V_{dc}}) = \boldsymbol{V_{max}/\pi = 0.318\, V_{max}}$$

The current flowing through the resistor, $I_{dc} = V_{dc}/R$and power consumed by the load, $P=I_{dc}^2R$.

- **Ripple factor:**

  As the voltage across the load resistor is present during the positive half cycle only, the resultant voltage is "ON" and "OFF" during every cycle resulting in a low average dc value. this variation on the rectified waveform is called "**Ripple**" and is an undesirable feature. ripple factor is defined as the ratio of the effective value of AC components to the average DC value. It is basically a measure of purity of the d.c. output of a rectifier and is defined as

$$\Upsilon = \left(\frac{V_{ac}}{V_{dc}}\right)_{output} = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}} = \sqrt{\frac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{\left(\frac{0.5}{0.318}\right)^2 - 1} = 1.21$$

  In case of a half-wave rectifier $V_{rms} = V_{max}/2 = 0.5V_{max}$

- **Rectification Efficiency:**

  Rectification efficiency ($\boldsymbol{\eta}$) is a measure of the percentage of total a.c. power input converted to useful d.c. power output.

$$\eta = \textit{d.c. power delivered tooled / a.c. power at input}$$

$$\eta = V_{dc} I_{dc} / V_{ac} I_{ac}$$

$$\eta = \frac{I_{dc}^2 R}{I_{ac}^2 (r_d + R)} = \frac{(0.318 V_{max})^2}{(0.5 V_{max})^2 \left(1 + \frac{r_d}{R}\right)} = \frac{0.405}{\left(1 + \frac{r_d}{R}\right)}$$

Here r_d is the forward resistance of diode. under the assumption of no diode loss r_d is very small, thus the rectification efficiency in case of a half-wave rectifier is approximately 40.5%.

- **Peak- Inverse – Voltage (*PIV*):**

It is the maximum voltage that has to be with stood by a diode when it is reverse biased

$PIV_{HWR} = V_{max}$

Filters:

The output of a rectifier gives a pulsating d.c. signal (Fig.8.1) because of presence of some a.c. components whose frequency is equal to that of the a.c. supply frequency. when rectifying an alternating voltage we wish to produce a "steady" direct voltage free from any voltage variations or ripple. filter circuits are used to smoothen the output.

Various filter circuits are available such as shunt capacitor, series inductor, choke input LC filter and π-filter etc. here we will use a simple **shunt capacitor** filter circuit (Fig. 8.2). since capacitors open to d.c. and offers low impedance path to a.c. current, putting a capacitor across the output will make the d.c. component to pass through the load resulting in small ripple voltage.

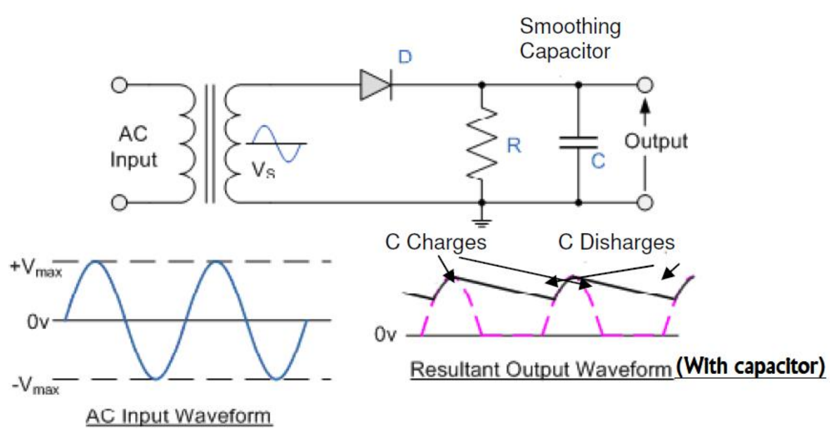


Figure 8.2: Half-Wave Rectifier Circuit with Capacitor Filter

When the rectifier output voltage is increasing, the capacitor charges to the peak voltage V_{max}. Just past the positive peak, the rectifier output voltage tries to fall. as the source voltage decreases below V_{max}, the capacitor will try to send the current back to diode making it reverse biased. thus the diode separates/disconnects the source from the load. hence the capacitor will discharge through the load until the source voltage becomes more than the capacitor voltage.

The diode again starts conducting and the capacitor is again charged to the peak value V_{max} and the process continues. although in the output waveform the discharging of capacitor is shown as a straight line for simplicity, the decay is actually the normal exponential decay of any capacitor discharging through a load resistor. the extent to which the capacitor voltage drops depends on the capacitance and the amount of current drawn by the load; these two factor effectively form the RC time constant for voltage decay. a proper combination of large capacitance and small load resistance can give out a steady output.

<u>Schematic Diagrams</u>:

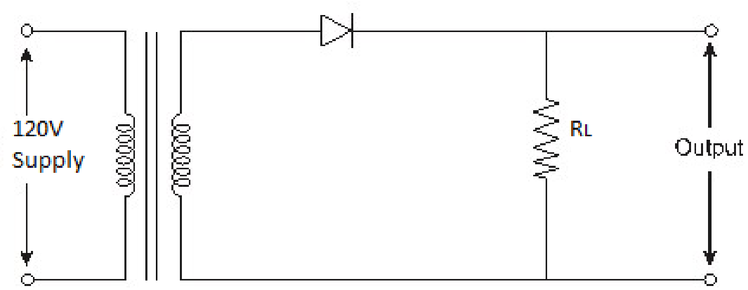


Figure 8.3: Half Wave Rectifier without capacitor

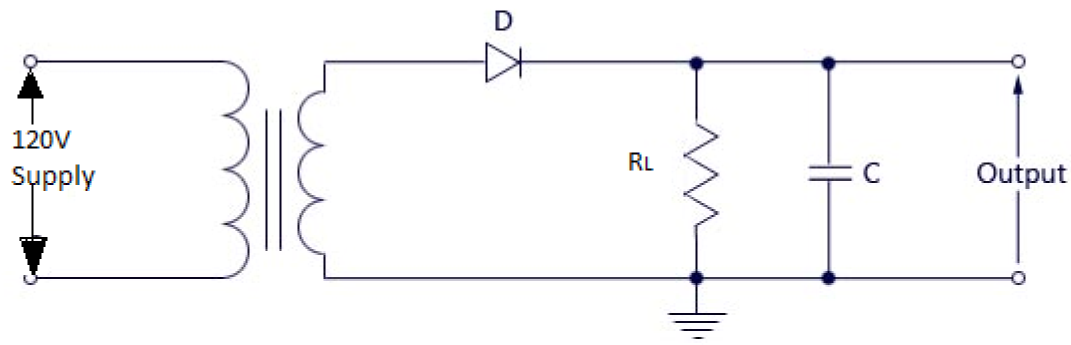


Figure 8.4: Half Wave Rectifier with capacitor

Experimental Procedure:

Without Capacitor Filter:

1. Test the transformer before giving supply.
2. Apply 230V, 50 Hz power supply to primary coil of the transformer.
3. Observe ac waveform of rated value without any distortion at secondary coil of the transformer.
4. Connect circuit to secondary terminals of the transformer.
5. Connect CRO across the load.
6. Keep CRO switch in “ground” mode, observe horizontal line and adjust it to x-axis.
7. Switch CRO into DC mode and observe waveform. Note down its amplitude, V_{max} and frequency from screen along with its multiplication factor.
8. Note and calculate V_{dc}.
9. Switch CRO into AC mode and observe waveform. Note amplitude and frequency from screen.
10. Calculate V_{ac}, ripple factor and efficiency.

With Capacitive Filter:

1. Connect an electrolytic capacitor (with –ve terminal connected to ground) across the output for each load resistor.
2. Measure the output a.c. and d.c. voltages once again and calculate the ripple factor.
3. Trace the input and output waveforms in oscilloscope and notice the change.
4. Repeat the above measurement for all values of capacitors and study the output.

Observations:

Input Voltage: V_{ac} = _________ Volt

Table 8.1: Half wave rectifier w/o filter

S. No	Load R (kΩ)	Input Current I_{ac} (mA)	Output Voltage			Ripple Factor 'γ'	Efficiency 'η' $(V_{dc}^2/R)/V_{ac}I_{ac}$ (%)
			V_{ac} (Volt)	V_{dc} (Volt)	V_{max}/π (Volt)		

Table 8.2: Half wave rectifier with filter (C = ____ μF) (Make separate tables for each capacitor)

S. No	Load R (kΩ)	Output Voltage		Ripple Factor γ
		V_{ac} (Volt)	V_{dc} (Volt)	

<u>Model Calculations</u>:

$V_{max} = V_{p\text{-}p}/2 =$

$V_{rms} = V_{max}/\sqrt{2} =$

$V_{dc} = V_{max}/\Pi =$

$V_{rms} = V_{max}/\sqrt{2} =$

$\gamma = \sqrt{[(V_{rms}/V_{dc})^2 - 1]} =$

<u>Trace</u>:

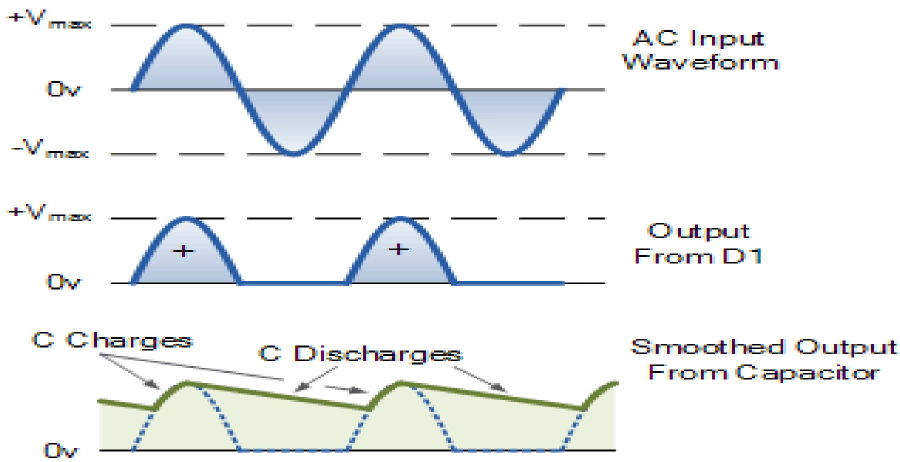


Figure 8.5: Output waveform of Half wave rectifier with and without capacitive filter

Result: Waveform for half wave rectifier with and without capacitive filter is traced. ripple factor and efficiency are to be found.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Depth knowledge of half wave rectifier.
2. Learning the operation of half wave rectifier with and without capacitive filter.
3. Learning the concept of Ripple factor in half wave rectifier.

Applications:

1. Rectifiers are used to derive DC power from an AC supply.
2. Rectifiers are used for detection of amplitude modulated radio signals.
3. Rectifiers supply polarized voltage for welding.

Precautions:

1. First measure the values with the help of multimeter then compare with oscilloscope.
2. Select proper AC or DC range of meters.
3. Use suitable wire (type and size).
4. Make all connections tight.
5. Do not connect leads to oscilloscope with supply switched ON.

EXPERIMENT NO: 09

Aim: Study of a full wave rectifier circuit with and without capacitor filter.

Objective:

i. Study the working of full wave rectifier.
ii. Study and analyze the centre-tapped and bridge full wave rectifier with and without capacitor filter.

Apparatus Required: Diode, multimeter, power supply, transformer, CRO, resistor, capacitor, connecting wires and breadboard.

Theory:

As a half wave rectifier circuit is unsuitable for applications which need a "steady and smooth" dc supply voltage. one method to improve on this is to use every half-cycle of the input voltage instead of using only one type of half-cycles (either +ve or –ve cycles). full wave rectifier circuit allows us to do this. in this circuit, unidirectional current flows in the output for both the cycles of input signal and rectifies it.

There are two types of full wave rectifier circuits:

1. **Full Wave Centre-tapped Rectifier**
2. **Full Wave Bridge Rectifier.**

Full Wave Rectifier:

In full wave rectification, current flows through the load in same direction for both half cycles of input ac voltage. this can be achieved with two diodes working alternatively for the +ve and –ve half cycles, current being always in the same direction through the load.

a) **Centre-tapped Full Wave Rectifier:**

The circuit consists of two diodes D1 and D2 as shown in Fig. 9.1. A centre-tapped secondary winding is used with two diodes connected so that each uses one half cycle of input ac voltage. in other words, diode D1 utilizes ac voltage appearing across the upper half of the secondary winding for rectification while diode D2 uses the lower half winding.

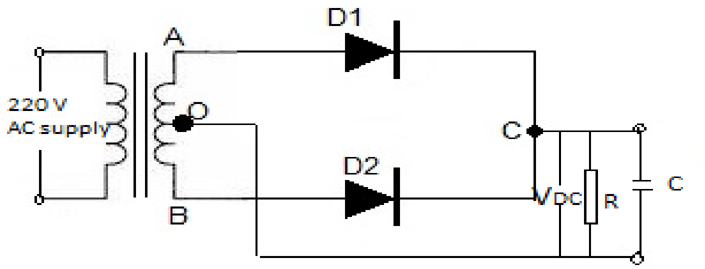


Figure 9.1: Centre-tapped Full Wave Rectifier

b) **Full Wave Bridge Rectifier:**

The need of a centre-tapped power transformer is eliminated in the bridge rectifier thereby reducing its size and cost. It consists of four diodes D1, D2, D3 and D4 connected to form a bridge as shown in Fig. 9.2. the ac supply to be rectified is applied to the diagonally opposite ends of the bridge through the transformer. between other two ends of the bridge, load resistance R_L is connected.

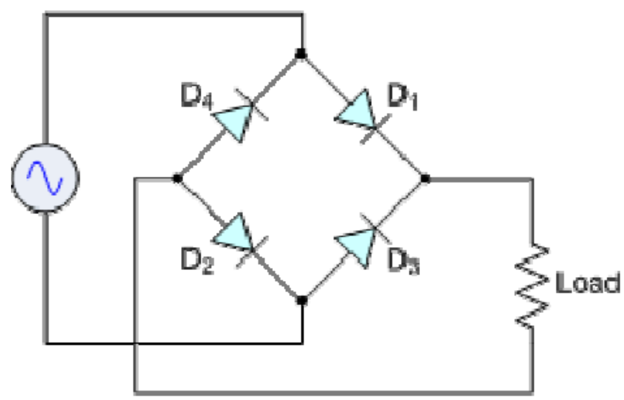


Figure 9.2: Full Wave Bridge Rectifier

During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodesD3 and D4 are reverse biased and the current flows through the load as shown in Fig. 9.3. during the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch off as they are now reverse biased. the current flowing through the load is in the same direction as before.

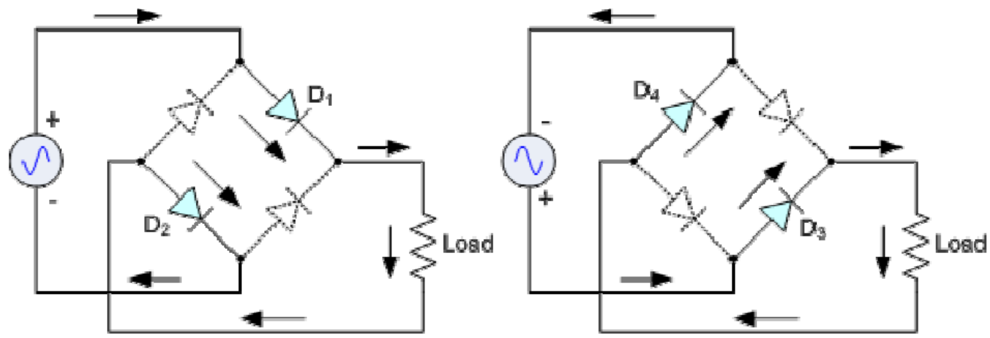


Figure 9.3: Working of Full Wave Bridge Rectifier

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional during both the half cycles. thus, the average dc output voltage across the load resistor is double that of a half-wave rectifier circuit, assuming no losses. thus,

Average (dc) load voltage ($\boldsymbol{V_{dc}}$)= $\mathbf{2V_{max}/\ \pi = 0.637V_{max}}$

where V_{max} is the peak value of the voltage.

The current flowing through the resistor, $I_{dc} = V_{dc}/R$and power consumed by the load, $P{=}I_{dc}{}^{2}R$.

- **Ripple factor:**

As mentioned in the previous lab the ripple factor is a measure of purity of the d.c. output of a rectifier and is defined as

$$\Upsilon = \left(\frac{V_{ac}}{V_{dc}}\right)_{output} = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}} = \sqrt{\frac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{\left(\frac{0.707}{0.637}\right)^2 - 1} = 0.48$$

In case of a full-wave rectifier V_{rms}= $V_{max}/\sqrt{2} = 0.707V_{max}$. the ripple frequency is now twice the supply frequency (e.g. 100Hz for a 50Hz supply).

- **Rectification Efficiency:**

Rectification efficiency ($\boldsymbol{\eta}$) is given by

η = d.c. power delivered tooled / a.c. power at input

$$\boldsymbol{\eta = V_{dc}\, I_{dc} / V_{ac}\, I_{ac}}$$

$$\eta = \frac{I_{dc}^2 R}{I_{ac}^2 (r_d + R)} = \frac{(0.637V_{max})^2}{(0.707V_{max})^2 \left(1 + \frac{r_d}{R}\right)} = \frac{0.811}{\left(1 + \frac{r_d}{R}\right)}$$

Here r_d is the forward resistance of diode. under the assumption of no diode loss r_d is very small, thus the rectification efficiency in case of a full-wave rectifier is approximately 81.1%, which is twice the value for a half-wave rectifier.

- **Peak- Inverse – Voltage (*PIV*):**

It is the maximum voltage that has to be with stood by a diode when it is reverse biased.

$PIV_{FWR(Centre\ tapped)} = 2V_{max}$

$PIV_{FWR(Bridge)} = 2V_{max}$

<u>Comparison of Half-wave and Full-wave rectifier:</u>

S. No.	Particulars	Type of Rectifier	
		Half-Wave	**Full-Wave**
1.	No. of diodes	1	2 (for centre tapped) 4 (for bridge)
2.	Maximum Rectification Efficiency	40.6%	81.1%
3.	V_{dc}(no load)	V_{max}/π	$2V_{max}/\pi$
4.	Ripple Factor	1.21	0.48
5.	Peak Inverse Voltage	V_{max}	$2V_{max}$(for centre tapped) V_{max}(for bridge)
6.	Output Frequency	f	2f
7.	Transformer Utilization Factor (TUF) = ($P_{output}(dc)/ P_{input}(ac)$)	0.287	0.693(for centre tapped) 0.812(for bridge)

Filters:

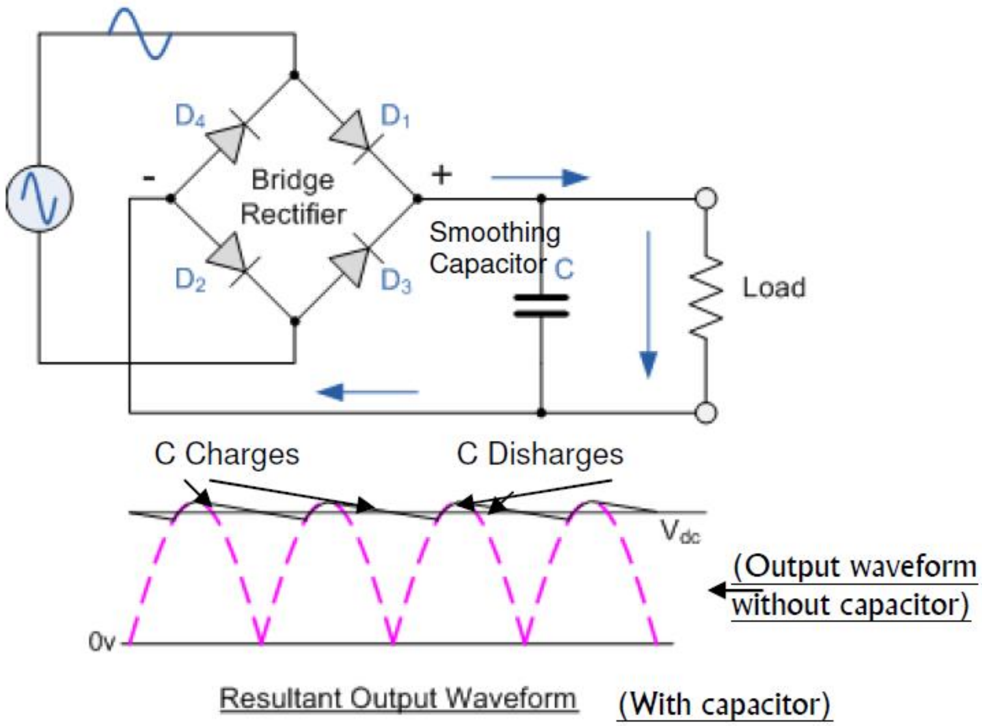


Figure 9.4: Full Wave Bridge Rectifier with capacitor filter

The full-wave rectifier circuit with capacitor filter is shown in Fig. 9.4. the smoothing capacitor converts the full-wave rippled output of the rectifier into a smooth dc output voltage. while choosing a suitable a capacitor, two parameters are required to consider: its working voltage and its capacitance value. the voltage across the capacitor must be higher than the no-load output value of the rectifier. capacitance value determines the amount of ripple in the dc output voltage.

Apart from rectification efficiency, the main advantages of a full-wave bridge rectifiers that it has a smaller ac ripple value for a given load and a smaller smoothing capacitor than an equivalent half-wave rectifier. the amount of ripple voltage that is superimposed on top of the dc supply voltage by the diodes can be virtually eliminated by adding other improved filters such as a pi-filter.

Schematic Diagrams:

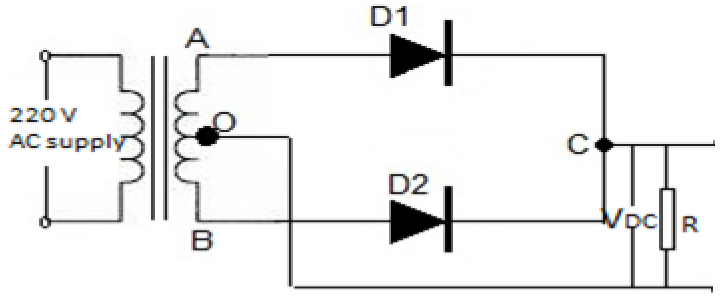


Figure 9.5: Centre-tapped Full Wave Rectifier without Filter

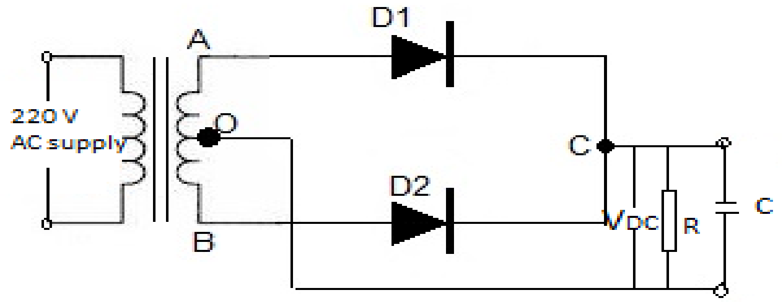


Figure 9.6: Centre-tapped Full Wave Rectifier with Capacitive filter

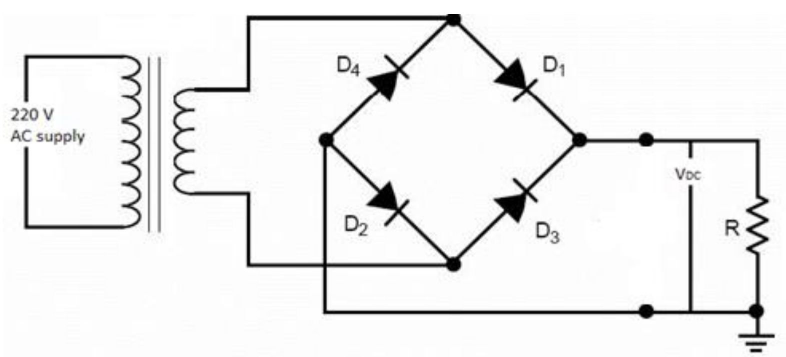


Figure 9.7: Full Wave Bridge Rectifier without Filter

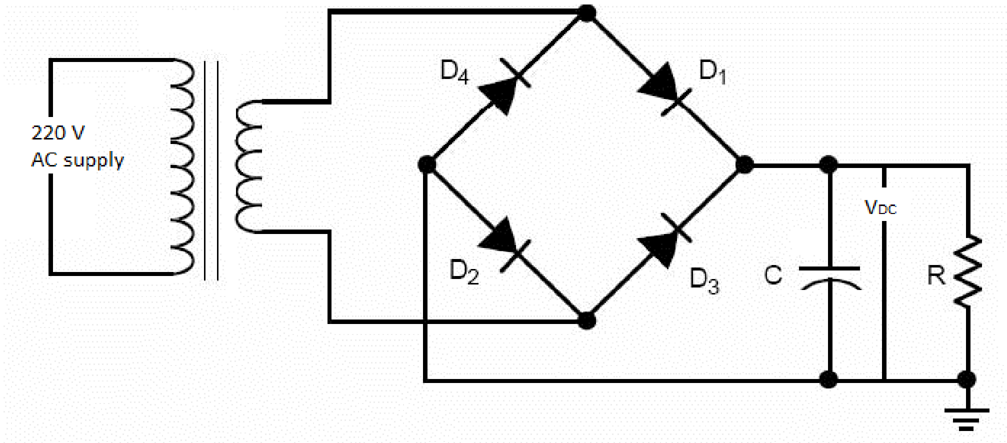


Figure 9.8: Full Wave Bridge Rectifier with Capacitive filter

Experimental Procedure:

Without Capacitor Filter:

1. Test the transformer before giving supply.
2. Apply 230V, 50 Hz power supply to primary coil of the transformer.
3. Observe ac waveform of rated value without any distortion at secondary coil of the transformer.
4. Connect circuit to secondary terminals of the transformer.
5. Connect CRO across the load.
6. Keep CRO switch in "ground" mode, observe horizontal line and adjust it to X-axis.
7. Switch CRO into DC mode and observe waveform. note down its amplitude, V_{max} and frequency from screen along with its multiplication factor.
8. Note and calculate V_{dc}.
9. Switch CRO into AC mode and observe waveform. note amplitude and frequency from screen.
10. Calculate V_{ac}, ripple factor and efficiency.

With Capacitive Filter:

1. Connect an electrolytic capacitor (with –ve terminal connected to ground) across the output for each load resistor.
2. Measure the output a.c. and d.c. voltages once again and calculate the ripple factor.
3. Trace the input and output waveforms in oscilloscope and notice the change.
4. Repeat the above measurement for all values of capacitors and study the output.

Observations:

Input Voltage: V_{ac} = __________ Volt

Table 9.1: Full wave rectifier w/o filter

S. No	Load R (kΩ)	Input Current I_{ac} (mA)	Output Voltage			Ripple Factor 'γ'	Efficiency 'η' $(V_{dc}^2/R)/V_{ac}I_{ac}$ (%)
			V_{ac} (Volt)	V_{dc} (Volt)	V_{max}/π (Volt)		

Table 9.2: Full wave rectifier with filter (C = ____ μF) (Make separate tables for each capacitor)

S. No	Load R (kΩ)	Output Voltage		Ripple Factor γ
		V_{ac} (Volt)	V_{dc} (Volt)	

Model Calculations:

$V_{max} = V_{p\text{-}p}/2$

$V_{rms} = V_{max}/\sqrt{2}$

$V_{dc} = 2V_{max}/\pi$

$V_{rms} = V_{max}/\sqrt{2}$

$\gamma = \sqrt{[(V_{rms}/V_{dc})^2-1]} =$

Trace:

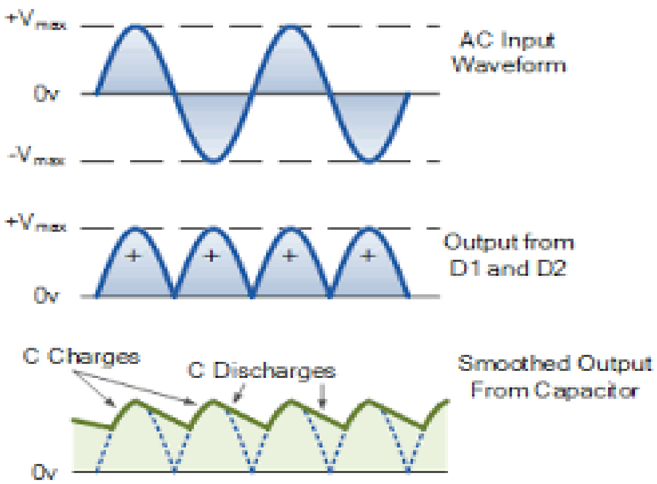


Figure 9.9: Output waveform of Full wave rectifier with and without capacitive filter

Result: Waveform for full wave rectifier with and without capacitive filter is traced. ripple factor and efficiency are to be found.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Depth knowledge of full wave rectifier.
2. Learning the operation of centre-tapped and bridge full wave rectifier.
3. Understanding the operation of full wave rectifier with and without capacitive filter.
4. Learning the concept of ripple factor in full wave rectifier.

Applications:

1. Rectifiers are used to derive DC power from an AC supply.
2. Rectifiers are used for detection of amplitude modulated radio signals.
3. Rectifiers supply polarized voltage for welding.

Precautions:

1. First measure the values with the help of multimeter then compare with oscilloscope.
2. Select proper AC or DC range of meters.
3. Use suitable wire (type and size).
4. Make all connections tight.
5. Do not connect leads to oscilloscope with supply switched ON.

EXPERIMENT NO: 10

Aim: Study the input and output characteristics of common base (CB) transistor.

Objective:

i. Study the working of bipolar junction transistor (BJT).
ii. Study the input and output characteristics of an NPN transistor in common base mode and determine transistor parameters.

Apparatus Required: Multimeter, D.C. power supply, resistors, NPN Transistor (BC 107 or equivalent), connecting wires and breadboard.

Theory:

A Bipolar Junction Transistor (BJT) is a three terminal device. each terminal is given a name to identify it and these are known as the emitter (E), base (B) and collector (C). there are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made. bipolar transistors are" **current**" amplifying or current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing current applied to their base terminal. the principle of operation of the two transistors NPN and PNP, is exactly the same the only difference being in the biasing (base current) and the polarity of the power supply for each type.

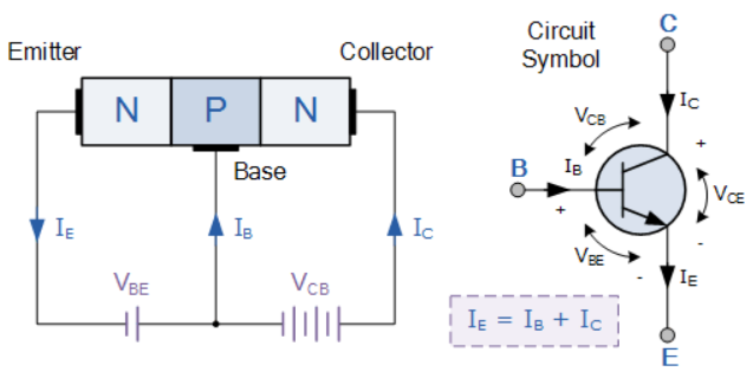


Figure 10.1: Schematic Symbol for NPN Transistor

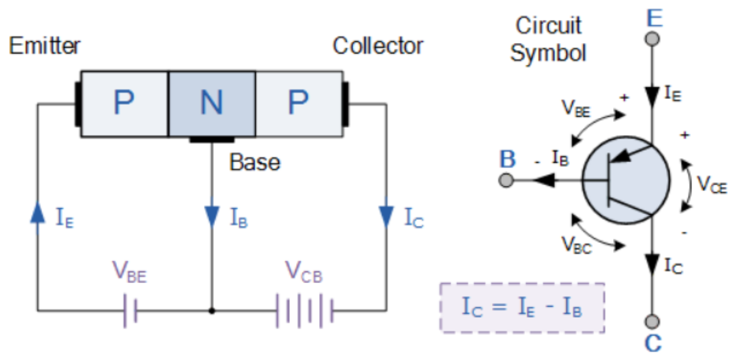


Figure 10.2: Schematic symbol for PNP transistor

The symbols for both the NPN and PNP bipolar transistor are shown in Fig. 10.1 and Fig. 10.2 along with terminal voltages and conventional current directions. the direction of the arrow in the symbol shows current flow between the base and emitter terminal, pointing from the positive P-type region to the negative N-type region, exactly the same as for the standard diode symbol. The different regions of operation of the BJT are given in Table 10.1.

Table 10.1 Different regions of operation of the BJT

Emitter –Base Junction	**Collector –Base Junction**	**Region**	**Application**
RB	RB	Cut Off	Off Switch
FB	FB	Saturation	On Switch
FB	RB	Active	Amplifier
RB	FB	Reverse Active	Attenuator

Transistor Configurations:

There are three possible configurations possible when a transistor is connected in a circuit:

a) Common base,
b) Common emitter and
c) Common collector

We will be focusing on the common base configuration in this experiment. the behavior of a transistor can be represented by d.c. current-voltage (I-V) curves, called the static characteristic curves of the device. the three important characteristics of a transistor are:

(i) Input characteristics,
(ii) Output characteristics and
(iii)Transfer Characteristics.

These characteristics give information about various transistor parameters, e.g. input and output dynamic resistance, current amplification factors, etc.

Common Base Transistor Characteristics:

In common base configuration, the base is made common to both input and output as shown in schematic diagram Fig. 10.3. this configuration offers low input impedance, high output impedance, high resistance gain and high voltage gain.

(1) Input Characteristics: The input characteristics are obtained by plotting a curve between I_E and V_{BE} keeping voltage V_{CB} constant. this is very similar to that of a forward-biased diode and the slope of the plot at a given operating point gives information about its input dynamic resistance.

Input Dynamic Resistance (*r_i*) is defined as the ratio of change in base emitter voltage (ΔV_{BE}) to the resulting change in emitter current (ΔI_E) at constant collector-emitter voltage(V_{CB}). this is dynamic as its value varies with the operating current in the transistor.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_E}\right)_{V_{CB}}$$

(2) Output Characteristics: The output characteristic curves are plotted between I_C and V_{CB}, keeping I_E constant. the output characteristics are controlled by the input characteristics. Since I_C changes with I_E, there will be different output characteristics corresponding to different values of I_E. These curves are almost horizontal. this shows that the output dynamic resistance is very high and defined below:

Output Dynamic Resistance (*r_o*): This is defined as the ratio of change in collector-base voltage (ΔV_{CB}) to the change in collector current (ΔI_C) at a constant base current I_E.

$$r_o = \left(\frac{\Delta V_{CB}}{\Delta I_C}\right)_{I_E}$$

(3) Transfer Characteristics: The transfer characteristics are plotted between the input and output currents (I_E versus I_C).

Current amplification factor (α)

This is defined as the ratio of the change in collector current to the change in emitter current at a constant collector-base voltage (V_{CB}) when the transistor is in active mode.

$$\alpha_{ac} = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}}$$

This is also known as small signal current gain and its value is very large. the ratio of I_C and I_E is called α_{dc} of the transistor. Hence,

$$\alpha_{dc} = \left(\frac{I_C}{I_E}\right)_{V_{CB}}$$

Since I_C increases with I_E almost linearly, the values of both α_{dc} and α_{ac} are nearly equal.

<u>Schematic Diagram</u>:

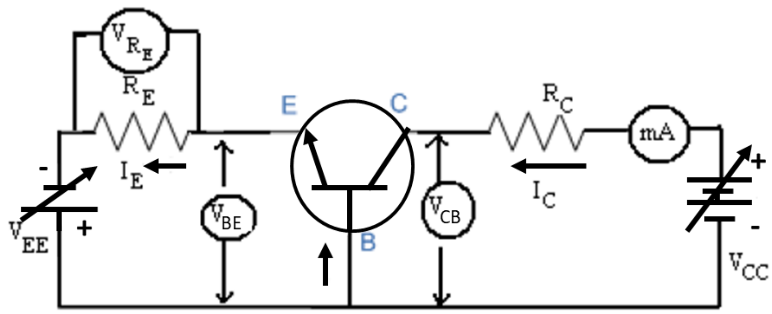
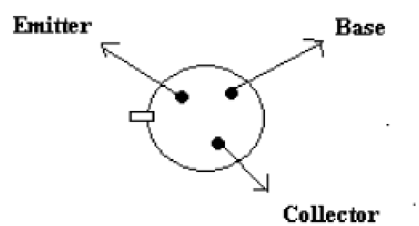


Figure 10.3: NPN transistor in CB configuration

Pin assignment of Transistor:



<u>Experimental Procedure</u>:

1. Note down the type number of transistor.
2. Identify different terminals (E, B and C) and the type (PNP/NPN) of the transistor. For any specific information refer the datasheet of the transistors.

3. Configure CB circuit using the NPN transistor as per the circuit diagram Fig. 10.3. Use R_E= R_C=150 Ω.
4. For input characteristics, first fix the voltage V_{CB} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{BE} slowly (say, in steps of 0.05V) by varying V_{EE}. Measure V_{BE} using a multimeter. If V_{CB} varies during measurement bring it back to the initial set value. To determine I_E, measure V_{RE} across the resistor R_E and use the relation $I_E= V_{RE}/ R_E$.
5. Repeat the above step for another value of V_{CB}.
6. Take out the multimeter measuring V_{BE} and connect in series with the output circuit to measure I_C. for output characteristics, first fix I_E= 0, i.e. V_{RE}= 0. By adjusting V_{CC}, vary the collector voltage V_{CB} in steps of say 1V and measure V_{CB} and the corresponding I_C using multimeters. after acquiring sufficient readings, bring back V_{CB} to 0 and reduce it further to get negative values. Vary V_{CB} in negative direction and measure both V_{CB} and I_C, till you get 0 current.
7. Repeat the above step for at least 5 different values of I_E by adjusting V_{EE}. You may need to adjust V_{EE} continuously during measurement in order to maintain a constant I_E.
8. Plot the input and output characteristics by using the readings taken above and determine the input (r_i) and output dynamic resistance (r_o).
9. To plot transfer characteristics, select a suitable voltage V_{CB} well within the active region of the output characteristics, which you have tabulated already. Plot a graph between I_C and the corresponding I_E at the chosen voltage V_{CB}. Determine α_{ac} from the slope of this graph.

<u>Expected Graphs</u>:

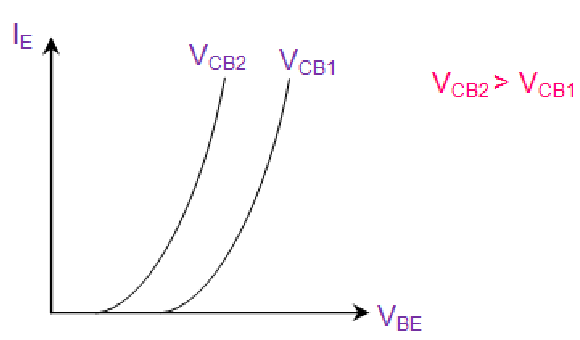


Figure 10.4: Input Characteristics of NPN Transistor in CB Configuration

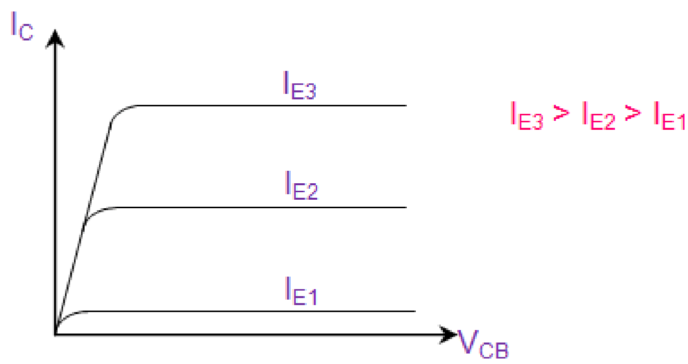


Figure 10.5: Output Characteristics of NPN transistor in CB configuration

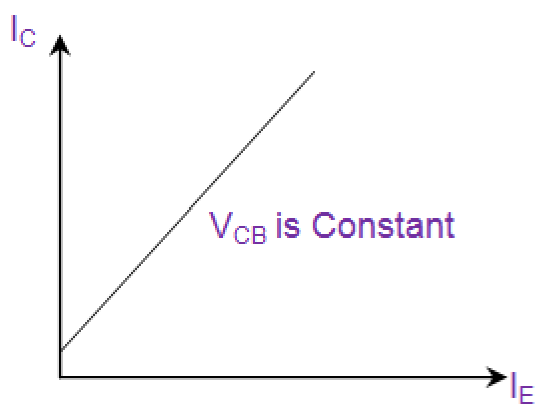


Figure 10.6 : Current Transfer Characteristics of NPN transistor in CB configuration

CB Configuration:

(1). Input characteristics: Plot V_{BE}~ I_E, for different V_{CB} and determine the input dynamic resistance (r_i) in each case at suitable operating points.

(2). Output characteristics: Plot V_{CB}~ I_C, for different I_E and determine the output dynamic resistance (r_o)in each case at suitable operating points in the active region.

(3). Transfer characteristics: Plot I_E~ I_C, for a fixed V_{CB} and determine α_{ac}.

Observations:

Transistor code: ________, Transistor type: ______ (PNP/NPN)

R_E = _____, R_C= ________.

Table (1): Input Characteristics

S. No.	V_{CB}= ___V			V_{CB} = ___V		
	V_{BE}(V)	V_{RE}(V)	I_E(mA)	V_{BE}(V)	V_{RE}(V)	I_E(mA)

Table (2): Output Characteristics

S. No.	I_{E1} = 0		I_{E2} = __		I_{E3} = __		I_{E4} = __		I_{E5} = __	
	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)

Table (3): Transfer Characteristics

V_{CB}= _______ V

S. No.	I_E (mA)	I_C (mA)

Calculations:

Input dynamic resistance can be calculated from input characteristics as

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_E}\right)_{V_{CB}}$$

From the output characteristics, the output resistance can be obtained as:

$$r_o = \left(\frac{\Delta V_{CB}}{\Delta I_C}\right)_{I_E}$$

The resulting current gain has a value less than 1 and can be mathematically expressed as:

$$\alpha_{ac} = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}}$$

Result: Input, Output and Transfer Characteristics of NPN transistor in Common Base Configuration are studied.

At V_{CB}=___ V; r_i=_____ Ω

At I_E =___ V; r_o=_____ Ω

At V_{CB}=___ V; α_{ac}=_______

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

1. Depth knowledge of Bipolar Junction Transistor.
2. Learning the operation of BJTs.
3. Understanding the V-I characteristics of BJTs.
4. Learning the concept of input dynamic resistance, output dynamic resistance and current amplification factor.

Applications:

1. The bipolar junction transistor (**BJT**) is used in logic circuits.
2. The **BJT** is used as an oscillator.
3. It is used as an amplifier.
4. It is used as a multivibrator.
5. For wave shaping it is used in clipping circuits.
6. Used as a detector or demodulator.
7. It is also used as modulator.
8. Used in timer and time delay circuits.

Precautions:

1. While performing the experiment do not exceed the ratings of the transistor. this may lead to damage the transistor.

2. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.

3. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.

4. Make sure while selecting the emitter, base and collector terminals of the transistor.

EXPERIMENT NO: 11

Aim: Study the input and output characteristics of common emitter (CE) transistor.

Objective:

iii. Study the working of bipolar junction transistor (BJT).
iv. Study the input and output characteristics of an NPN transistor in common emitter mode and determine transistor parameters.

Apparatus Required: Multimeter, D.C. power supply, resistors, NPN Transistor (BC 107 or equivalent), connecting wires and breadboard.

Theory:

A Bipolar Junction Transistor (BJT) is a three terminal device. each terminal is given a name to identify it and these are known as the emitter (E), base (B) and collector (C). there are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made. bipolar transistors are" **current**" amplifying or current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing current applied to their base terminal. the principle of operation of the two transistors NPN and PNP, is exactly the same the only difference being in the biasing (base current) and the polarity of the power supply for each type.

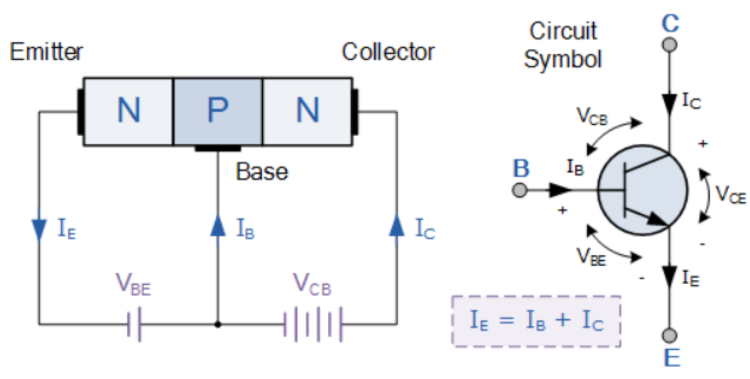


Figure 11.1: Schematic Symbol for NPN Transistor

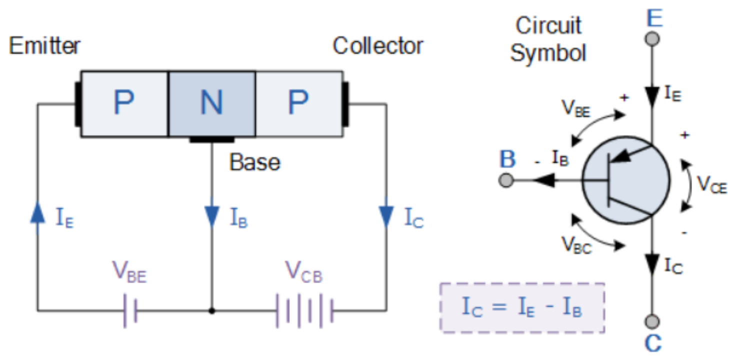


Figure 11.2: Schematic symbol for PNP transistor

The symbols for both the NPN and PNP bipolar transistor are shown in Fig. 10.1 and Fig. 10.2 along with terminal voltages and conventional current directions. the direction of the arrow in the symbol shows current flow between the base and emitter terminal, pointing from the positive P-type region to the negative N-type region, exactly the same as for the standard diode symbol. The different regions of operation of the BJT are given in Table 10.1.

Table 11.1 Different regions of operation of the BJT

Emitter –Base Junction	Collector –Base Junction	Region	Application
RB	RB	Cut Off	Off Switch
FB	FB	Saturation	On Switch
FB	RB	Active	Amplifier
RB	FB	Reverse Active	Attenuator

Transistor Configurations:

There are three possible configurations possible when a transistor is connected in a circuit:

d) Common base,
e) Common emitter and
f) Common collector

We will be focusing on the common base configuration in this experiment. the behavior of a transistor can be represented by d.c. current-voltage (I-V) curves, called the static characteristic curves of the device. the three important characteristics of a transistor are:

(iv) Input characteristics,
(v) Output characteristics and
(vi) Transfer Characteristics.

These characteristics give information about various transistor parameters, e.g. input and output dynamic resistance, current amplification factors, etc.

Common Emitter Transistor Characteristics:

In common base configuration, the base is made common to both input and output as shown in schematic diagram Fig. 10.3. this configuration offers low input impedance, high output impedance, high resistance gain and high voltage gain.

(1) Input Characteristics: It is the curve between input current IB and input voltage VBE constant collector emitter voltage VCE. The input characteristic resembles a forward biased diode curve. After cut in voltage the IB increases rapidly with small increase in VBE. It means that dynamic input resistance is small in CE configuration. It is the ratio of change in VBE to the resulting change in base current at constant collector emitter voltage. It is given by ΔVBE / ΔIB.

Input Dynamic Resistance (*r_i*) is defined as the ratio of change in base emitter voltage (ΔV_{BE}) to the resulting change in emitter current (ΔI_E) at constant collector-emitter voltage(V_{CE}). this is dynamic as its value varies with the operating current in the transistor.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_E}\right)_{V_{CE}}$$

(2) Output Characteristics: This characteristic shows relation between collector current IC and collector voltage for various values of base current. The change in collector emitter voltage causes small change in the collector current for the constant base current, which defines the dynamic resistance and is given as ΔVCE / ΔIC at constant IB. The output characteristic of common emitter configuration consists of three regions: Active, Saturation and Cut-off.

Output Dynamic Resistance (*r_o*): This is defined as the ratio of change in collector-base voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current I_B.

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

(3) Transfer Characteristics: The transfer characteristics are plotted between the input and output currents (I_b versus I_c).

Current amplification factor (*β*)

This is defined as the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active mode.

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

This is also known as small signal current gain and its value is very large. the ratio of I_C and I_E is called α_{dc} of the transistor. Hence,

$$\beta_{dc} = \left(\frac{I_C}{I_B}\right)_{V_{CE}}$$

<u>Schematic Diagram</u>:

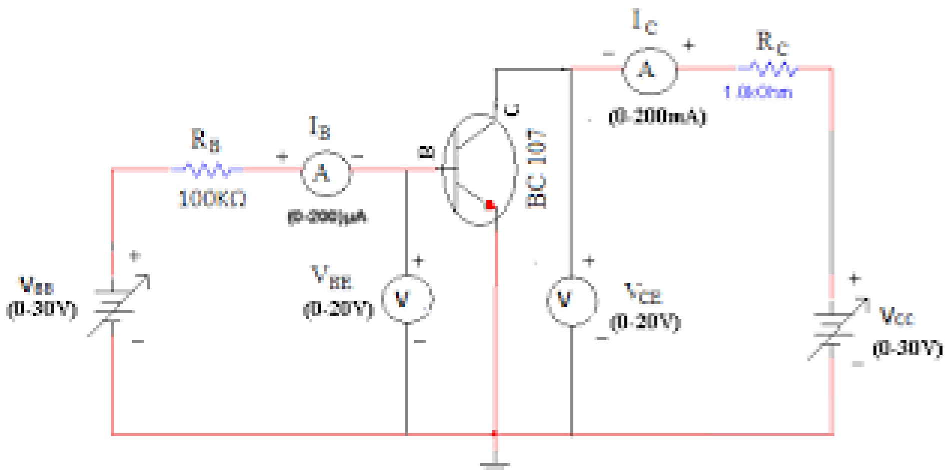
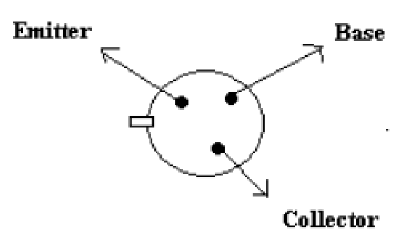


Figure 11.3: NPN transistor in CE configuration

Pin assignment of Transistor:



<u>Experimental Procedure</u>:

10. Note down the type number of transistor.

11. Identify different terminals (E, B and C) and the type (PNP/NPN) of the transistor. For any specific information refer the datasheet of the transistors.
12. Configure CE circuit using the NPN transistor as per the circuit diagram Fig. 11.3. Use R_E= R_C=150 Ω.
13. For input characteristics, first fix the voltage V_{CE} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{BE} slowly (say, in steps of 0.05V) by varying V_{EE}. Measure V_{BE} using a multimeter. If V_{CE} varies during measurement bring it back to the initial set value. To determine I_B, measure V_{RB} across the resistor R_B and use the relation I_B= V_{RB}/ R_B.
14. Repeat the above step for another value of V_{CE}.
15. Take out the multimeter measuring V_{BE} and connect in series with the output circuit to measure I_C. for output characteristics, first fix I_B= 0, i.e. V_{RB}= 0. By adjusting V_{CC}, vary the collector voltage V_{CE} in steps of say 1V and measure V_{CE} and the corresponding I_C using multimeters. after acquiring sufficient readings, bring back V_{CE} to 0 and reduce it further to get negative values. Vary V_{CE} in negative direction and measure both V_{CE} and I_C, till you get 0 current.
16. Repeat the above step for at least 5 different values of I_B by adjusting V_{BB}. You may need to adjust V_{BB} continuously during measurement in order to maintain a constant I_E.
17. Plot the input and output characteristics by using the readings taken above and determine the input (r_i) and output dynamic resistance (r_o).
18. To plot transfer characteristics, select a suitable voltage V_{CE} well within the active region of the output characteristics, which you have tabulated already. Plot a graph between I_C and the corresponding I_B at the chosen voltage V_{CE}. Determine β_{ac} from the slope of this graph.

<u>Expected Graphs</u>:

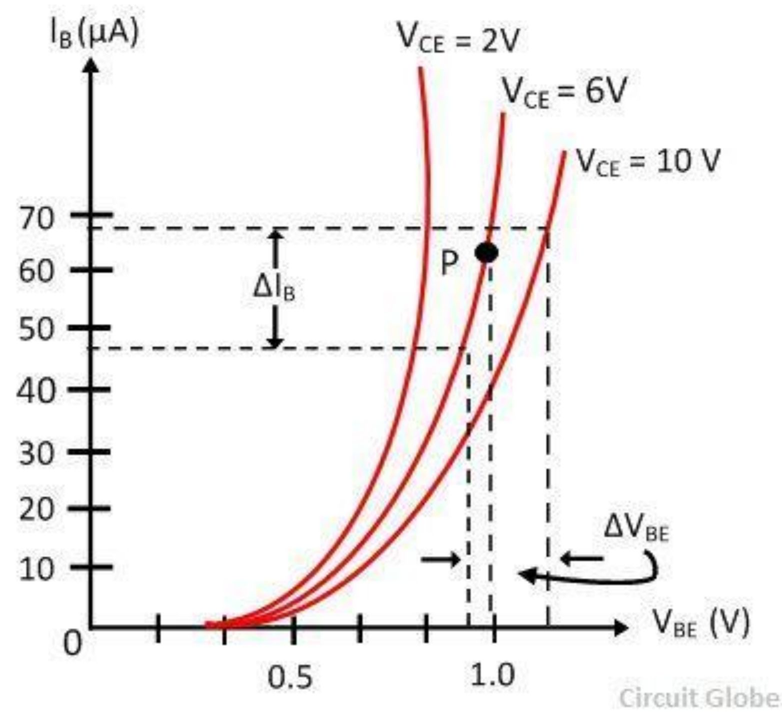


Figure 11.4: Input Characteristics of NPN Transistor in CB Configuration

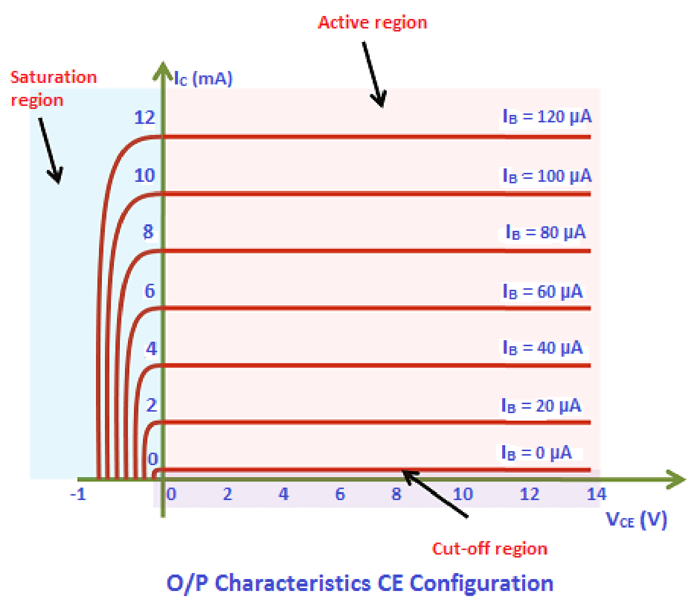


Figure 11.5: Output Characteristics of NPN transistor in CB configuration

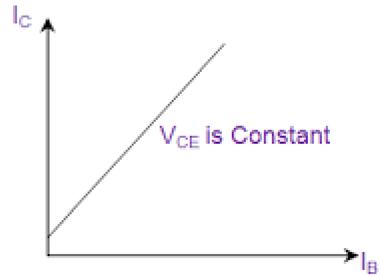


Figure 11.6 : Current Transfer Characteristics of NPN transistor in CE configuration

CE Configuration:

(1). Input characteristics: Plot V_{BE}~ I_B, for different V_{CE} and determine the input dynamic resistance (r_i) in each case at suitable operating points.

(2). Output characteristics: Plot V_{CE}~ I_C, for different I_B and determine the output dynamic resistance (r_o)in each case at suitable operating points in the active region.

(3). Transfer characteristics: Plot I_B~ I_C, for a fixed V_{CB} and determine β_{ac}.

<u>Observations</u>:

Transistor code: ________, Transistor type: ______ (PNP/NPN)

R_E = _____, R_C= ________.

Table (1): Input Characteristics

S. No.	**V_{CE}= ___V**			**V_{CE} = ___V**		
	V_{BE}(V)	**V_{RB}(V)**	**I_B(mA)**	**V_{BE}(V)**	**V_{RB}(V)**	**I_B(mA)**

Table (2): Output Characteristics

S. No.	$I_{B1} = 0$		$I_{B2} =$ __		$I_{B3} =$ __		$I_{B4} =$ __		$I_{B5} =$ __	
	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)

Table (3): Transfer Characteristics

V_{CE}= _______ V

S. No.	I_B(µA)	I_C (mA)

Calculations:

Input dynamic resistance can be calculated from input characteristics as

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

From the output characteristics, the output resistance can be obtained as:

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

The resulting current gain has a value less than 1 and can be mathematically expressed as:

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

Result: Input, Output and Transfer Characteristics of NPN transistor in Common Base Configuration are studied.

At V_{CE}=___ V; r_i=_____ Ω

At I_B =___ V; r_o=_____ Ω

At V_{CE}=___ V; β_{ac}=_______

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

5. Depth knowledge of Bipolar Junction Transistor.
6. Learning the operation of BJTs.
7. Understanding the V-I characteristics of BJTs.
8. Learning the concept of input dynamic resistance, output dynamic resistance and current amplification factor.

Applications:

9. The bipolar junction transistor (**BJT**) is used in logic circuits.
10. The **BJT** is used as an oscillator.
11. It is used as an amplifier.
12. It is used as a multivibrator.
13. For wave shaping it is used in clipping circuits.
14. Used as a detector or demodulator.
15. It is also used as modulator.
16. Used in timer and time delay circuits.

Precautions:

1. While performing the experiment do not exceed the ratings of the transistor. this may lead to damage the transistor.

2. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.

3. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.

4. Make sure while selecting the emitter, base and collector terminals of the transistor.

EXPERIMENT NO. 12

Title: To design and test open-loop & closed-loop inverting & non-inverting configuration of Op-Amp.

Objective:

a) To design and test open-loop inverting configuration of Op-Amp.
b) To design and test open loop non-inverting configuration of Op-Amp.
c) To design and test closed loop inverting configuration of Op-Amp.
d) To design and test closed loop non-inverting configuration of Op-Amp.

Apparatus Required:

a) IC 741.
b) Multimeter
c) Connecting wires
d) CRO
e) Resistances of value 10 kΩ & 1 kΩ
f) Function generator

Precautions:

a) All the connections should be tight.
b) Switch on the power supply only after all the connections are made.
c) Take the observation carefully.
d) Show the complete circuit to the faculty in-charge.

Theory:

An Op-Amp is a very high gain differential amplifier having high input impedance and low output impedance. For open loop Op-Amp, gain is very high and ideally it is infinite. Due to this reason, negative feedback is applied to the Op-Amp to avoid distortions and noise in the output due to very high gain. The IC which is used for Op-Amp is IC 741, diagram of which is shown below in figure 1.1. The circuit diagram of open and closed inverting amplifier is shown in figure 1.2 & 1.4. respectively. The open and closed loop non-inverting configuration of an ideal Op-Amp is shown below in figures 1.3 and 1.5, respectively.

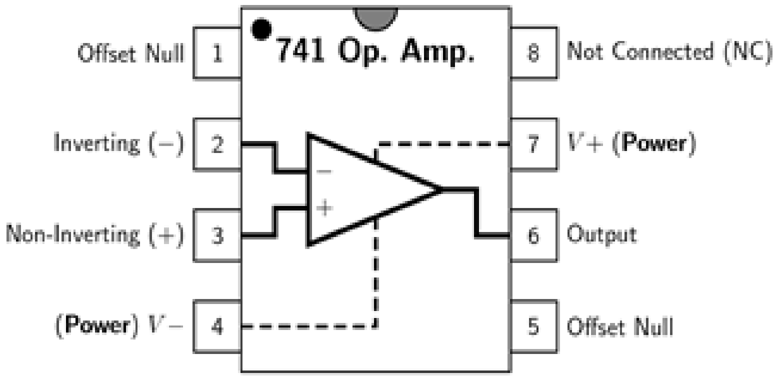


Figure 1.1: IC 741

Circuit Diagram:

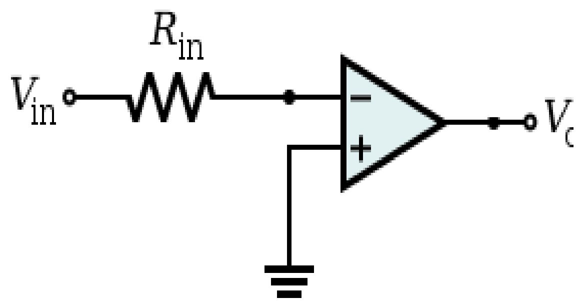


Figure 1.2: Open loop inverting Op-Amp

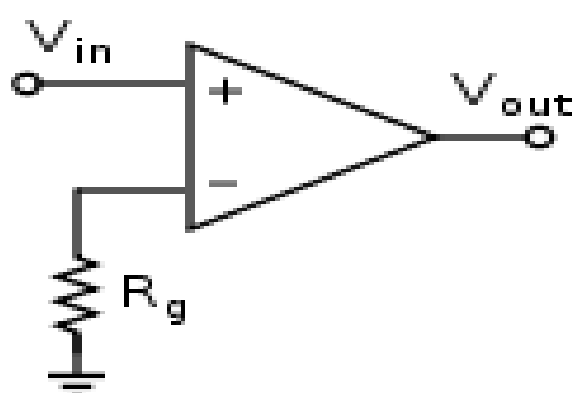


Figure 1.3: Open loop non-inverting Op-Amp

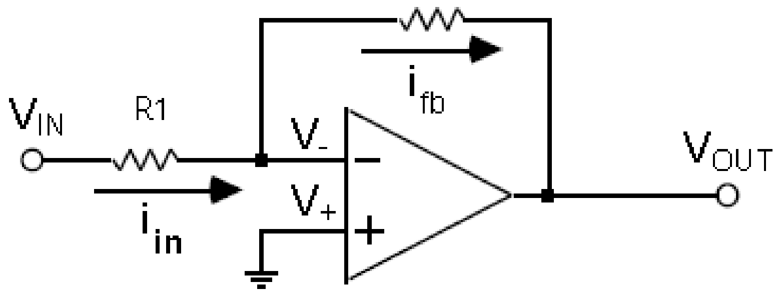


Figure 1.4: Closed loop inverting Op-Amp

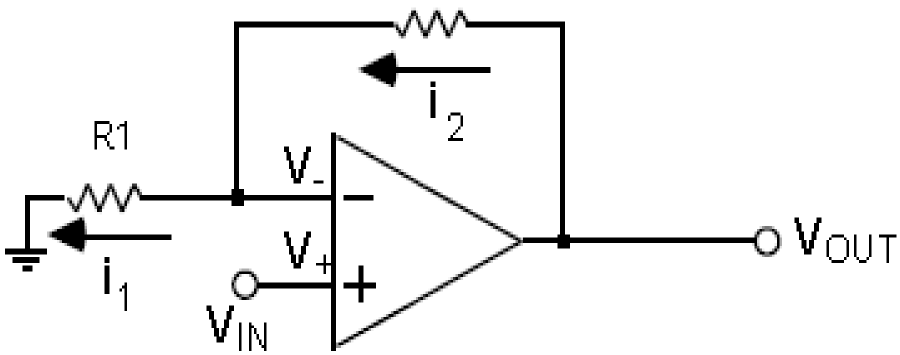


Figure 1.5: Closed loop non-inverting Op-Amp

Procedure:

a) Make the connections on the bread board according to the circuit diagram.
b) The output of circuit is obtained from pin no-6 of IC 741.
c) Observe the output waveform on CRO.
d) Take the readings and do the calculations.

Observation & Results:

	Open loop		Closed loop	
	Inverting	Non- inverting	Inverting	Non- inverting
Input voltage				
Output voltage				
Gain practical (V_o/V_{in})				
Gain theoretical				

Conclusion: Write in your own words, what have you learnt from this experiment and what are its real-life applications.

EXPERIMENT NO. 13

Aim: Study of summer using Op-Amp IC

Objective: To study the application of Operational Amplifier (Op-Amp) IC 741 as summer.

Apparatus Required: Op-Amp IC 741, resistors of value 10kΩ and 1kΩ, CRO, Function Generator, Regulated power supply, Breadboard, Multimeter and connecting wires.

Theory: An operational amplifier ("op amp") is a direct-coupled, differential-input, high gain voltage amplifier, usually packaged in the form of a small integrated circuit. The symbol for an operational amplifier is shown in Fig. 1.1.

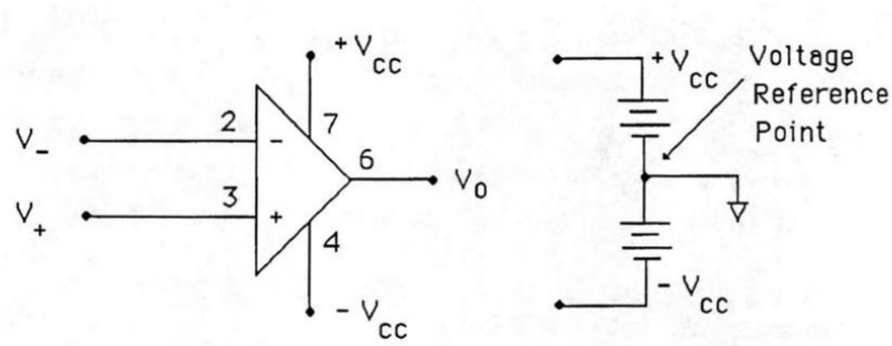


Fig.1.1. Symbol of Op-Amp (Pin numbers are those of a 741 eight pin dual-inline package)

V_+ and V_- are the input voltages and V_o is the output voltage.

$$V_o = A_o (V_+ - V_-)$$

where A_o is the open-loop voltage gain and $+V_{cc}$ and $-V_{cc}$ are the positive and negative DC power supply voltages, respectively.

There is no internal "ground" or "common" connection; voltages are measured relative to the common connection of the two power supplies. Pin diagram of 741 integrated circuit (IC) package is shown in Fig. 1.2.

The ideal operational amplifier is characterized by the following three properties:

1. The open-loop voltage gain A_o is very high.

Typically, $A_o \geq 10^5$

Ideally, $A_o = \infty$

2. The input impedance R_i is very high and can be assumed to be infinite. This means that there is no current into the op amp at input ports V_+ and V_- .
3. The output impedance R_o is very low and can usually be assumed to be 0 Ω. This means that the output will drive any load without any drop in output voltage.

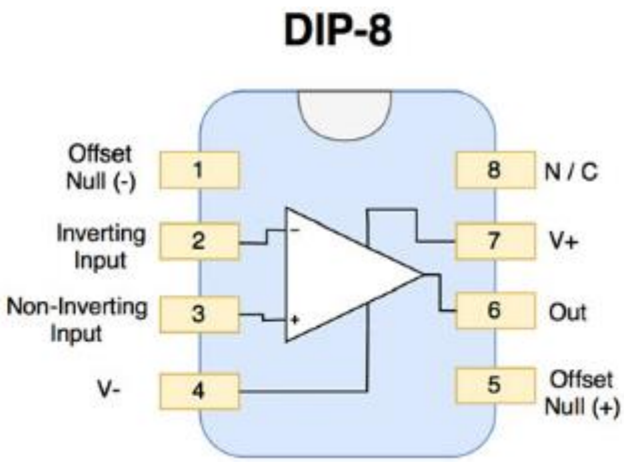


Fig.1.2. Pin diagram of 741 Op-Amp IC

Op-amp can be used to design a circuit whose output is the sum of several input signals. Such a circuit is called a summing amplifier or an adder. Summing amplifier can be classified as inverting & non-inverting summer depending on the input applied to inverting & non-inverting terminals respectively. An inverting summing amplifier with 2 inputs is shown in Fig. 1.3. The output will be amplified version of the sum of the two input voltages with 180^0 phase reversal.

$$V_{out} = -\left[\frac{R_F}{R_1}V_1 + \frac{R_F}{R_2}V_2\right]$$

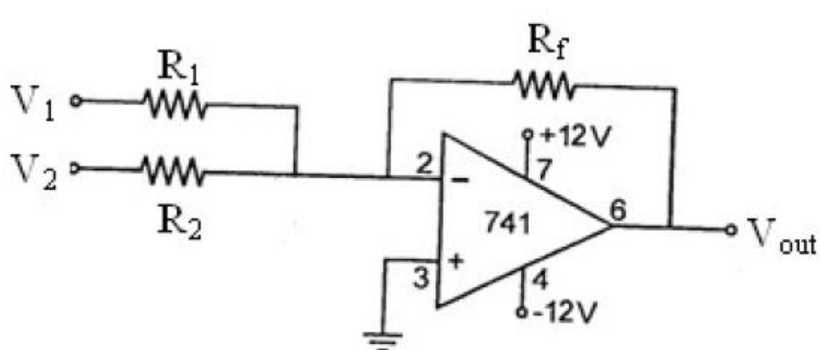


Fig.1.3. Op-Amp based adder circuit

Experimental Procedure:

11. Assemble the circuit on the bread board according to Fig. 1.3 choosing R_F = 10kΩ and R_1 = R_2= 1kΩ.
12. Take inputs from function generator and also trace them on CRO.
13. The output of circuit is obtained from pin no-6 of Op-Amp IC.
14. Observe the output waveform in CRO.

Observations:

R_F = 10kΩ
R_1 = R_2= R=1kΩ

S.No.	Input Voltage (V_1)	Input Voltage (V_2)	Observed Output Voltage (V_{out})	Calculated Output Voltage $\left[-\frac{R_F}{R}\,(V_1+V_2)\right]$
1.				
2.				
3.				

Result: Performed and tabulated the addition operation on IC 741 Op-Amp. Observed and calculated outputs are quite similar, thus verifying addition operation using Op-Amp IC.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Precautions:

4. Make null adjustment before applying the input signal.
5. Maintain proper V_{cc} levels.

EXPERIMENT NO.13(PART 2)

Aim: Study of subtractor using Op-Amp IC

Objective: To study the application of Operational Amplifier (Op-Amp) IC 741 as subtractor.

Apparatus Required: Op-Amp IC 741, resistors of value 10kΩ and 1kΩ, CRO, Function Generator, Regulated power supply, Breadboard, Multimeter and connecting wires.

Theory: An operational amplifier ("op amp") is a direct-coupled, differential-input, high gain voltage amplifier, usually packaged in the form of a small integrated circuit. The symbol for an operational amplifier is shown in Fig. 2.1.

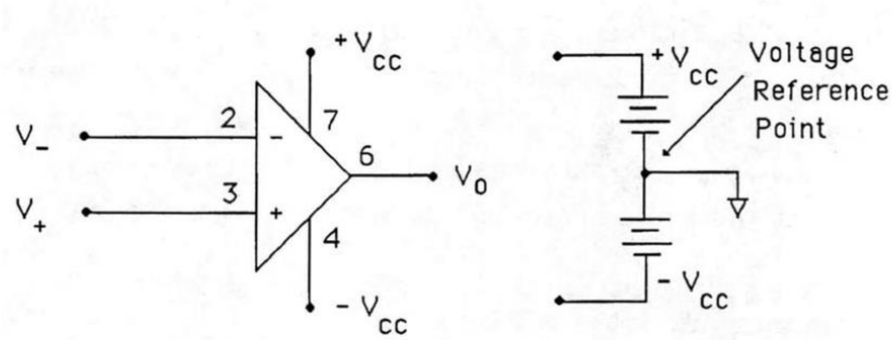


Fig.2.1. Symbol of Op-Amp (Pin numbers are those of a 741 eight pin dual-inline package)

V_+ and V_- are the input voltages and V_o is the output voltage.

$$\mathbf{V_o = A_o (V_+ - V_-)}$$

where A_o is the open-loop voltage gain and $+V_{cc}$ and $-V_{cc}$ are the positive and negative DC power supply voltages, respectively.

There is no internal "ground" or "common" connection; voltages are measured relative to the common connection of the two power supplies. Pin diagram of 741 integrated circuit (IC) package is shown in Fig. 2.2.

The ideal operational amplifier is characterized by the following three properties:

1. The open-loop voltage gain A_o is very high.

   Typically, $A_o \geq 10^5$

Ideally, $A_o = \infty$

2. The input impedance R_i is very high and can be assumed to be infinite. This means that there is no current into the op amp at input ports V_+ and V_-.
3. The output impedance R_o is very low and can usually be assumed to be 0 Ω. This means that the output will drive any load without any drop in output voltage.

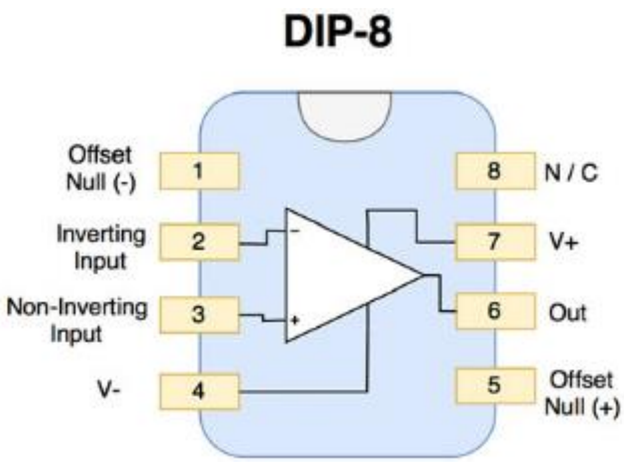


Fig.2.2. Pin diagram of 741 Op-Amp IC

A subtractor using Op-Amp is a circuit that gives the amplified version of the difference of the two inputs shown in Fig. 2.3.

$\mathbf{V_o = A\ (V_1 - V_2)}$

where V_1 and V_2 are the inputs and A is the voltage gain of Op-Amp.

Input voltage V_1 is connected to inverting terminal and V_2 to the non-inverting terminal. This is also called as differential amplifier. Output of a differential amplifier can be determined using superposition theorem. When V_2=0, the circuit becomes an inverting amplifier with input V_1 and the resulting output is $V_{01} = -R_F/R_1\ (V_1)$. When V_1=0, the circuit become a non-inverting amplifier with input V_2 and the resulting output is $V_{02} = R_F/R_2\ (V_2)$.

Therefore the resulting output according to super position theorem is

$$V_{out} = V_{O1} + V_{O2} = \left[\frac{R_F}{R_2}V_2 - \frac{R_F}{R_1}V_1\right]$$

For $R_1 = R_2 = R$

$$V_{out} = V_{O1} + V_{O2} = \frac{R_F}{R}[V_2 - V_1]$$

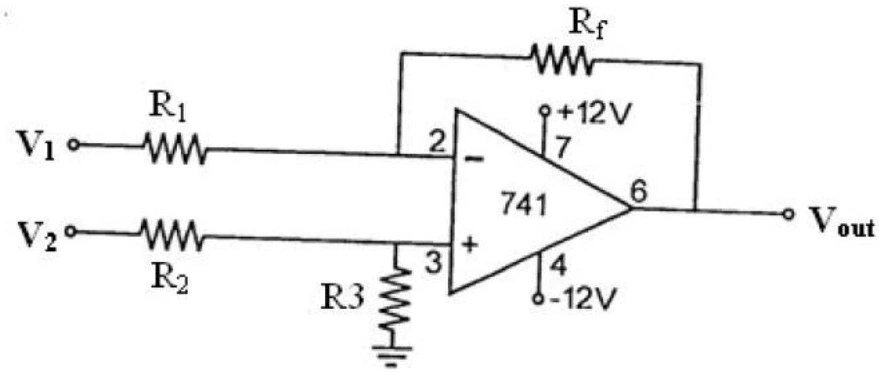


Fig.2.3. Op-Amp based adder circuit

Experimental Procedure:

1. Assemble the circuit on the bread board according to Fig. 2.3 choosing R_F = 10kΩ, R_1 = R_2= 10kΩ and R_3 = 10kΩ.
2. Take inputs from function generator and also trace them on CRO.
3. The output of circuit is obtained from pin no-6 of Op-Amp IC.
4. Observe the output waveform in CRO.

Observations:

R_F = 10kΩ
R_1 = R_2= R= 10kΩ
R_3= 10kΩ

S.No.	Input Voltage (V_1)	Input Voltage (V_2)	Observed Output Voltage (V_{out})	Calculated Output Voltage $\left[\frac{R_F}{R}\,(V_2 - V_1)\right]$
1.				
2.				
3.				

Result: Performed and tabulated the subtraction operation on IC 741 Op-Amp. Observed and calculated outputs are quite similar, thus verifying subtraction operation using Op-Amp IC.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Precautions:

1. Make null adjustment before applying the input signal.
2. Maintain proper V_{cc} levels.

EXPERIMENT NO.14

Aim: Study of half adder using logic gates

Objectives: To design and test half adder circuit (For addition of two bits) using digital IC gates.

Apparatus Required: IC 7408 (AND Gate), IC 7486 (XOR Gate), Bread Board, Power Supply, Connecting Wires, LED.

Theory:

Adders are digital circuits that carry out addition of numbers. Basically, two types of binary adders are used:

i. Half Adder (For addition of two bits).
ii. Full Adder (For addition of more than two bits).

Adding two 1– bit binary values produces a sum and a carry output. This operation is called a half addition and the combinational circuit that realizes the function is called a **half- adder**. It is used to add the least significant binary bits of two n-bits binary numbers, because no carry- in occurs.

Subsequent bit additions require carry–in input to accommodate value overflow from lower order bit positions. So, **full adder circuit** is used to add two 1– bit binary values with the inclusion of a carry input, producing two outputs, a sum and a carry.

Half Adder:

Considering A and B as the two bits whose addition is to be performed, a truth table for half adder with A, B as inputs and Sum, Carry as outputs can be tabulated as follows (Table 3.1).

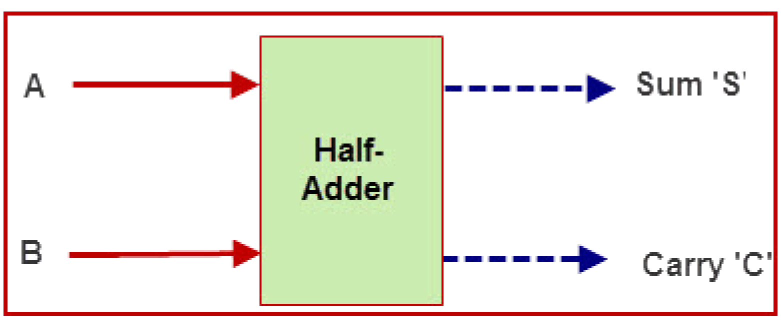
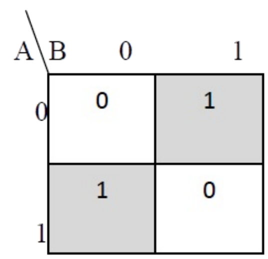


Fig. 3.1. Block Diagram of Half Adder

Table 3.1. Truth Table of Half Adder

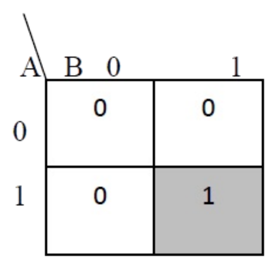
Truth Table			
Input		Output	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

K-Map simplification for sum output using truth table is shown below:



S = ∑ (1,2)
S = AB’ + A'B
S = A ⊕ B

Similarly, K-Map simplification for carry output is shown below:



C = ∑ (3) = AB

Therefore, if A and B are binary inputs to the half adder, then the logic function to calculate sum S is Ex – OR of A and B and logic function to calculate carry C is AND of A and B. The same is verified above with help of Karnaugh Map. Combining these two, the logical circuit to implement the combinational circuit of half adder is shown in Fig. 3.2.

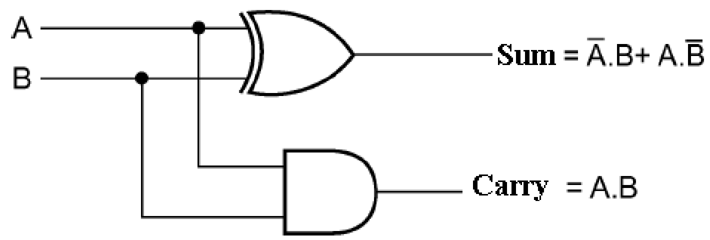


Fig. 3.2. Logic Diagram of Half Adder

NAND and NOR are called universal gates as any logic system can be implemented using these two, the half adder circuit can also be implemented using them as shown below.

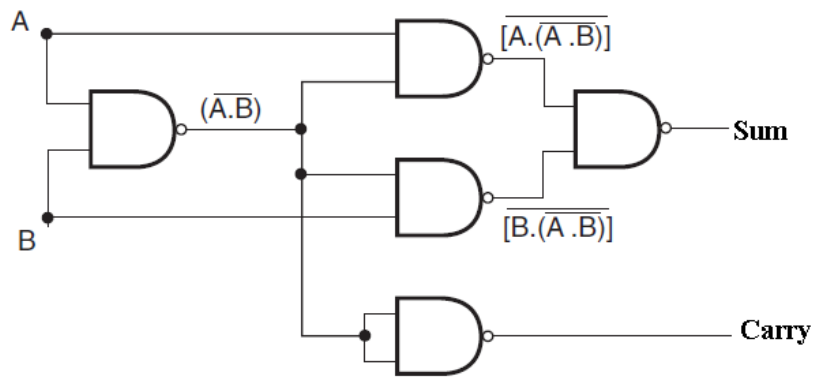


Fig. 3.3. Half Adder Circuit using only NAND Gates

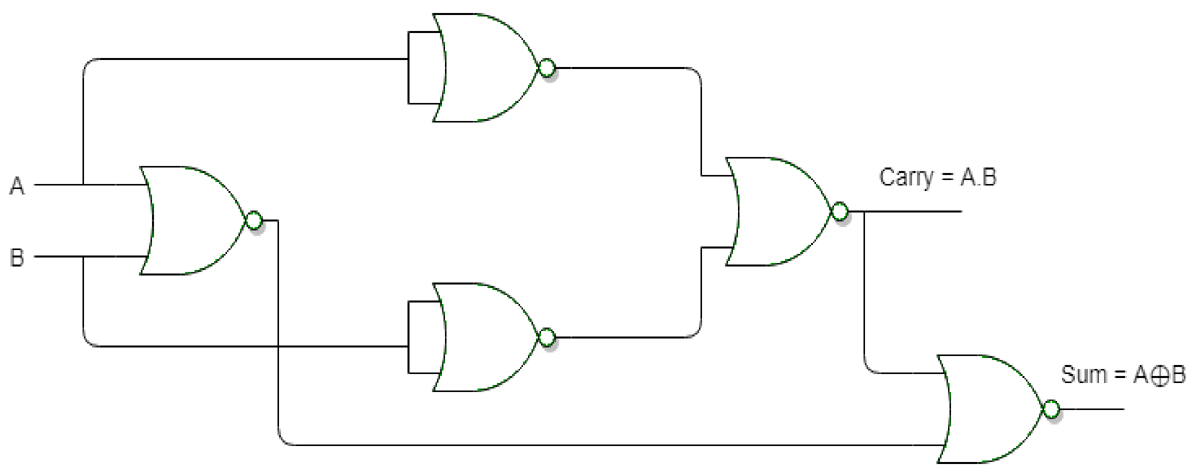


Fig. 3.4. Half Adder Circuit using only NOR Gates

Experimental Procedure:

19. See the data sheets of ICs for pin configuration: IC 7408 (AND Gate) and IC 7486 (XOR Gate).
20. Connect the +5V and ground (GND) leads of the power supply to the power and ground bus strips on your breadboard.
21. Place the ICs on the Breadboard. Point all the chips in the same direction with pin 1 at the lower-left corner on breadboard. (Pin 1 is often identified by a dot or a notch next to it on the chip package). Next, apply a high-level voltage to all the V_{cc} inputs (pin 14) and keep low level voltage to all the GND inputs (pin 7).
22. Select a connection and place a piece of hook-up wire between corresponding pins of the chips on breadboard. Make all the connections required as shown in schematic diagrams.
23. After connecting the circuit properly, switch ON the power supply.
24. Finally, observe the output for different input combinations and match it with the truth table given.

Schematic Diagram:

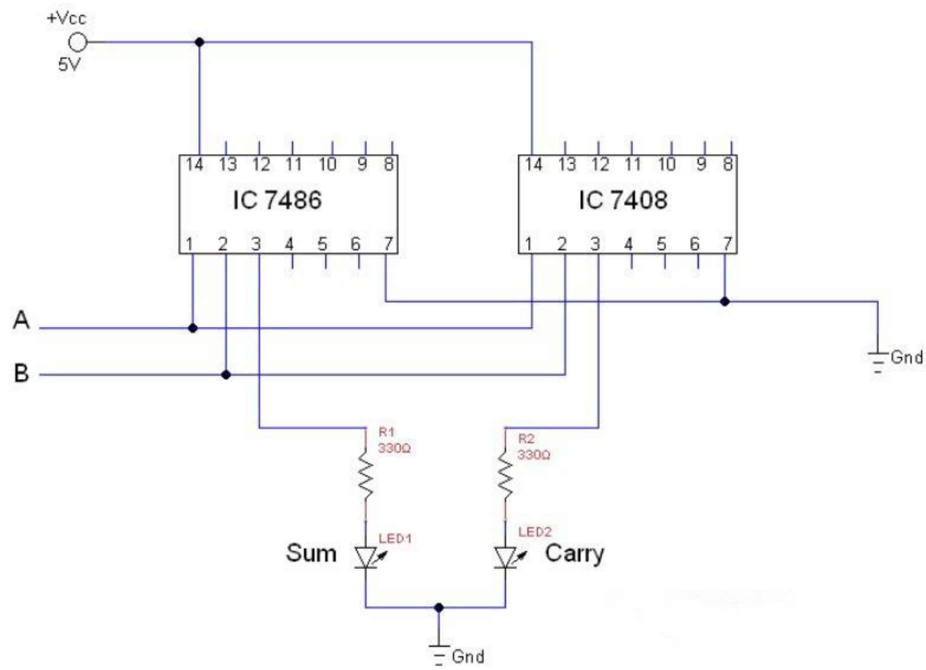


Fig. 3.5. Schematic diagram of Half Adder Circuit

Observations:

Truth Table for Half Adder

Input		**Output**	
A	**B**	**Sum**	**Carry**
0	0		
0	1		
1	0		
1	1		

Result: Half adder circuit has been designed and tested using logic gates ICs.

Result Analysis & Discussion: This section should be written individually by each student.

Inferences & Conclusion: This section should be written individually by each student.

Learning Outcomes:

7. Depth knowledge of Binary Addition.
8. Learning design steps of combinational circuits.

Applications:

10. Adders are a key component of arithmetic logic unit.
11. Adders are also used in certain digital applications like table index calculation, address decoding etc.

Precautions:

7. Turn the power off before making any connection.
8. Check the output of all ICs.
9. All the connections should be proper according to the circuit diagram.
10. Handle the kit carefully.