LAB MANUAL

FOR

ELECTRONICS ENGINEERING LABORATORY

ECI102

DEPARTMENT OF ELECTRONICS ENGINEERING,

INDIAN INSTITUTE OF TECHNOLOGY (ISM),

DHANBAD- 826004

DEPARTMENT OF ELECTRONICS ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY (ISM) DHANBAD

Subject: Electronics Engineering Lab (ECI102), L-T-P: 0-0-3

Modular Course (half semester course)

Electronics Engineering Laboratory:

S.No.	List of experiments
1.	Familiarization with the electronic components and lab instruments
2.	Diode V-I characteristics and its applications as a rectifier.
3.	Realization of Clipper and clamper circuits using diode.
4.	Bipolar Junction Transistor: output characteristics in common emitter configuration and its application as switch.
5.	Inverting/Non-inverting action of operational amplifier and its application as a Differentiator/Integrator circuits.
6.	Realization of logic gates using Universal gate (NAND).

GENERAL GUIDELINES AND SAFETY INSTRUCTIONS

1. You should strictly maintain the lab timings and follow the written and verbal instructions given to you. In case of any doubts, please ask the instructor.
2. Do not bring any bags inside the lab.
3. Read the procedures in the Lab Manual before starting the experiments.
4. Do your wiring, setup, and a careful circuit checkout before applying power. Do not make circuit changes or perform any wiring when power is on.
5. Be sure instrument grounds are connected properly.
6. Never connect an ammeter across a voltage source. Only connect ammeters in series with loads. An ammeter is a low-resistance device that, if connected in parallel, will short out most components and usually destroy the ammeter or its protecting fuse.
7. Do not exceed the voltage and current ratings of instruments or other circuit elements.
8. Immediately report dangerous or exceptional conditions to the Lab instructor.
9. Please report immediately in case any equipment is not working as expected, wires or connectors are broken, the equipment that smells or “smokes”. If you are not sure what the problem is or what's going on, switch off the mains supply
10. Never use damaged instruments, wires or connectors. Hand over these parts to the Lab instructor.
11. After completion of Experiment, return the multimeter, bread board, CRO probes and other components to lab staff. Do not take any item from the lab without permission.
12. Strict disciplinary action will be taken if any equipment is found damaged and you have not informed the instructor/lab staff.
13. Observation notebook and lab record should be carried to each lab. Readings of current lab experiment are to be entered in Observation notebook and previous lab experiment should be written in Lab record book. Both the books should be corrected by the instructor in each lab. 1
14. Sensitive electronic circuits and electronic components have to be handled with great care. The inappropriate handling of electronic component can damage or destroy the devices. The devices can be destroyed by driving to high currents through the device, by overheating the device, by mixing up the polarity, or by wrong connections. Therefore, always handle the electronic devices as per the instructions.

EXPERIMENT No. 1

OBJECTIVE:

a. To familiarize with the components to be used in the lab
b. To learn and practice the usage of instruments like Digital multimeter, DC Power Supply, Function Generator and Oscilloscope

Learning Outcome: To be able to identify components along with their specifications and learn the usage of the instruments required for the experiments..

COMPONENTS/APPARATUS REQUIRED:

Sl. No.	Component/Apparatus	Quantity
1	Breadboard	1
2	Multimeter	1
3	Diode, Transistor	1
4	Transformer	1
5	Resistor	1
6	Capacitor	1
7	Connecting Wires	1
8	CRO/DSO	1
9	DC variable power supply	1
10	Function generator	1

Identification of Circuit Components

Breadboards:

Breadboards are useful for making temporary connections of components and for testing the circuits. The breadboard has strips of metal underneath the board and connect the holes on the top of the board. The metal strips are laid out as shown below. Note that the top and bottom rows of holes are connected horizontally and split in the middle while the remaining holes are connected vertically.

Resistors

We need to understand how to apply it in order to get the correct value of the resistor. The "left-hand" or the most significant coloured band is the band which is nearest to a connecting lead with the colour coded bands being read from left-to-right as follows:

Digit, Digit, Multiplier = Colour, Colour x 10^{colour} in Ohm's (Ω)

For example, a resistor has the following coloured markings;

Yellow Violet Red = 4 7 2 = 4 7 x 10^2 = 4700Ω or 4.7 K Ω.

The fourth and fifth bands are used to determine the percentage tolerance of the resistor. Resistor tolerance is a measure of the resistors variation from the specified resistive value and is a consequence of the manufacturing process and is expressed as a percentage of its "nominal" or preferred value.

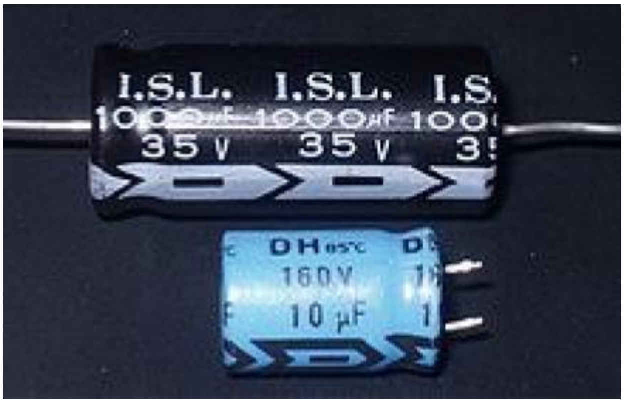
Typical resistor tolerances for film resistors range from 1% to 10% while carbon resistors have tolerances up to 20%. Resistors with tolerances lower than 2% are called precision resistors with the or lower tolerance resistors being more expensive.

Color code of resistors

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	

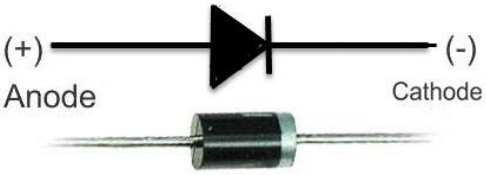
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Capacitors:



Electrolytic capacitors An electrolytic capacitor is a type of capacitor that 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 figure. The arrowed stripe indicates the polarity, with the arrows pointing towards the negative pin.

Ceramic capacitors are generally non-polarized and almost as common as radial electrolytic capacitors. Generally, they use an alphanumeric marking system. The value represented is in pF. They may also be written out directly, for instance, 2n2 = 2.2 nF.



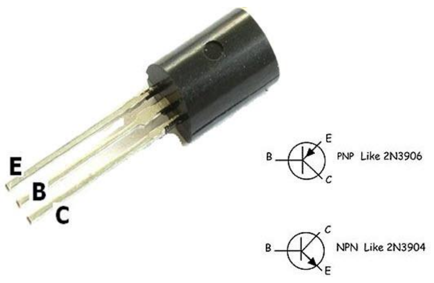
Diodes

Diodes are a two lead semiconductor. They are polarized and typically have axial leads. The two leads are referred to as the anode and cathode. Signal diodes are around the size of ¼ watt resistors and sometimes use a glass body. The cathode is marked by a band or stripe on the body of the diode. The cathode of an LED is usually marked by a flat spot on the plastic housing or by the shorter of the two leads.

Rectifier diode

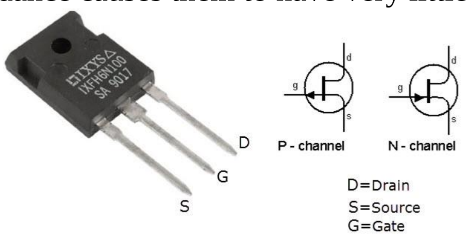
Bipolar Junction Transistor (BJT)

Bipolar Junction Transistors are transistors which are built up of 3 regions, the base, the collector, and the emitter. Bipolar junction transistors come in two major types, NPN and PNP. A NPN transistor is one in which the majority current carrier are electrons. Electron flowing from the emitter to the collector forms the base of the majority of current flow through the transistor.



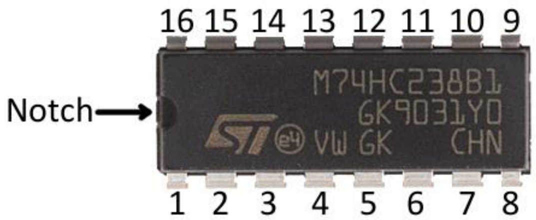
Field Effect Transistor

Field Effect Transistors are made up of 3 regions, a gate, a source, and a drain. Different bipolar transistors, FETs are voltage-controlled devices. A voltage placed at the gate controls current flow from the source to the drain of the transistor. Field Effect transistors have a very high input impedance, from several mega ohms (MΩ) of resistance to much, much larger values. This high input impedance causes them to have very little current run through them.



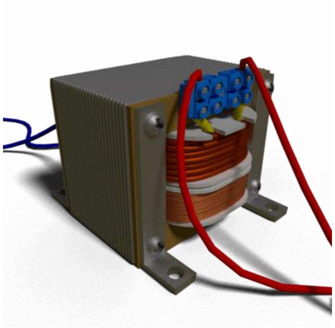
Integrated Circuits

There are a very wide variety of integrated circuits. Multi-lead versions of the TO-5 can are sometimes used but the most common through-hole package is the Dual In-Line Package, denoted as DIP or DIL.



Transformers

Transformers can vary from tiny audio devices to room size devices used in power generation and distribution. A common application of transformer is stepping down a 120 VAC line voltage to a more modest level so that it can be rectified, filtered, and turned into a stable DC source to drive electronic circuits. Besides the voltage turns ratio, the most important characteristic is the VA or volt-amps rating of the device. Transformers only operate with AC voltages.



Measuring Instruments

Digital Multimeter

The digital multimeter is a multi-function instrument that can measure ac and dc voltage or current, and resistance. Some multimeters can also measure capacitance and test components like diode and transistor.

The specifications of DM-81 are given below

Technical Data :

Basic Functions	**Range**	**Basic Accuracy**
DC Voltage	200mV/2V/20V/200V/1000V	±(1.2% + 5)/±(1.5% + 5)
AC Voltage	200mV/2V/20V/200V/750V	±(2% + 5)/±(1.8% + 5)/ ±(1.5% + 5)/ ±(2% + 7)
DC Current	2mA/200mA/20A	±(1.5% + 5)/±(2% + 5)/ ±(3% + 5)
AC Current	2mA/200mA/20A	±(2% + 5)/±(2.5% + 5)/ ±(3% + 7)
Resistance	200Ω, 2KΩ, 20KΩ.. 200MΩ	±(1.5% + 5)/±(2% + 5)/ ±(5% + 5) -10
Capacitance	20nF/200nF/2uF/200uF	±(3% + 10)/±(5% + 10)

Special Function: Diode testing, Transistor testing

DC Power Supply:

DC Power supply is used for DC current and voltage source. The ones in the lab provide three channels with 0-30 V, 0-30 V, and 0-5 V output.

Oscilloscope:

Oscilloscopes are useful for measuring signals in the lab. The ones in the lab have two channels for simultaneous measurement of two signals.

Function generators:

Function generator is used for providing various signals like sine wave, square wave and triangular wave output.

Students are required to familiarize themselves with the various components and instruments provided in the lab and practise some measurements using the instruments.

QUESTIONS

1. What is the differenc between passive and active components? Give examples.
2. How do you identify the terminals of BJT and FET?
3. What are the quantities that can be measures using a multimeter?
4. What are the main differences between a CRO and a DSO?

EXPERIMENT No. 2

OBJECTIVE:

To study the V-I characteristics of P-N junction diode and its application as half and full wave rectifier.

Learning Outcome: Develop an understanding of the diode characteristics and relate it to its application in rectification.

COMPONENTS/APPARATUS REQUIRED:

Sl. No.	Component/Apparatus	Quantity
1	Breadboard	1
2	Multimeter	2
3	Diode(IN4007)	2
4	Transformer(6-0-6)	1
5	CRO/DSO	1
6	DC variable power supply(0-30V)	1
7	Resistor(680 Ω, 1kΩ,2 kΩ ,10kΩ)	4
8	Capacitor(100μF)	1
9	Connecting Wires	5

THEORY:

Diode:-

It is a two terminal device consisting of a P-N junction formed either in Ge or Si crystal. A P-N junction has P-type and N-type semiconductor pieces before they are joined. P-type material has a high concentration of holes and N-type material has a high concentration of free electrons and hence there is a tendency of holes to diffuse over to N side and electrons to P-side. The process is known as diffusion. Volt-Ampere Characteristics of P-N Junction: - Fig.1 showsthe circuit arrangement for drawing the volt-ampere characteristics of a P-N junction diode. When no external voltage is applied the circuit current is zero. The characteristics are studied as following:

(i)Forward bias:-For the forward bias of a P-N junction, P-type is connected to the positive terminal while the N-type is connected to the negative terminal of a battery. The potential at P-N junction can be varied with the help of potential divider. At some forward voltage (0.3 V for Ge and 0.7V for Si) the potential barrier is altogether eliminated and current starts flowing. This voltage is known as threshold voltage (Vth) or cut in voltage or knee voltage .It is practically same as barrier voltage VB. For V<Vth, the current flow is negligible. As the forward applied voltage increases beyond threshold voltage, the forward current rises exponentially.

(ii)Reverse bias: -For the reverse bias of p-n junction, P-type is connected to the negative terminal while N-type is connected to the positive terminal of a battery. Under normal reverse voltage, a very little reverse current flows through a P-N junction. But when the reverse voltage is increased, a point is reached when the junction break down with sudden rise in reverse current. The critical value of the voltage is known as break down (VBR). The break down voltage is defined as the reverse voltage at which P-N junction breakdown with sudden rise in reverse current.

Application of Diode in Rectifier:-

A rectifier is a circuit that converts a pure AC signal into a pulsating DC signal or a signal that is a combination of AC and DC components. A half wave rectifier makes use of single diode to carry out this conversion. It is named so as the conversion occurs for half input signal cycle. During the positive half cycle, the diode is forward biased and it conducts and hence a current flows through the load resistor. During the negative half cycle, the diode is reverse biased and it is equivalent to an open circuit, hence the current through the load resistance is zero. Thus the diode conducts only for one half cycle and results in a half wave rectified output. A full wave rectifier makes use of a two diodes to carry out this conversion. It is named so as the conversion occurs for complete input signal cycle. The full-wave rectifier consists of a center-tap transformer, which results in equal voltages above and below the center-tap. During the positive half cycle, a positive voltage appears at the anode of D1 while a negative voltage appears at the anode of D2. Due to this diode D1 is forward biased it results in a current Id1 through the load R. During the negative half cycle, a positive voltage appears at the anode of D2 and hence it is forward biased. Resulting in a current Id2 through the load at the same instant a negative voltage appears at the anode of D1 thus reverse biasing it and hence it doesn't conduct.

Circuit Diagrams:-

1. **Diode V-I Characteristics :-**

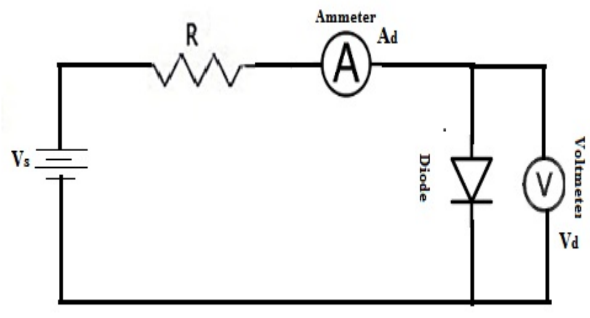


Fig.1. Forward Bias Circuit

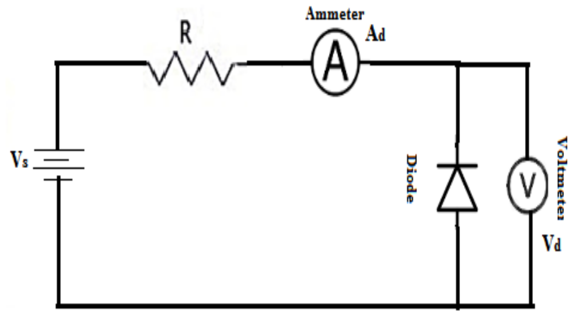


Fig.2. Reverse Bias Circuit

2. **Rectifier:-**

2a. Half –Wave Rectifier:-

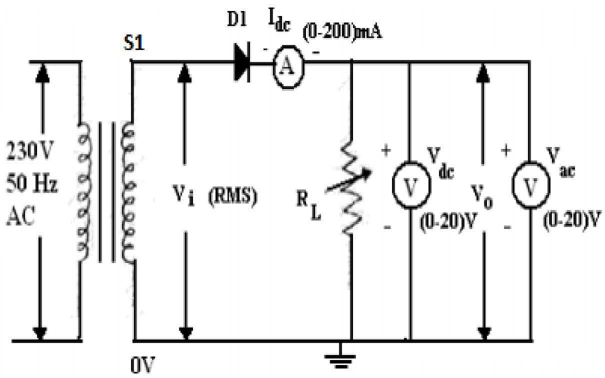


Fig.3. Half –Wave Rectifier without Capacitor

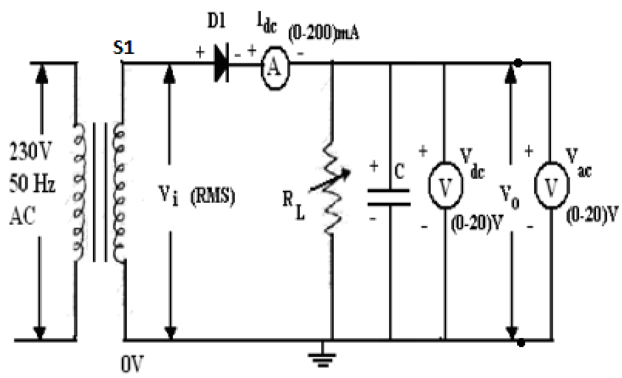


Fig.4. Half –Wave Rectifier with Capacitor

2b. Full - Wave Rectifier

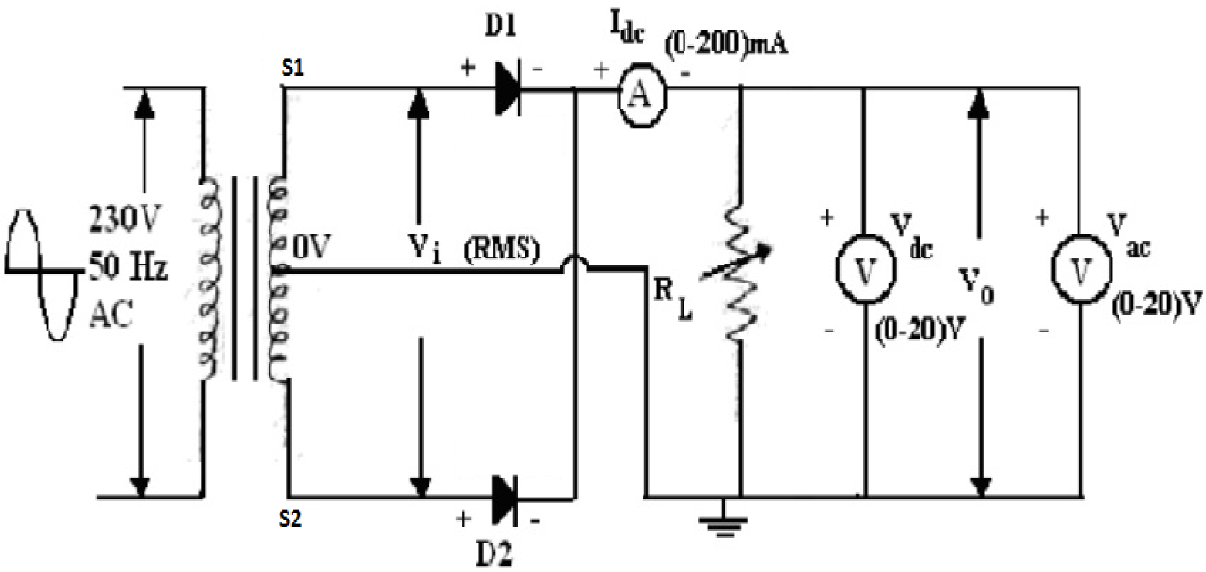


Fig.5. Center-Tap Full- Wave Rectifier without capacitor

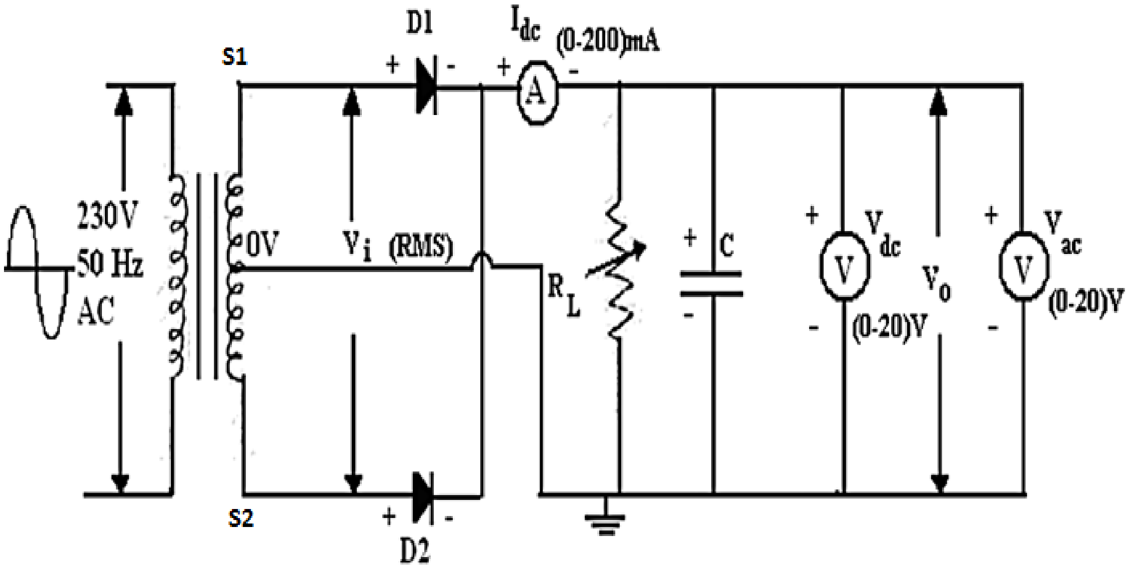


Fig.6.Center-Tap Full- Wave Rectifier with capacitor

PROCEDURE:

Before you proceed, identify the p and n-side of the diode in order to connect properly in forward and reverse bias mode.

1. Forward and reverse bias characteristics of a normal diode:

Forward Bias characteristics:

1. Assemble the circuit on your breadboard as shown in Fig.1. Connect to the 0-30 V DC power supply.
2. Switch on the power supply. Slowly increase the supply voltage in steps of 0.1 V using the fine adjustment knob and note down the corresponding readings of diode current. When the change in current is larger (which means you have already crossed the threshold point), increase the supply voltage in steps of 0.5 to note down current.
3. Using multimeters in appropriate modes, measure voltage drop across the diode and the current in the circuit. Tabulate the readings in an observation table.
4. Plot the I-V characteristics and estimate the threshold voltage.

Reverse Bias characteristics:

1. Assemble the circuit on your breadboard as shown in Fig.2. Connect to the 0-30 V DC power supply.
2. Switch on the supply. Increase the supply voltage in steps of 0.5 V to note down the diode current.
3. Use multimeters for voltage and current measurements. Keep in mind that magnitude of current flowing in the circuit will be very small, so choose current range properly. Switch off the supply after taking sufficient readings.

4. Plot the I-V characteristics on the same graph sheet and estimate the reverse saturation current.

Procedure for half-wave and full-wave rectifier:

1. Assemble the circuit according to Fig. 3. for half-wave and Fig. 5. for full wave without capacitor and Fig. 4. for half- wave and Fig. 6. for full wave with capacitor with R_{load} = 100Ω-2KΩ. Use the 6-0-6 Vrms output of the transformer.
2. Observe the input and output signal on the oscilloscope with different diode and measure its peak value Vp at output and its period T.
3. Note the readings as indicated in figure for DC current, DC voltage and AC voltage.
4. Now change the load resistance RL values between 100Ω to 2kΩ and repeat the procedure as the above.
5. Tabulate the readings as per the tabular column indicated in observations and calculate the ripple factor and if time permits then repeat the procedure by changing capacitance values.

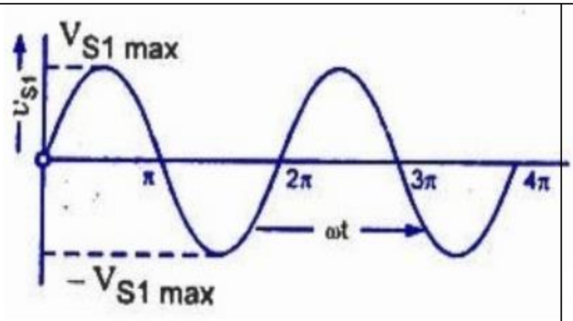
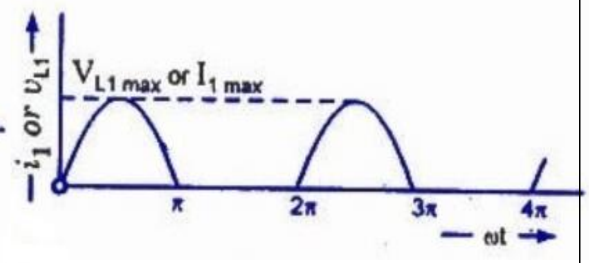
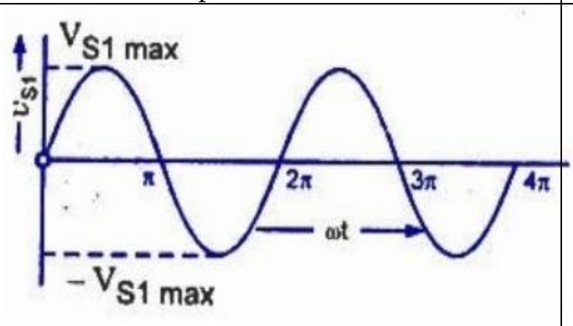
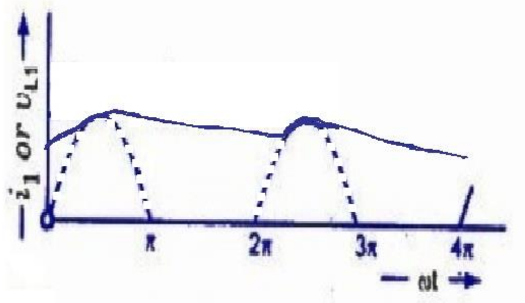
OBSERVATION:

1. **V-I Characterstics of Diode:**

Forward Bias			
Sl.No.	**Applied Voltage (V_s)**	**Diode Voltage (V_d)**	**Diode Current (I_d)**

Reverse Bias			
Sl.No.	**Applied Voltage (V_s)**	**Diode Voltage (V_d)**	**Diode Current (I_d)**

2. Half-Wave Rectifier

Waveform Observation	
 Input waveform	 Output waveform across D1
 Input waveform	 Output waveform with capacitor

3.Observation table for Half-Wave Rectifier without capacitor:-

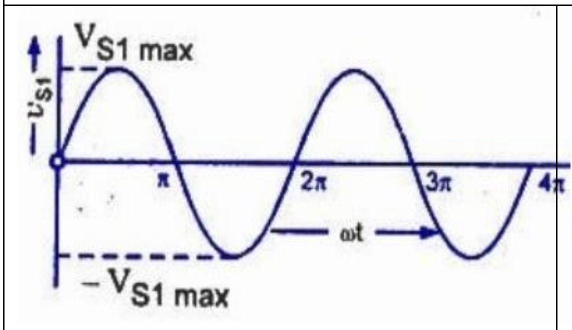
Sl. No.	Input Voltage Peak(V_m)	Load Resistance (R_l)	Output Voltage Peak(V_0)	Average Dc Current (I_{dc})	Average Dc voltage (V_{dc})	RMS Voltage (V_{ac})	Ripple Factor $\Gamma=\frac{V_{ac}}{V_{dc}}$
1							
2							
3							

4. Observation table for Half-Wave Rectifier with capacitor:-

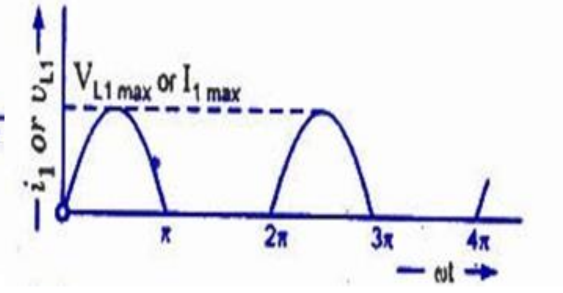
Sl. No.	Input Voltage Peak(V_m)	Load Resistance (R_l)	Output Voltage Peak(V_0)	Average Dc Current (I_{dc})	Average Dc voltage (V_{dc})	RMS Voltage (V_{ac})	Ripple Factor $\Gamma=\frac{V_{ac}}{V_{dc}}$
1							
2							
3							

5. Full-Wave Rectifier :-

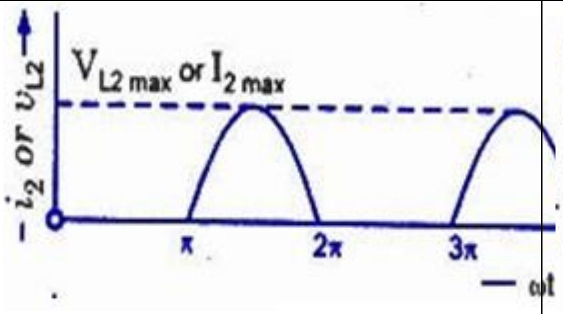
Waveform Observation



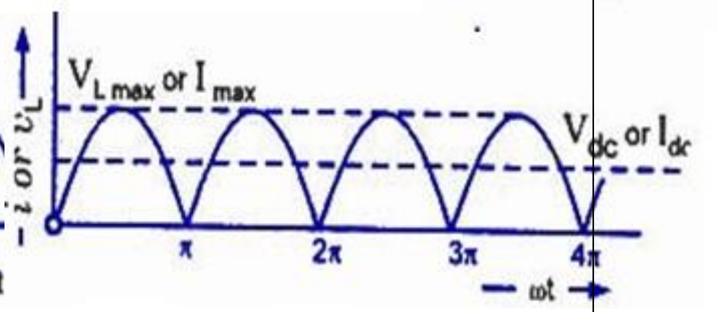
Input Waveform



Output Waveform across D1



Output Waveform across D2



Output Waveform across D1 & D2

6. Observation table for Full-Wave Rectifier without capacitor:-

Sl. No.	Input Voltage Peak(V_m)	Load Resistance (R_l)	Output Voltage Peak(V_0)	Average Dc Current (I_{dc})	Average Dc voltage (V_{dc})	RMS Voltage (V_{ac})	Ripple Factor $\Gamma=\frac{V_{ac}}{V_{dc}}$
1							
2							
3							

7. Observation table for Full-Wave Rectifier with capacitor:-

Sl. No.	Input Voltage Peak(V_m)	Load Resistance (R_l)	Output Voltage Peak(V_0)	Average Dc Current (I_{dc})	Average Dc voltage (V_{dc})	RMS Voltage (V_{ac})	Ripple Factor $\Gamma=\frac{V_{ac}}{V_{dc}}$
1							
2							

3							

CONCLUSION:

1. V-I Characteristics of PN junction diode for silicon diode is observed.
2. The input and output waveforms of a half-wave and full- wave rectifier with /without filter is observed.
3. The ripple factor (γ) for half-wave and full wave rectifier without filter is calculated.
   For example ripplefactor (γ) with
   680Ω=
   1KΩ=
   10kΩ=
4. The ripple factor (γ) for half-wave and full wave rectifier with filter is calculated.
   For example ripple factor (γ) with
   1KΩ, 100μF =
   2KΩ, 100μF =
   10 KΩ, 100μF

PRECAUTIONS:

1. Ensure that the polarity of the power supply is properly connected.
2. Keep the input voltage knob of the regulated power supply in minimum position while switching ON or switching OFF the power supply.
3. There should be no loose contacts at the junctions.

QUESTIONS:

1. Draw the basic block diagram of regulated power supply? Why we need regulated power supply and types of regulated power supply?
2. What are the two schemes of full wave rectifiers?
3. What are the advantages of center tap rectifier over half wave rectifier?
4. What is voltage regulation?

EXPERIMENT No. 3

OBJECTIVE:

a. Understanding the operating principle of diode clipping circuit.
b. Understanding the operating principle of clamping circuit.
c. Understanding the waveform change of diode clipping and clamping circuits when the bias is applied.

Learning Outcome: Develop an understanding of diode applications in wave shaping and ability to design simple diode based circuits

COMPONENTS/APPARATUS REQUIRED:

a. Resistors of 1KΩ, Diode IN4001, IN4007, Capacitor 0.1μF
b. Bread Board, Connection cables and short circuit clips
c. A Multiple Power Supply Unit
d. A Multimeter
e. A Digital Storage Oscilloscope and Function generator.

THEORY:

Clipping circuits:

A clipper is a device which limits, remove or prevents some portion of the waveform (input signal voltage) above or below a certain level, in other words the circuit which limits positive or negative amplitude ,or both is called clipping circuit. A clipper is used to limit the amplitude of a waveform to a desired voltage level. Hence it is also called amplitude limiter. There are two types of clipper circuits, the series and parallel diode clipping circuits.

1. <u>Series positive clipper</u>

In a series positive clipper, a diode is connected in series with the output, as shown in Fig. below During the positive half of the input voltage, this reverse biases the diode and it acts as an open switch Therefore all the applied voltage drops across the diode and none across the resistor. As a result of this there is no output voltage during the positive half cycle of the input voltage.
Note: All the waveforms shown below are for ideal diode.

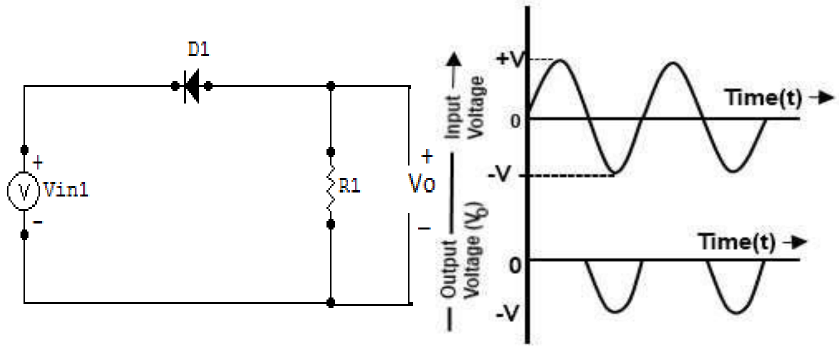


Fig.1. Circuit for series positive clipper

During the negative half cycle of the input voltage, therefore it forward biases the diode and it acts as a closed switch. Thus there is on voltage drop across diode during the negative half cycle of the input voltage. All the input voltage is dropped across the resistor as shown in the output wave form.

Note: Positive clipper is that which removes or clips the positive half completely.

<u>Series-positive clipper with bias</u>

Sometimes it is desired to remove a small portion of positive or apposite half cycle of the signal voltage (input signal). For this purpose a biased clipper is used.

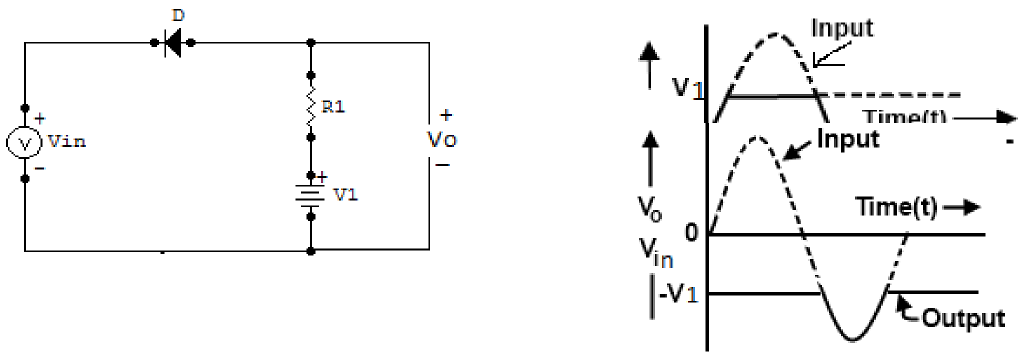


Fig.2. Series positive clipper with positive bias

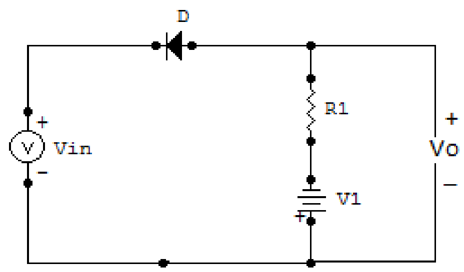
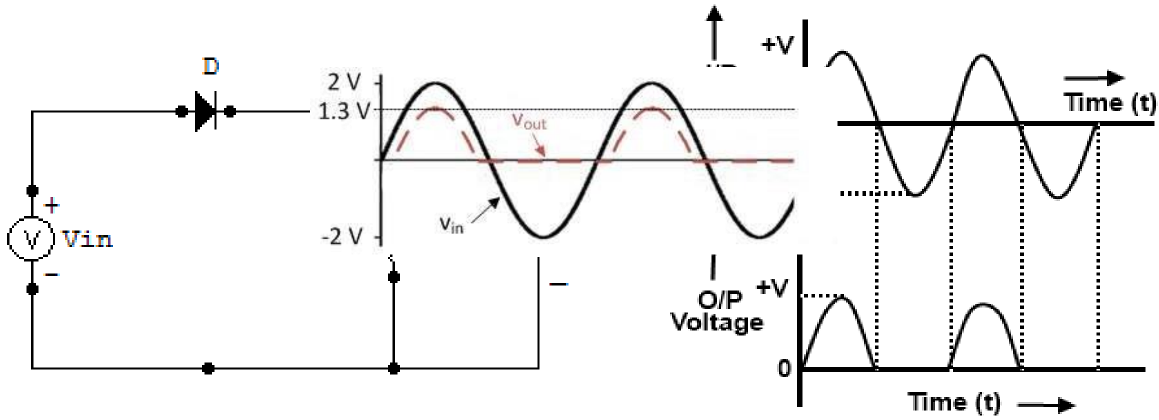


Fig.3. Series positive clipper with negative bias

2. <u>Series negative clipper</u>

In a series negative clipper a diode is connected in a direction apositive to that of a positive clipper.

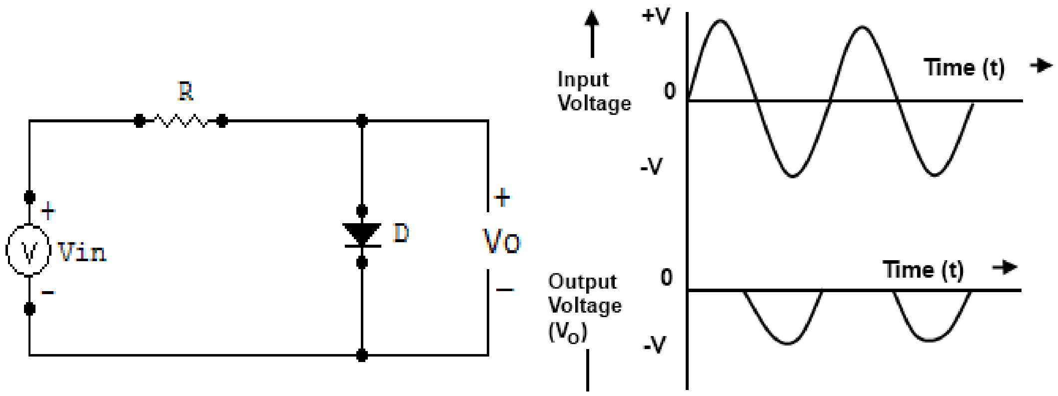
Fig.4. Circuit diagram for series negative clipper



3. Shunt or parallel positive clipper

A parallel clipper circuit uses the same diode theory and circuit operation a resistor and diode are connected in series with the input signal and the output signal is developed across the diode. The output is in parallel with the diode hence the circuit name parallel clipper the parallel clipper can limit either the positive or negative alternation of the input signal.

Fig.5. Circuit diagram for shunt or parallel positive clipper



The diode acts as a closed switch when the input voltage is positive (i.e. Vin> 0 and as an open switch when the input voltage is negative (i.e. Vin < 0) the output waveform is the same as that of a series positive clipper in the parallel clippers.

Shunt or parallel positive clipper with bias

In such a circuit clipping take place during the negative half cycle only when the input voltage ($V_{in} < V_1$) the clipping level can be shifted up or down by varying the bias voltage ($—V_1$).

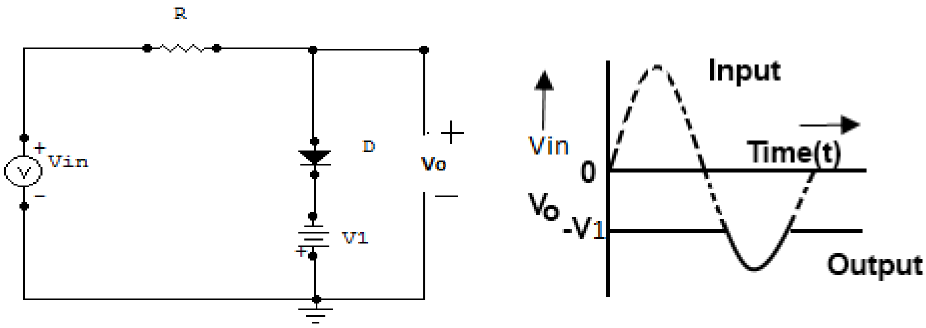


Fig.6. Circuit diagram for parallel positive clipper with positive bias

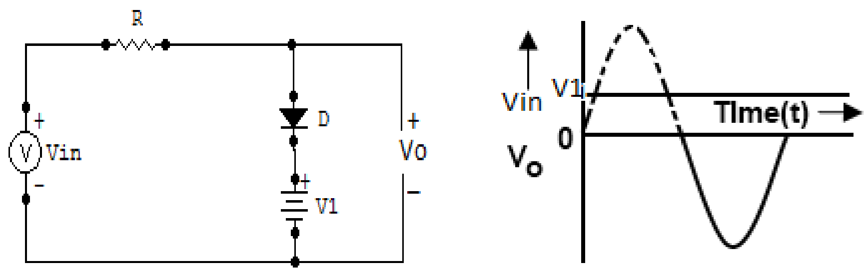


Fig.7. Circuit diagram for parallel positive clipper with negative bias

4. Shunt negative clipper

In a shunt negative clipper a diode is connected in a direction appositive to that of a positive clipper.

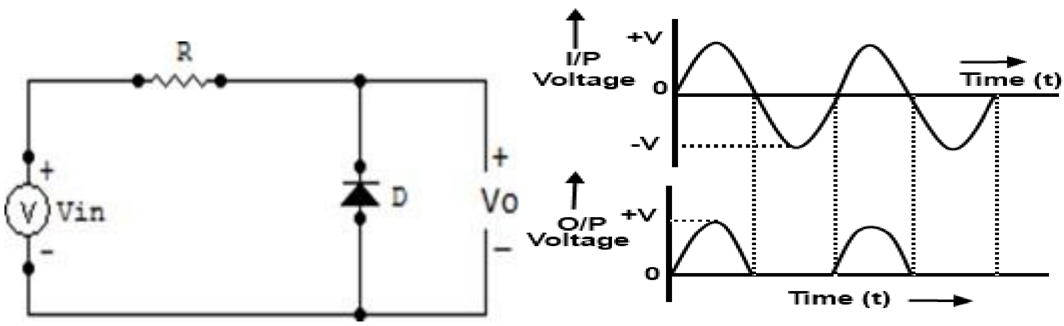


Fig.8. Circuit diagram for shunt negative clipper

Clamping circuits

The *clamping* network is one that will "clamp" a signal to a different dc level. The network must have a capacitor, a diode, and a resistive element, but it can also employ an independent dc supply to introduce an additional shift. The magnitude of R and C must be chosen such that the time constant $\tau = RC$is large enough to ensure that the voltage across the capacitor does not discharge significantly during the interval the diode is non-conducting. Throughout the analysis we will assume that for all practical purposes the capacitor will fully charge or discharge in five timeconstants.

1. Positive clamping circuit

Positive clamping occurs when negative peaks raised or clamped to ground or on the zero level In other words, it pushes the signal upwards so that negative peaks fall on the zero level.

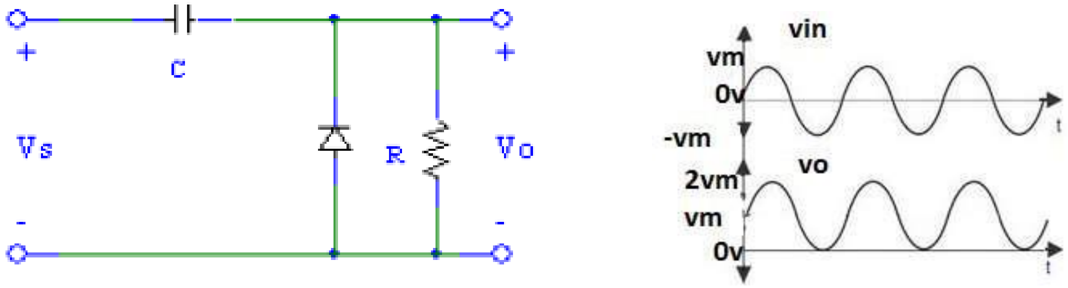
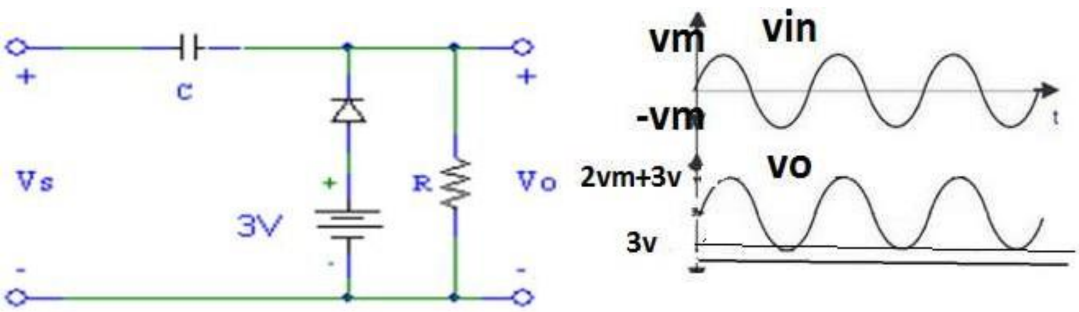


Fig.9. Circuit diagram for positive clamper

2. Positive Biased Clamper:



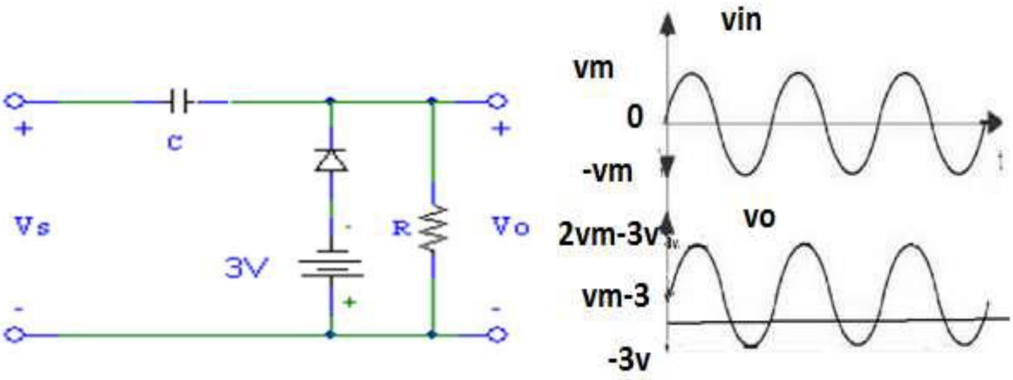


Fig.10. Circuit diagram for positive biased clamper

3. Negative clamping circuit

Negative clamping occurs when positive peaks raised or clamped to ground or on the zero level In other words, it pushes the signal downwards so that the positive peaks fall on the zerolevel.

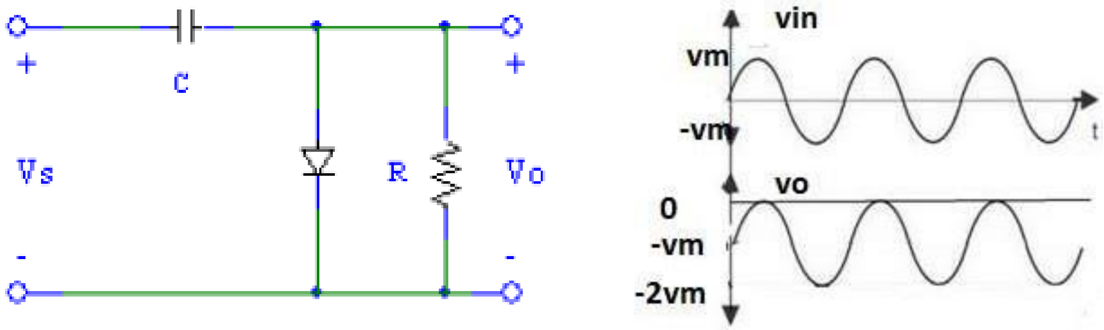


Fig.11. Circuit diagram for negative clamping circuit

4. Negative Biased Clamper:

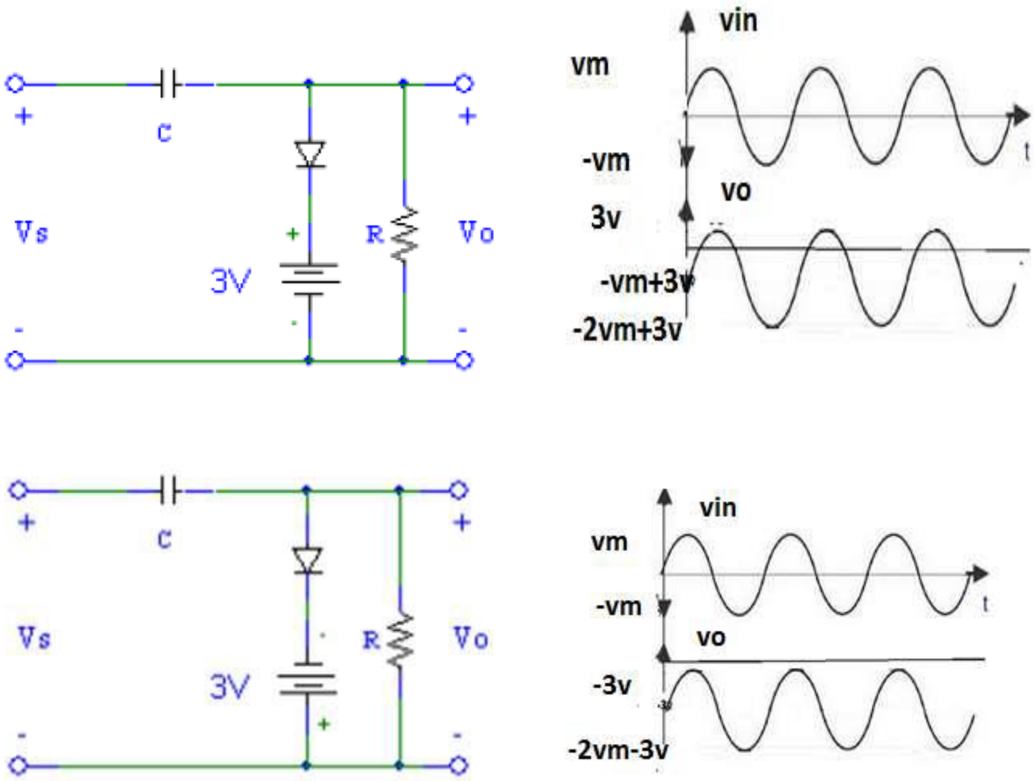


Fig.12. Circuit diagram for negative biased clamper

PROCEDURE:

1. Set up the circuit one by one after testing the components. Apply 5-10V_{pp}sine wave at the input with frequency of 1kHz. Choose the reference voltage in biased clippers within 2-3V to obtain the waveforms shownabove.
2. Observe the input & output waveforms simultaneously on the DSO screen.
3. Note the values & plot the waveforms.

CONCLUSION:

Various clipper and clamper circuits have been realized and output waveforms have been observed.

PRECAUTIONS:

1. Ensure that the polarities of the power supply is properly connected.
2. Keep the input voltage knob of the regulated power supply in minimum position while switching ON or switching OFF the power supply.
3. There should be no loose contacts at the junctions.

QUESTIONS:

1. What are the applications of clippers?
2. Explain the operation of positive and negative clipper?
3. Define clamping operation? And how it is different from clippers?
4. Why capacitors are used in clampers?

EXPERIMENT No. 4

OBJECTIVE:

1. To study the output characteristics of a bipolar junction transistor in Common Emitter configuration.
2. To calculate output impedance from the obtained graph.

Learning Outcome: Develop an understanding of the basics of BJT and its characteristics

COMPONENTS/APPARATUS REQUIRED:

Sl. No.	Component/Apparatus	Type	Range	Quantity
1	Transistor	NPN-BC147		1
2	Resistance	---	1kΩ	2
3	Regulated power supply	---	(0 – 30V), 2A Rating	2
4	Ammeter	Digital	(1-30)mA,(0-500)μA	1
5	Voltmeter	Digital	(0 – 1)V, (0 – 30)V	1
6	Bread board and connecting wires	---		As Required

THEORY:

Bipolar junction transistor (BJT) is a 3 terminal (emitter, base, collector) semiconductor device. There are two types of transistors namely NPN and PNP. It consists of two P-N junctions namely emitter junction and collector junction.

In Common Emitter configuration the input is applied between base and emitter and the output is taken from collector and emitter. Here emitter is common to both input and output and hence the name common emitter configuration. Input characteristics are obtained between the input current and input voltage taking output voltage as parameter. It is plotted between V_{BE} and I_B at constant V_{CE} in CE configuration. Output characteristics are obtained between the output voltage and output current taking input current as parameter. It is plotted between V_{CE} and I_C at constant I_B in CE configuration.

Circuit Diagram:

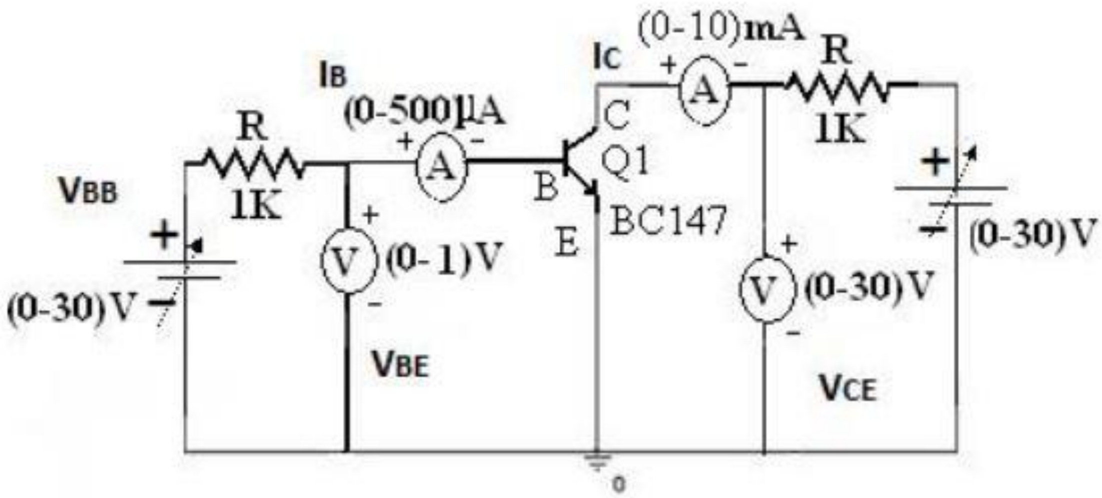


Fig.1. NPN Transistor in Common Emitter (CE) Configuration.

Transistor as a switch:

The Transistor can act as a switch. To operate the transistor as a switch, for **ON** state it has to be operated in saturation region for **ON** state and to be operated in cut off region for **OFF** state.

When the I/P voltage $\mathbf{V_i}$ is negative or zero, transistor is cut-off and no current flows through Rc. Hence $\mathbf{V_0}$ is approximately equal to $\mathbf{V_{CC}}$, When I/P Voltage $\mathbf{V_i}$ is changed to positive voltage, transistor will be driven into saturation. Then $\mathbf{V_0 = V_{cc} - I_C R_C \cong V_{CESat}}$, which is very small voltage.

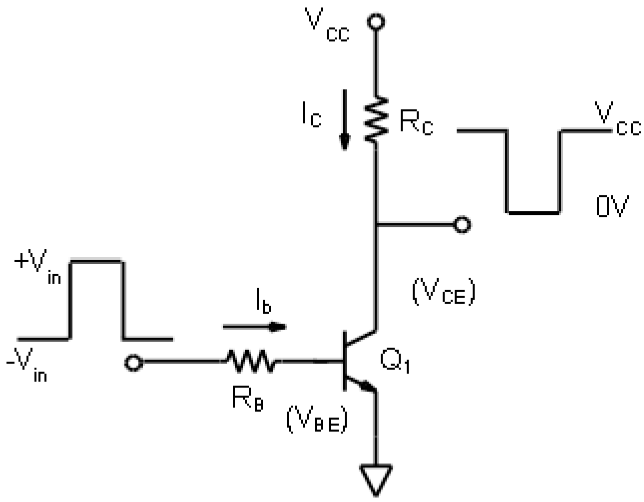


Fig.2. Transistor as a switch

PROCEDURE:

Output Characteristics:

1. Make the connections as per circuit diagram.
2. Vary V_{BB} keeping the base current I_B = 20µA.
3. Vary V_{CC} gradually and note down the readings of collector-current (I_C) and collector-emitter voltage (V_{CE}).
4. Repeat above procedure (atleast thrice) for different values of I_B

OBSERVATION:

For Output Characteristics

I_B = 30 µA		I_B = 60 µA	
V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)

Model Graph:

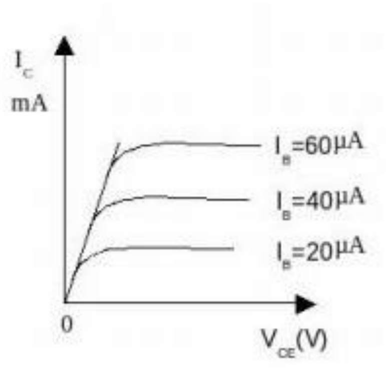


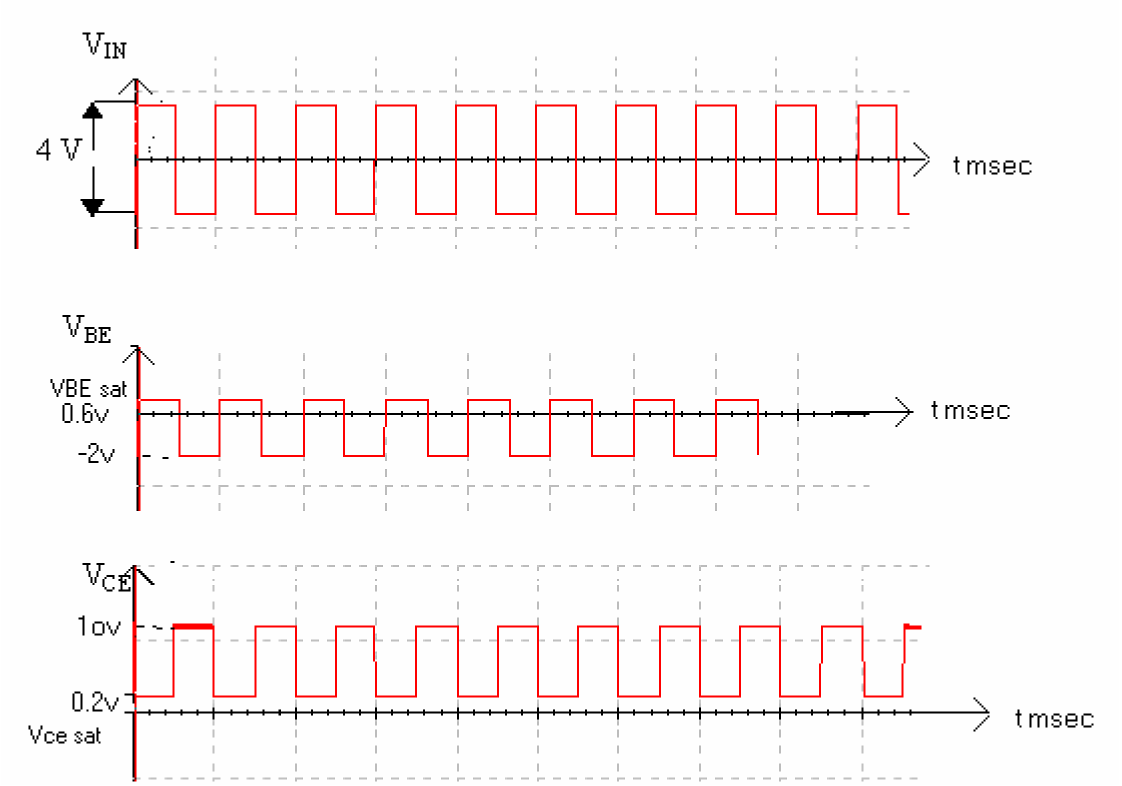
Fig.3. Output Characteristics

Output Impedance = $\Delta V_{EC} / \Delta I_C$, at constant I_B

Procedure for transistor as a switch:

1. Connect the circuit as shown in the above figure with RC = 1 KΩ and RB = 10 KΩ .
2. Apply the Square wave 4Vp-p frequency of 1KHz
3. Observe the waveforms at Collector and Base of the transistor and plot it.

Graph:



CONCLUSION:

The output characteristic of BJT is observed for common emitter configuration. Transistor as a switch is also studied.

PRECAUTIONS:

1. Ensure that the polarity of the power supply is properly connected.
2. Keep the input voltage knob of the regulated power supply in minimum position while switching ON or switching OFF the power supply.
3. There should be no loose contacts at the junctions.

QUESTIONS:

1. Why transistor is called current controlled device?
2. Which of the transistor currents is always the largest? Which is always the smallest? Which two currents are relatively close in magnitude?
3. Define cut-off, saturation and active modes of transistor.
4. Explain how BJT can be used as an amplifier.
5. Why CE configuration is most popular in BJT based amplifier circuits?

EXPERIMENT No. 5

OBJECTIVE:

Inverting/Non inverting action of operational amplifier (op-amp) and its application as Differentiator/Integrator circuits.

Learning Outcome: Acquire an understanding of the main features of an operational amplifier and its important applications

COMPONENTS/APPARATUS REQUIRED:

Sl.No	Apparatus/Components	Range	Quantity
1.	Function Generator	--	1
2.	DSO	--	1
3.	Power Supply	0 – 30 V	1
4.	Op-Amps	IC 741	1
5.	Bread Board		1
6.	Capacitors	As required	
7.	Resistors	As required	
8.	Connecting wires and probes	As required	

THEORY:

An operational amplifier (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this laboratory experiment, we will learn several basic ways in which an op-amp can be connected using negative feedback to stabilize the gain and increase the frequency response. The extremely high open-loop gain of an op-amp creates an unstable situation because a small noise voltage on the input can be amplified to a point where the amplifier in driven out of its linear region. Also unwanted oscillations can occur. Negative feedback takes a portion of output and applies it back out of phase with the input, creating an effective reduction in gain. This closed-loop gain is usually much less than the open-loop gain and independent of it.

An ideal op-amp is usually considered to have the following properties:

- Infinite open-loop gain $G = v_{out} / v_{in}$
- Infinite input impedance R_{in} and so zero input current
- Zero input offset voltage and zero noise
- Infinite bandwidth with zero phase shift and infinite slew rate

- Zero output impedance Rout
- Infinite Common-mode rejection ratio (CMRR).

The most common used IC in Op-Amp is the 741 and it is used in many circuits.

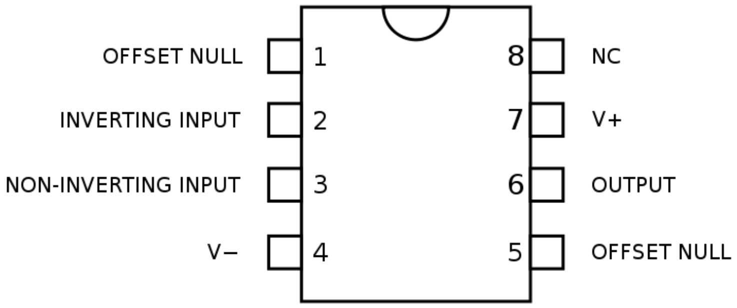


Fig. 1. Pin configuration of op-amp

Non-inverting amplifier:

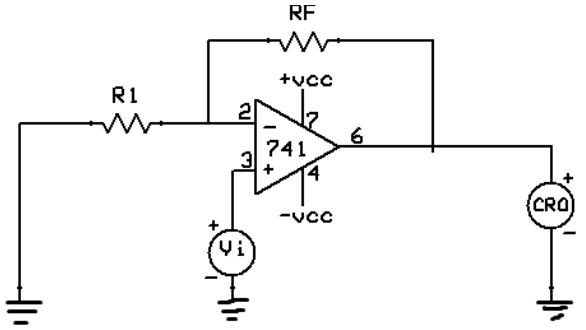


Fig. 2. Non-inverting amplifier configuration of op-amp

The input signal is applied to the non-inverting (+) input. The output is applied back to the inverting (-) input through the feedback circuit (closed loop) formed by the input resistor R_1 and the feedback resistor R_f. This creates –ve feedback as follows. Resistors R_1 and R_f form a voltage-divider circuit, which reduces V_O and connects the reduced voltage V_f to the inverting input.

$$V_f = (\frac{R_1}{R_1 + R_f})Vo$$

The output voltage is expressed as:

$$Vo = \left(1 + \frac{R_f}{R_1}\right)V_{in}$$

The closed-loop gain of the non-inverting amplifier is, thus

$$A_{CL(NI)} = 1 + \frac{R_f}{R_1}$$

Notice that the closed loop gain is

- independent of open-loop gain of op-amp
- set by selecting values of R_1 and R_f

Expression for the input impedance of a non-inverting amplifier can be written as

$$Z_{in(NI)} = (1 + A_{OL}\beta)Z_{in}$$

where, A_{OL} = open-loop voltage gain of op-amp

Z_{in} = internal input impedance of op-amp (without feedback)

β = attenuation of the feedback circuit

Inverting amplifier:

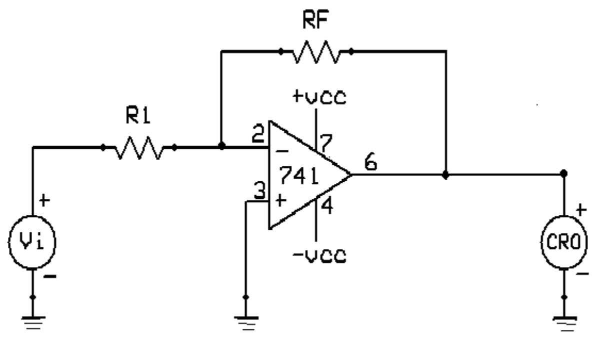


Fig. 3. Inverting amplifier configuration of op-amp

Expression for the output voltage of the inverting amplifier is written as

$$V_O = -\frac{R_f}{R_1}V_{in}$$

The negative sign indicates inversion. The closed-loop gain of the inverting amplifier is, thus

$$A_{CL(I)} = -\frac{R_f}{R_1}$$

The input & output impedances of an inverting amplifier are

$$Z_{in(I)} = R_1$$

$$Z_{O(I)} = \frac{Zo}{1 + A_{OL}\beta}$$

Integrator:

An op-amp integrator simulates mathematical integration which is basically a summing process that determines the total area under the curve of a function ie., the integrator does integration of the input voltage waveform. Here the input element is resistor and the feedback element is capacitor as shown in Fig. 4.

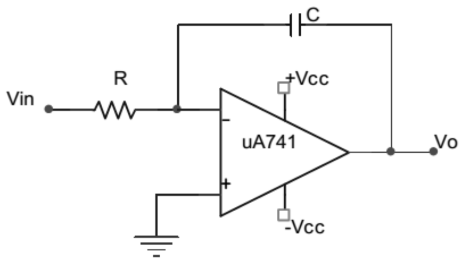


Fig. 4. Basic op-amp integrator

The output voltage is given by

$$V_O = -\frac{1}{RC}\int_o^t V_S dt + V_C(t=0)$$

Where V_C (t=0) is the initial voltage on the capacitor. For proper integration, R_C has to be much greater than the time period of the input signal.

It can be seen that the gain of the integrator decreases with the increasing frequency so, the integrator circuit does not have any high frequency problem unlike a differentiator circuit. However, at low frequencies such as at dc, the gain becomes infinite. Hence the op-amp saturates (ie. the capacitor is fully charged and it behaves like an open circuit). In order to limit the gain of the integrator at low frequencies, usually the feedback capacitor is shunted by a resistance R_f, and hence saturation problems can be avoided. A practical integrator circuit is shown in Fig. 5.

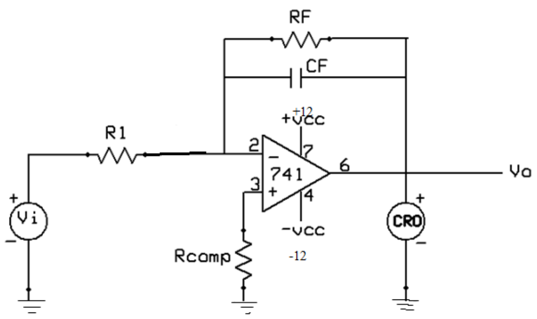


Fig. 5. Practical op-amp integrator

Differentiator:

An op-amp differentiator simulates mathematical differentiation, which is a process of determining the instantaneous rate of change of a function. Differentiator performs the reverse of integration function. The output waveform is derivative of the input waveform. Here, the input element is a capacitor and the feedback element is a resistor. An ideal differentiation is shown in Fig. 6.

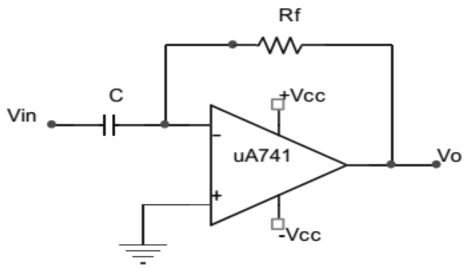


Fig. 6. Basic op-amp differentiator

The output voltage is given by

$$V_O = -RC(\frac{dV_S}{dt})$$

For proper differentiation, R_C has to be much smaller than the time period of the input signal.It can be seen that at high frequencies a differentiator may become unstable and break into oscillation. Also, the input impedance of the differentiator decreases with increase in frequency, thereby making the circuit sensitive to high frequency noise. So, in order to limit the gain of the differentiator at high frequencies, the input capacitor is connected in series with a resistance R_1 and hence avoiding high frequency noise and stability problems. A practical differentiator circuit is shown in Fig. 7.

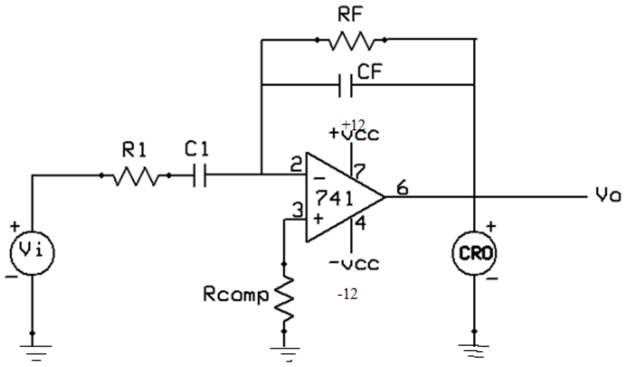


Fig.7. Practical op-amp differentiator

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Apply + V_{cc} and - V_{cc} supply from the DC power supply to the supply terminals of the op-amp.
3. Adjust the amplitude and frequency knobs of the function generator and apply appropriate input voltage to the inverting terminal of the op-amp.
4. Observe the output in the DSO and plot the output voltage waveforms on a graph sheet.

OBSERVATIONS:

op-amp configuration / Circuit	Input signal		Output signal		Voltage gain	
	Amplitude	Frequency	Amplitude	Frequency	Desired value	Observed value
Non-inverting amplifier						
Inverting amplifier						
Integrator						
Differentiator						

CONCLUSION:

Operational amplifier in their inverting and non inverting configurations have been realised and their application as differentiator and integrator circuits have been studied.

PRECAUTIONS:

1. Ensure that proper polarities of power supply are connected at +Vcc and -Vcc of the IC.
2. Avoid loose connections.

QUESTIONS:

1. What is virtual ground concept?
2. Define CMRR, slew rate and input bias current?
3. Explain the effect of negative and positive feedback in op-amp?
4. Explain block and pin diagram of op-amp?

<u>EXPERIMENT No. 6</u>

OBJECTIVE:

Verification and Realization of logic gates using NAND Gate.

Learning Outcome: Develop a basic understanding of logic gates and to appreciate how various kinds of applications can be realized using the universal gates

COMPONENTS/APPARATUS REQUIRED:

Logic trainer kit, logic gates (IC 7400), wires.

THEORY:

Logic gates are electronic circuits which perform logical functions on one or more inputs to produce one output. When all the input combinations of a logic gate are written in a series and their corresponding outputs written along them, then this input/ output combination is called truth table. Various gates and their working is explained here. NAND gate is actually a series of AND gate with NOT gate. If we connect the output of an AND gate to the input of a NOT gate, this combination will work as NOT-AND or NAND gate. Its output is 1 when any or all inputs are 0, otherwise output is 1.

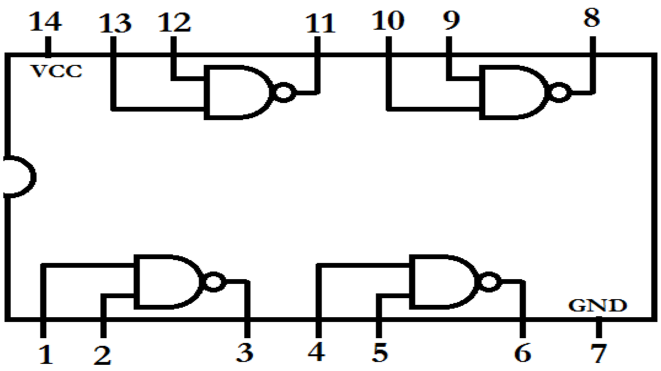
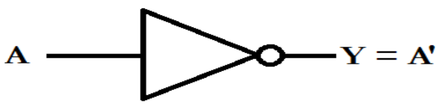


Fig. 1. Pin configuration of IC 7400

NOT Gate:

NOT gate produces the complement of its input. This gate is also called an INVERTER. It always has one input and one output. Its output is 0 when input is 1 and output is 1 when input is 0.

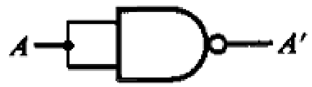


Input(A)	Output(Y=A')
0	1
1	0

(a) (b)

Fig. 2. (a) Symbol of NOT gate (b) Truth table of NOT gate

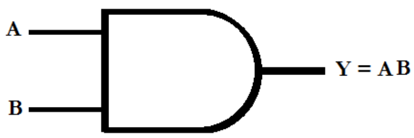
NAND Gate as NOT Gate:



NOT (inverter)

AND Gate:

A NAND produces complement of AND gate. So, if the output of a NAND gate is inverted, overall output will be that of an AND gate.The output is low level when any one of the input is low.



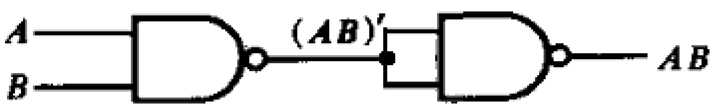
(a)

A	B	Y=AB
0	0	0
0	1	0
1	0	0
1	1	1

(b)

Fig. 3. (a) Symbol of AND gate (b) Truth table of AND gate

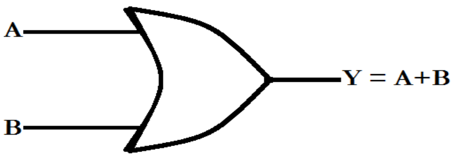
NAND Gate as AND Gate:



AND

OR Gate:

The OR gate performs a logical additional commonly known as OR function. The output is high when any one of the inputs is high.



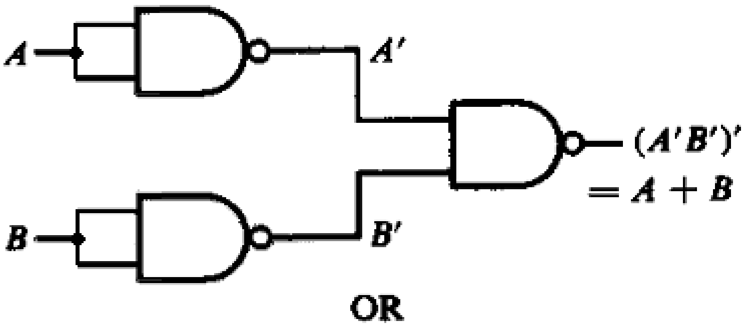
(a)

A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

(b)

Fig. 4. (a) Symbol of OR gate (b) Truth table of OR gate

NAND Gate as OR Gate:



NAND Gate:

The NAND gate is a contraction of AND-NOT. The output is high when both inputs are low and any one of the input low. The output is low when both inputs are high**.**

(a)

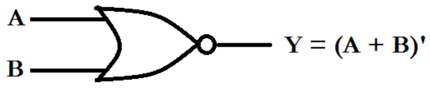
A	B	Y = (AB)′
0	0	1
0	1	1
1	0	1
1	1	0

(b)

Fig. 5. (a) Symbol of NAND gate (b) Truth table of NAND gate

NOR Gate:

A NOR gate is an OR gate followed by NOT gate. So connect the output of OR gate to a NOT gate, overall output is that of a NOR gate.The output is high when both inputs are low.



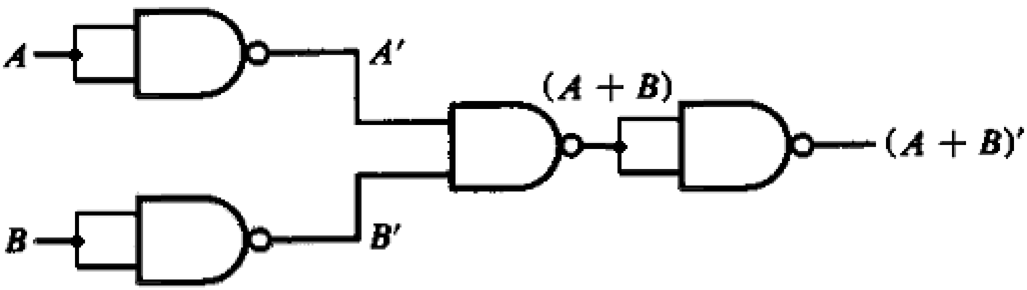
(a)

A	B	Y = (A + B)'
0	0	1
0	1	0
1	0	0
1	1	0

(b)

Fig. 6. (a) Symbol of NOR gate (b) Truth table of NOR gate

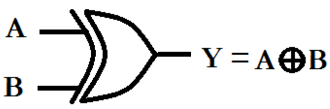
NAND Gate as NOR Gate:



NOR

EX-OR Gate:

EX-OR gate produces an output as 1, when number of 1's at its inputs is odd, otherwise output is 0. It has two inputs and one output.



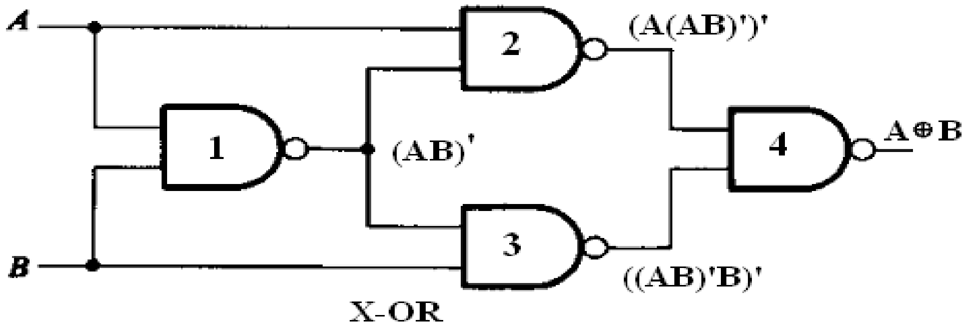
(a)

A	B	Y = A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

(b)

Fig. 7. (a) Symbol of EX-OR gate (b) Truth table of EX-OR gate

NAND Gate as EX-OR Gate:



PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Apply supply voltage and ground potential as per the pin configuration of IC 7400.
3. Give the input data via the switches and observe the output on the LEDs.
4. Verify the truth tables.

CONCLUSION:

Various logic gates have been realised using NAND gate and their truth tables have been verified.

PRECAUTIONS:

1. Follow the pin configurations of the IC carefully while connecting the circuit.
2. Handle the digital trainer kit carefully.

QUESTIONS:

1. What is meant by universal gate?
2. List out the IC's for various logic operations like NAND, NOR, XOR, OR, AND.
3. Design the NAND, NOR, XOR, OR, AND gates using NOR gate.
4. How do you convert XOR gate into a buffer and an inverter?