Chapter 18

ELECTRONICS

LEARNING OBJECTIVES

At the end of this chapter the students will be able to:

- Describe forward and reserve biasing of a p-n junction.
- Understand half and full wave rectification.
- Know the uses of light emitting diode, photo diode and photo voltaic cell.
- Describe the operations of transistor.
- Know current equation and solve related problems.
- Understand the use of transistors as an amplifier and a switch.
- Understand operational amplifier and its characteristics.
- Know the applications of an operational amplifier as inverting and non-inverting amplifier using virtual ground concept.
- Understand the use of an operational amplifier as a comparator e.g., night switch.
- Understand the function of each of the following logic gates: AND, NOT, OR and NAND gates and represent their functions by means of truth tables (limited to a maximum of two inputs).
- Describe how to combine different gates to form XOR and XNOR gates.
- Understand combinations of logic gates to perform control functions.

ELECTRONICS

The branch of physics which deals with motion of electrons (flow of current) through semiconductors is called electronics.

Q.1 What is p-n junction? Also describe forward biased and reverse biased p-n junction.

Ans. **p-n JUNCTION**

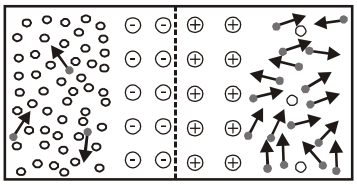
A p-n junction is formed when a crystal of Germinium or silicon is grown in such a way that its one half is doped with trivalent impurity and one half with pentavalent impurity. p-n junction is an important building block of electronics.

Characteristics of p-n Junction

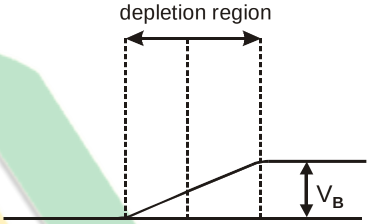
(i) n-region of p-n junction contain free electrons as majority charge carriers.

(ii) p-region contains holes as majority charge carriers.

(iii) Depletion Region



(a)



(b)

Just after the formation of p-n junction. The free electrons in n-region due to their random motion, diffuse into the p-region. As result of diffusion, a chargeless region is formed around the junction in which no charge carriers present which is called depletion region.

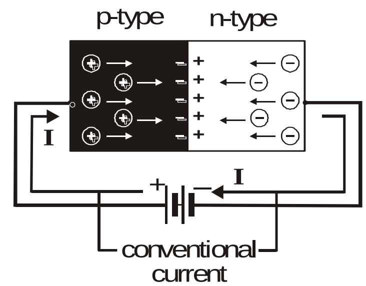
In the figure, black dots represents the free electron and small circles show the holes whereas the circles with +ve and –ve ions which make the depletion region.

(iv) Potential Barrier

Due to the diffusion of electrons from n to p region, a potential difference develops across the depletion region called potential barrier. Its value is 0.7 volt for silicon and 0.3 volt for Germinium. This potential difference stops further diffusion of electrons into the p-region.

Forward Biased p-n Junction

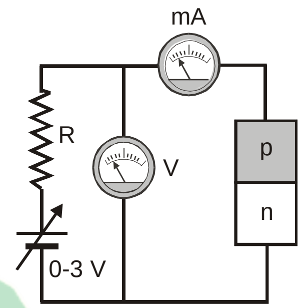
If a battery is connected to a p-n junction such that the p side is positive and n side is negative, then the external potential of battery supplies energy to free electron to n-region and holes in p-region. A current of the order of few milliampere flows across the p-n junction. In this state the p-n junction is said to forward biased.



Variation of Current with Biasing Voltage

Variation of current through junction with biased voltage is studied by the circuit shown in figure. The values of biasing voltage is recorded. The graph is drawn between current and biased voltage which is as shown. It is observed from graph that as forward biased voltage is increased, the current also increases. If ΔV_f is the increase in biased voltage and ΔI_f is the increase in current then the forward resistance of p-n junction is given by

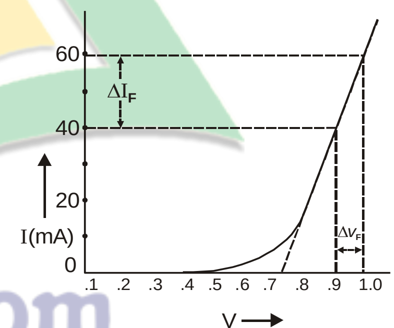
$$r_f = \frac{\Delta V_f}{\Delta I_f}$$



(b)

Fig. There is an appreciable current through the diode when the diode is forward biased.

It is the resistance offered by the p-n junction when it is conducting. The value of this resistance is only a few ohm.



(b)

Reverse Biased p-n Junction

When a battery is connected to p-n junction such that p-side is –ve and n-side is +ve then the p-n junction is reverse biased. In this situation no current flows due to majority charge carriers. However, a very small current due to minority charge carriers flows across the junction which is of the order of few micro amperes. It is known as reverse current or leakage current.

Variation of Current with Biasing Voltage

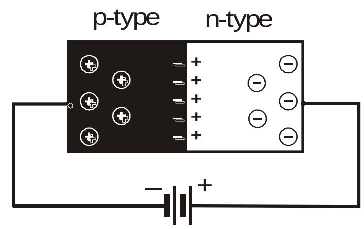
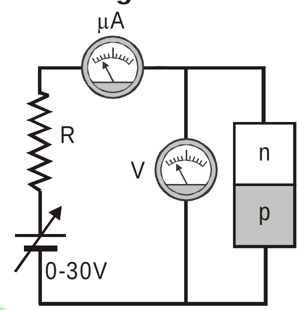


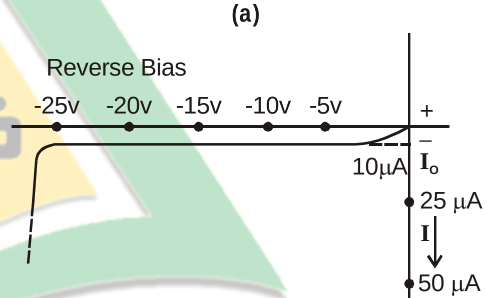
Fig. Under a reversed biased condition there is almost no current through the diode.

Variation of reverse current with applying biasing voltage can be studied in circuit shown in a figure. A graph is drawn between reverse current and biased voltage is as shown. It is seen that reverse voltage increase from zero, the reverse current quickly rises to I_o. As the reverse voltage is further increased, the reverse current remains constant. The resistance offered by p-n junction is very high of the order of several mega ohm.

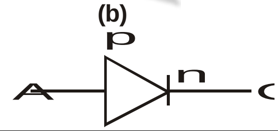
As the reverse voltage is increased, the kinetic energy of the minority charge carriers with which they cross the depletion region also increases till it is sufficient to break a covalent bond. When the covalent bond breaks, more electron hole pairs are created. Thus minority charge carriers begins to multiply due to which the reverse current begins to increase till a point is reached when the junction breaks down and reverse current rises. After break down, the reverse curve will rise to very high value which will damage the junction. p-n junction is also known as semi-conductor diode whose symbolic representation is as shown. The arrow head represents the p-region and known as anode. The vertical line shows the n-region and is known as cathode.



(a)



(b)



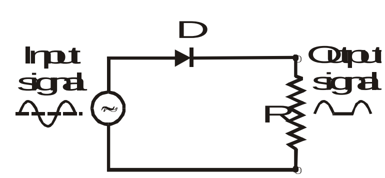
Q.2 What is meant by rectification? Explain the action of semi-conductor diode as half wave rectifier.

Ans. **RECTIFICATION**

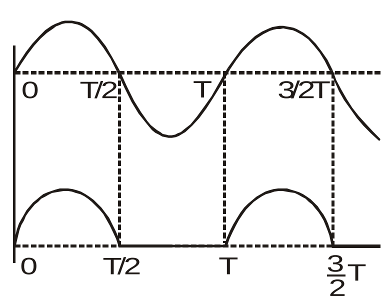
Conversion of alternating current into direct current is called rectification. Semi-conductor diode (p-n junction) is used for rectification. There are two types of rectification

(1) Half wave rectification (2) Full wave rectification

(1) Half Wave Rectification



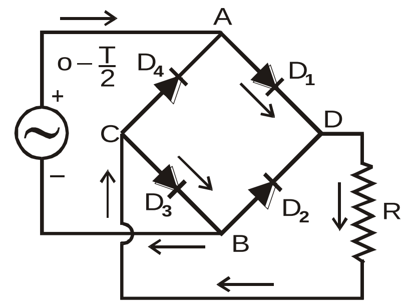
(a)



A half wave rectification is shown in figure. When an alternating voltage of period T called input – (input signed) voltage applied to diode D which is connected in series with resistance R. Half of alternating current cycle are converted into direct current. During +ve half cycle of input alternating voltage. That is 0 → T/2, the diode is forward biased. So, it offers a very low resistance and current flows through R. The flow of current through R causes a potential drops across it. During –ve half cycle T/2 → T the diode is reverse biased and it offers a very high resistance. So, practically no current flows through R and potential drop across R is almost zero. The current through resistance flows in only one direction which means that it is direct current. However this current flows in pulses as shown.

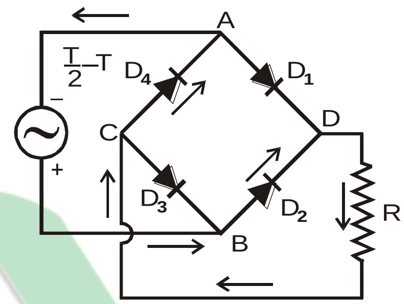
(2) Full Wave Rectification

When both half of the input voltage can be used to send unidirectional current in output circuit, then such rectification is called full wave rectification. Its circuit consist of4 diodes connected in bridge type arrangement as shown in figure. During the +ve half cycle i.e., 0 → T/2, the terminal A of the bridge is +ve with respect to its other terminal B. Now, diode D_1 and D_3 become forward biased and conduct current. Current flows through the circuit as shown in figure.



(a)

A current flows through the circuit in the direction shown by arrows in figure (a). During the negative half cycle i.e., T/2 → T, the terminal A is negative with respect to terminal B, now the diode D_2 and D_4 become forward bias and conduct current A current flows through the circuit in the direction shown by arrows in figure (b). It can be seen that the direction of current flow through the resistance R is the same in both the halves of the cycle. Thus both halves of the alternating input voltage send a unidirectional current. However the output voltage is not smooth but pulsating. It can be made smooth by using a circuit known as filter.



(b)

Q.3 What are the specially designed p-n junction? (OR) What are the application of p-n junction?

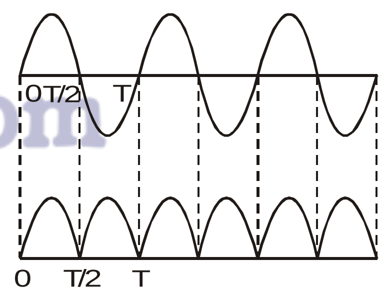
Ans. SPECIALLY DESIGNED p-n JUNCTION

In addition to a use of p-n junction, as rectifier, many types of p-n junction have made for special purposes. The following p-n junctions are most commonly used

(i) Light Emitting Diode (LED)

(ii) Photo-diode

(iii) Photovoltaic cell



Light Emitting Diode

LED are made from semi-conductors. Such as Galium Arsenide Phosphide and galium Arsenide in which potential barrier in n and p side is such that when an electron combine with the hole during forward biased, a photon of visible light is emitted. These diodes are commonly used as small light sources e.g., indictors etc. A specially formed arra of seven LED's is used for displaying digits in electronic devices.

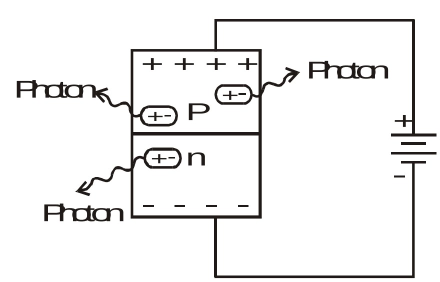


Photo Diode

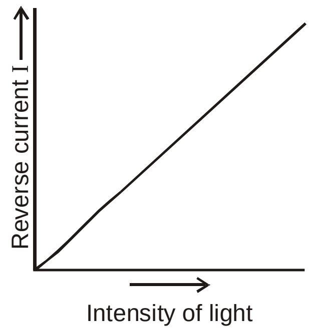
Photo diode is used for detection of light both visible and invisible. It is operated in reverse biased condition. When no light is incident on the junction, the reverse current is almost zero. But when p-n junction is exposed to light, the reverse current increases with the intensity of light as shown. A photo diode can turn its current ON and OFF in nanoseconds. Thus, it is the fastest photo detection device. Applications of photo diode are

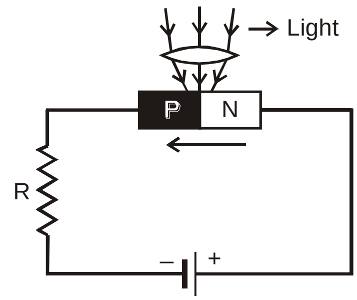
(i) Detection both visible and invisible light.

(ii) Automatic switching.

(iii) Optical communication systems.

(iv) Logic circuits.





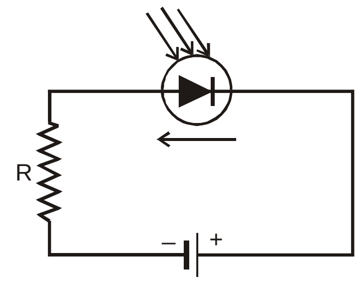
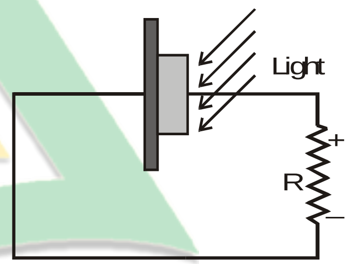


Photo-Voltaic Cell

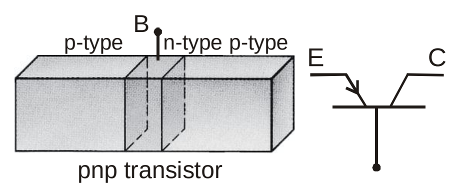


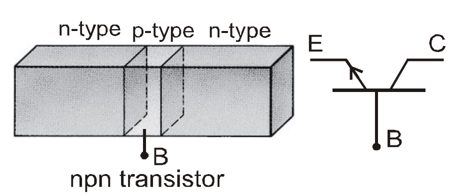
There are p-n junctions in which potential barriers between p and n regions is used to drive a current through external circuit when light is incident on junctions. The current is directly proportional to the intensity of light. A single silicon photo-voltaic cell produces a small voltage of 0.6 volt and a current of the order of few milli ampere. In order to obtain greater power, a series-parallel thousands of small cells are used. They are called photo-voltaic panels and are commonly used in satellites and space stations.

Q.4 What is transistor?

Ans. **TRANSISTORS**

A transistor consist of a single crystal of germinium or silicon which is grown in such a way
shown.





n-p-n and p-n-p Transistors

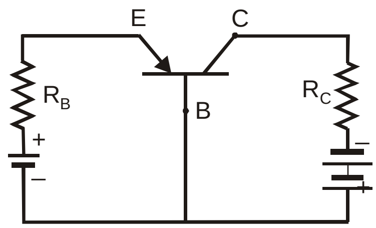
If a thin layer of p-type substance is sandwiched between two n-type substances, the transistor is called **n-p-n transistor**. If a thin n-type substance is sandwiched between two p-type substance, the transistor is called **p-n-p transistor**.

Emitter Base and Collector

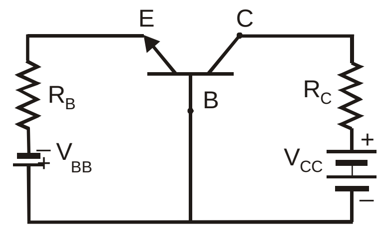
The central region of transistor is known as **base** which is very thin of the order of 10^{-6} meter. The thicker regions on either side of the base are called **emitter and collector**. The emitter and collector have greater strength of impurity. The collector is comparitively larger than emitter. The emitter has greater concentration of impurity as compare to collector.

Operation of Transistor

For normal operation of transistor batteries V_{BB} and V_{CC} are connected in such away that its emitter-base junction is forward biased and collector-base junction is reverse biased. The battery V_{CC} is of much higher value than V_{BB}. Figure shows biasing arrangement for p-n-p transistor. In actual partice n-p-n transistors is generally used.



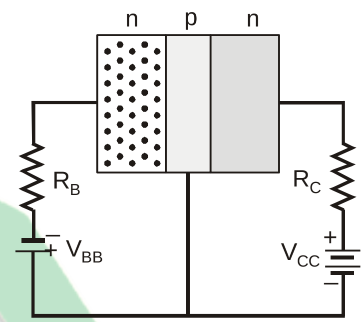
p-n-p



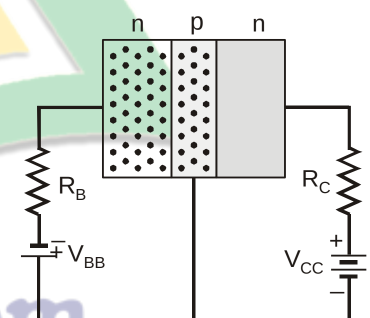
n-p-n

Current Flow in a n-p-n Transistor

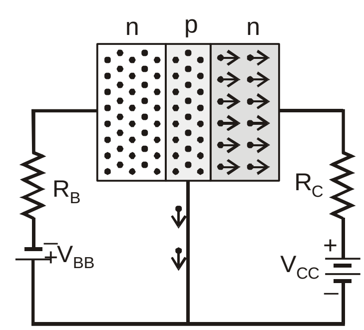
Figure (a) shows a n-p-n transistor at the instant when the biasing voltage is applied. Electrons in the emitter have not yet entered the base region. After the application of the biasing voltage, emitter base junction is forward biased, so emitter injects a large number of electrons in base region (Figure b). These free electrons in the base can flow in either of two directions. They can either flow out of the base to the positive terminal of V_{BB} or they can be attracted towards the collector because of battery V_{CC}. Since the base is extremely thin, very few electrons manage to recombine with holes and escape out of the base. Almost all of the free electrons injected from the emitter into the base are attracted into the collector by the large positive V_{CC} (Figure c). Thus, in a normally biased transistor due to above mentioned flow of electrons, we can say, that an electronic current I_E, flows from the emitter into the base. A very small part of it, current I_B, flows out of the base, the rest of it I_C flows out of the collector (Figure).



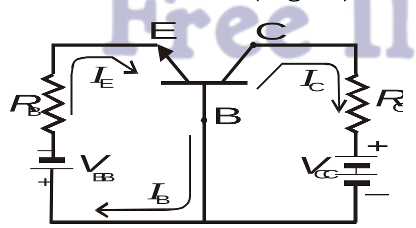
(a)



(b)



(c)



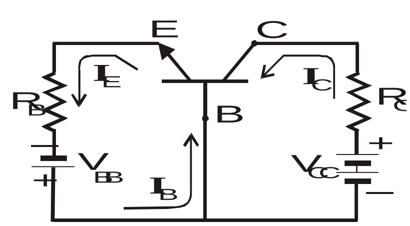
The flow of conventional current is shown in figure. In future we will use conventional current only. From the figure, it can be seen that

$$I_E = I_C + I_B \qquad \text{...... (i)}$$

As very few electrons flow out of base, so I_B is very small as compared to I_C.

It is also found that for a given transistor the ratio of collector current I_C to base current I_B is nearly constant i.e.,

$$\beta = \frac{I_C}{I_B} \qquad \text{...... (ii)}$$



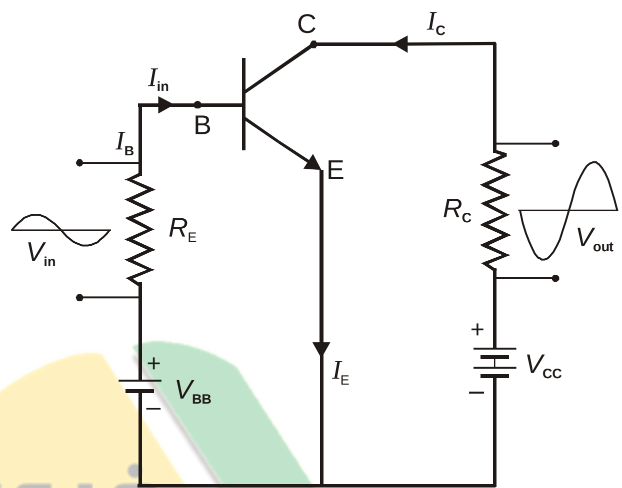
The ratio β is called current gain of transistor. Its value is quite large of the order of hundreds. Eq. (i) and (ii) are fundamental equations of all transistors.

Q.5 *How is it used as an amplifier? Give its circuit diagram. Deduce the relation for its voltage gain.*

Ans. TRANSISTOR AS AN AMPLIFIER

Conversion of low voltage input into a large voltage output is called **amplification**.

In majority of electronic circuits, transistors are basically used as amplifiers. An amplifier is thus the building block of every complex electronic circuit. It is for this reason that study of transistor amplifier is important.



The circuit in figure is a transistor voltage amplifier. The battery V_{BB} forward biases the base-emitter junction and V_{CC} reverse biases the collector-base junction. V_{BE} and V_{CE} are the input and output voltages respectively. The base current is

$$I_B = \frac{V_{BE}}{r_{ie}}$$

where r_{ie} is base emitter resistance of the transistor. The transistor amplifies it β times. So

$$I_C = \beta I_B = \beta \frac{V_{BE}}{r_{ie}}$$

The output voltage $V_o = V_{CE}$ is determined by applying KVL equation in the output loop which gives

$$V_{CC} = I_C R_C + V_{CE} \quad \text{or} \quad V_{CE} = V_{CC} - I_C R_C$$

Substituting the value of I_C and replacing V_{CE} by V_o.

$$V_o = V_{CC} - \beta \frac{V_{BE} R_C}{r_{ie}} \qquad \ldots\ldots (a)$$

When a small signal voltage V_{in} ... the input terminal B, the input voltage changes from V_{BE} to $V_{BE} + \Delta V_{in}$. This causes a little change in base current from I_B to $(I_B + \Delta I_B)$ due to which the collector current changes from I_C to $(I_C + \Delta I_C)$. As the collector current changes, the voltage drop across R_C i.e., $(I_C R_C)$ also changes due to which the output voltage V_o changes by ΔV_o. Substituting the changed values in equation (a).

$$V_o + \Delta V_o = V_{CC} - \beta (V_{BE} + \Delta V_{in}) \frac{R_C}{r_{ie}} \qquad \ldots\ldots (b)$$

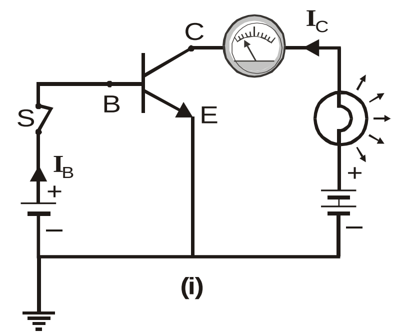
Substracting eq. (a) from eq. (b)

$$\Delta V_o = -\beta \, \Delta V_{in} \frac{R_C}{r_{ie}}$$

$$\frac{\Delta V_o}{\Delta V_{in}} = -\beta \frac{R_C}{r_{ie}}$$

Therefore the gain of the amplifier is

$$A = \frac{\Delta V_o}{\Delta V_{in}} = -\beta \frac{R_C}{r_{ie}}$$



The value of the factor $\beta \frac{R_C}{r_{ie}}$ is of the order of hundreds, so the input voltage is amplified. The negative sign shows that there is a phase shift of 180° between the input and the output signals. This is also called common emitter amplifier.

Q.6 How a transistor is used as a switch?

Ans. **TRANSISTOR AS A SWITCH**

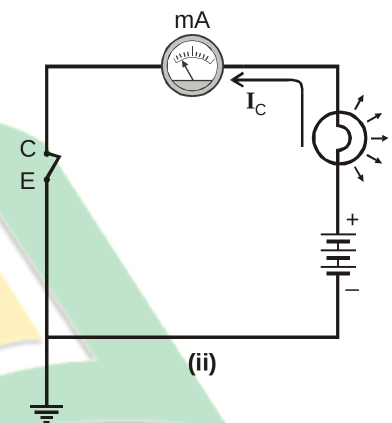
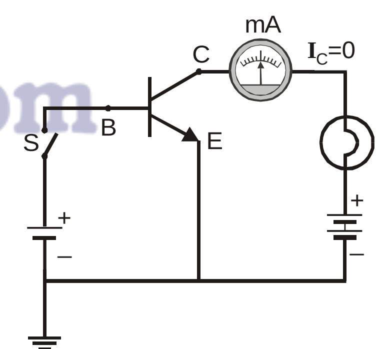


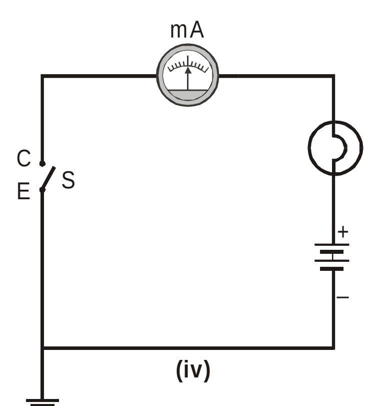
Fig. (i) shows a circuit in which transistor is used as a switch. The collector (C) and emitter (E) behaves as terminals of switch. The circuit in which current is to be turned OFF and ON is connected across these terminals. The base (B) and emitter (E) act as control terminals which decide the state of the switch.

Working

In order to turn on the switch a large P.D V_B is applied between control terminals B.E. This inject a large current I_B into base circuit due to which very large current I_C began to flow in C.E circuit. This value of large current is possible only when resistance between C and E drops to such a small value that the potential drops across C.E is nearly 0.1 volts. In figure (i) ammeter is at ground potential. So, we can suppose that collector is also at ground potential and C.E circuit can be drawn as shown in figure (ii). C.E switch is closed and bulb glows due to large value of collector current.



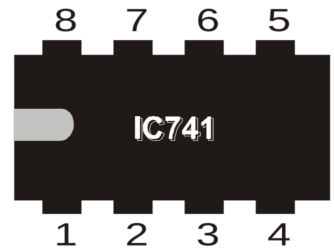
To turn the switch OFF, the base current I_B is set zero by opening the base circuit as shown in figure (iii). As I_B become zero and C.E circuit becomes open. Now the resistance between C and E nearly becomes infinite which open the C.E switch as shown in figure (iv).



Q.7 Explain operational amplifier.

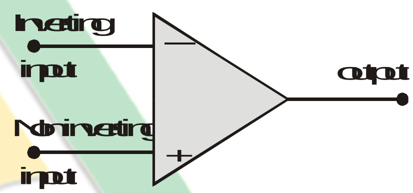
Ans. **OPERATIONAL AMPLIFIER**

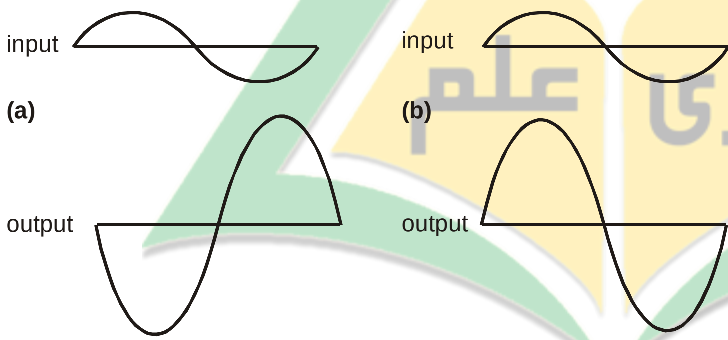
It is an important electronic circuit that is used in almost every electronic devices. So, instead of making amplifier circuit by discrete components, the whole amplifier is integrated on a small silicon chip and enclosed in a capsule. Pins connected with working terminals such as input, output and power supply project outside the capsule. The enclosed circuit of amplifier is used by making required connection with these (three) pins. Such an integrated amplifier is known as operational amplifier.



The operational amplifier in symbolic form is shown in figure. It has 2 input terminals. One is known as inverting input (–) and the other is known as non-inverting input (+). A signal that is applied at inverting (–) input, appears after amplification, at the output terminal with a phase shifted to 180°.

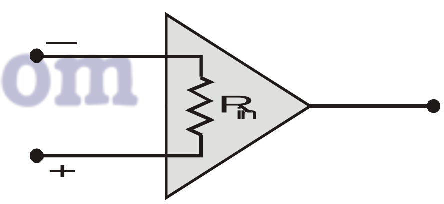
A signal that is applied at non-inverting (+) input is amplified at output without any phase change. An operational amplifier has a large no of characteristics.





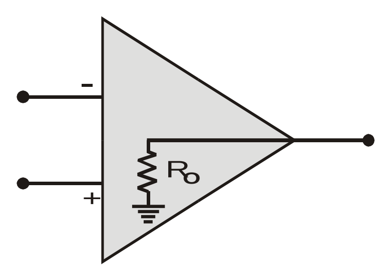
Input Resistance

It is the resistance between +ve and –ve inputs of the amplifier as shown in figure. Its value is very high of the order of several mega ohm. Due to high input resistance R_{in}, practically no current flows between two input terminals. It is very important feature of operational amplifiers.



Output Resistance

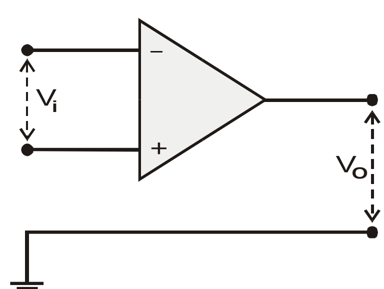
It is the resistance between the output terminals and ground. Its values is only a few ohms.



Open Loop Gain

It is the ratio of output voltage V_o to the voltage difference between inverting and non-inverting inputs when there is no external connection between the output and inputs that is

$$A_{OL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$



The open loop gain of the amplifier is very high. It is of the order of 10^5.

Q.8 Draw the circuit diagram of inverting amplifier and label it. Evaluate a relation for its gain.

Ans. OP-AMP AS INVERTING AMPLIFIER

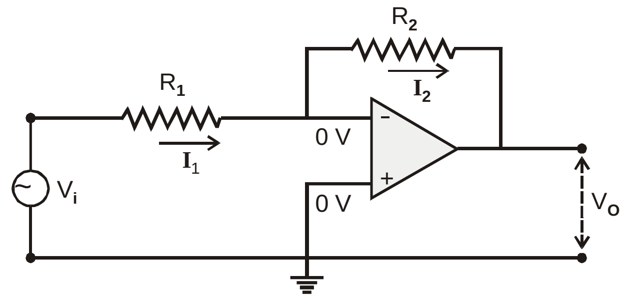


Figure shows the circuit of an op-amps when used as an inverting amplifier. The input signal V_i which is to be amplified, is applied at inverting terminal (–) through a resistance R_1, V_o is its output. The non-inverting terminal (+) is grounded, i.e., its potential is zero. We know that A_{OL} is very high, of the order of 10^5 for any value of V_o, $V_+ - V_- \approx 0$ or $V_+ \approx V_-$. Since V_+ is at ground so V_- is virtually at ground potential i.e., $v_- \approx 0$. Referring to figure.

$$\text{Current through } R_1 = I_1 = \frac{V_i - V_-}{R_1} = \frac{V_i - 0}{R_1} = \frac{V_i}{R_1}$$

$$\text{Current through } R_2 = I_2 = \frac{V_- - V_o}{R_2} = \frac{0 - V_o}{R_2} = -\frac{V_o}{R_2}$$

As practically no current flows between (–) and (+) terminals, so according to Kirchhoff's current rule $I_1 = I_2$

$$\text{or} \quad \frac{V_i}{R_1} = -\frac{V_o}{R_2} \quad \text{or} \quad \frac{V_o}{V_i} = -\frac{R_2}{R_1}$$

As V_o/V_i is defined as gain G of the inverting amplifier, so

$$G = -\frac{R_2}{R_1} \qquad \text{...... (i)}$$

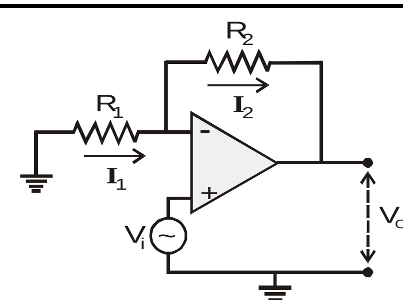
The negative sign indicates that the output signal is 180° out of phase with respect to input signal. It is interesting to note that the closed loop gain depends upon the two externally connected resistances R_1 and R_2. The gain is independent of what is happening inside the amplifier.

If $R_1 = 10\ k\Omega$ and $R_2 = 100\ k\Omega$, the gain of the amplifier is

$$G = \frac{V_o}{V} = \frac{-R_2}{R} = \frac{-100\ \Omega}{10\ k\Omega} = -10$$

Q.9 Draw the circuit diagram of non-inverting amplifier and label it. Evaluate a relation for its gain.

Ans. OP-AMP AS NON-INVERTING AMPLIFIER



The circuit diagram of op-amp as non-inverting amplified is shown in figure. In this case the input signal V_i is applied at the non-inverting terminal (+). As explained earlier, due to high open loop gain of amplifier, the inverting (–) and non-inverting (+) inputs are virtually at the same potential. That is,

$$V_- \approx V_+ = V_i$$

Also, from figure

$$\text{Current through } R_1 = I_1 = \frac{0 - V_-}{R_1} = \frac{0 - V_i}{R_1} = \frac{-V_i}{R_1}$$

Current through $R_2 \quad = I_2 = \dfrac{V_- - V_o}{R_2} = \dfrac{V_i - V_o}{R_2}$

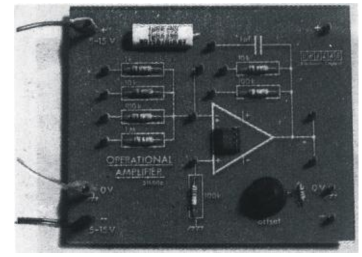
As practically no current flows between (–) and (+) terminals, so by Kirchhoff's current rule $I_1 = I_2$.

Hence
$$\frac{-V_i}{R_1} = \frac{V_i - V_o}{R_2}$$

or
$$V_i\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{V_o}{R_2}$$

or
$$\text{Gain} = \frac{V_o}{V_1} = 1 + \frac{R_2}{R_1} \quad \text{...... (ii)}$$

For Your Information

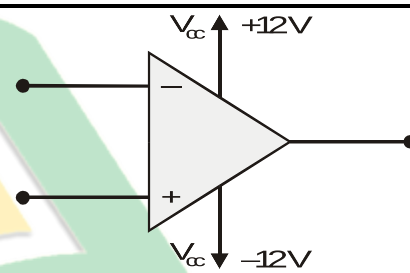


An op amplifier – The circuits in the black box.

Again the gain of the amplifier is independent of the internal structure of the op-amp. It just depends upon the two externally connected resistances R_1 and R_2. The positive sign of gain indicates that the input and output signals are in phase.

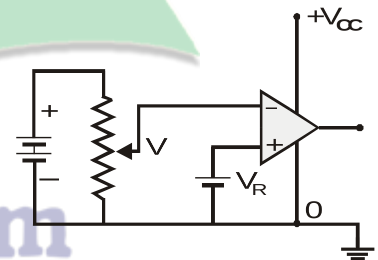
Q.10 Write a note on op-amp as a comparator.

Ans. **OP-AMP AS A COMPARATOR**



Op-amp usually requires two power supplies of equal voltage but of opposite polarity. Most op-amp operate with $V_{CC} = \pm 12V$ supply.

As the open loop gain of the op-amp is very high (10^5), even a very small potential difference between the inverting and non-inverting inputs is amplified to such a large extent that the amplifier gets saturated, i.e., its output either becomes equal to $+V_{CC}$ or $-V_{CC}$. This feature of op-amp is used to compare tw voltages. Figure shows the circuit of an op-amp used as comparator. V_R is reference voltage which is connected with (+) terminal and V is the voltage which is to be compared with the reference V_R. It is connected with (–) terminal.



When $\quad V_- > V_+$ or $V > V_R$, then $V_o = -V_{CC}$

and if $\quad V_- < V_+$ or $V < V_R$, then $V_o = +V_{CC}$

Q.11 Explain comparator as a night switch.

Ans. **COMPARATOR AS A NIGHT SWITCH**

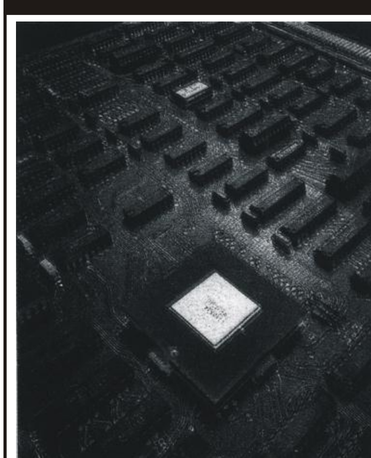
Suppose it is required that when intensity of light falls below a certain level, the street light is automatically switched on. This can be accomplished by using op-amp as a comparator. In figure resistances R_1 and R_2 form a potential divider. The potential drop across R_2 provides the reference voltage V_R to the (+) input of the op-amp. Thus

$$V_R = \frac{R_2}{R_1 + R_2} \times V_{CC} \quad \text{...... (i)}$$

LDR is a light dependent resistance. The value of its resistance R_L depends upon the intensity of light falling upon it. R_L and R_3 form another potential divider. The potential drop across R_3 is V' which is given by

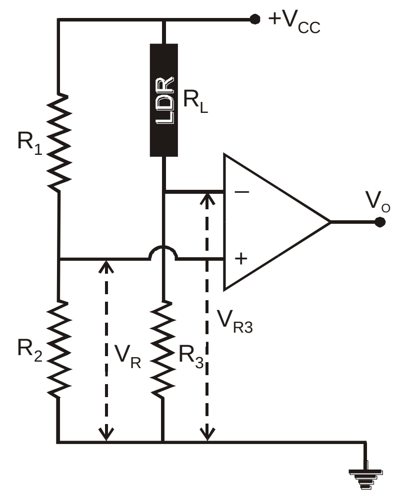
$$V' = \frac{R_3}{R_L + R_3} \times V_{CC} \quad \text{...... (ii)}$$

Do You Know?



Integrated circuit (IC) chips are manufactured on wafers of semi-conductor material.

V′ provides the voltage to (–) input of the op-amp. V′ will not be a constant voltage but it will vary with the intensity of light. During day time, when light is falling upon LDR, R_L is small. According to eq. (ii), V′ will be large such that $V' > V_R$ so that $V_o = -V_{CC}$. The output of the op is connected with a relay system which energizes only when $V_o = +V_{CC}$ and then it turn on the street lights. Thus when $V_o = -V_{CC}$, the light will not be switched ON.



As it gets darker, R_L becomes larger and V′ decreases. When V′ becomes just less than V_R, the output of op-amp switches to $+V_{CC}$ which energizes the relay system and the street lights are turned ON.

Q.12 What is digital system?

Ans. **DIGITAL SYSTEM**

Digital system is that one which deals quantities or variables which have two discreet values or states.

For example

(i) A switch can be either open or closed.

(ii) The answer of a question can either be yes or no.

(iii) A certain statement can either true or false.

(iv) A bulb can be either off or on.

Various designs are used to represent the two quantized states of such quantities. The most common of these are

	1	2	3	4	5	6
One of the states	True	High	1	Yes	On	Closed
The other state	False	Low	0	No	Off	Open

Mathematical calculations of these quantities can be best carried if they are represented by binary regions 1 and 0. In describing functions of digital systems, a closed switch will be shown as 1 and open switch will be shown as 0. Similarly a lighter bulb will be described as 1 and off bulb will be described as 0.

Boolean Algebra

For mathematical calculations, we need two basic mathematical operations addition and subtraction. Similarly, in digital system, we require special algebra known as Boolean algebra for the calculation of quantities which have values 1 and 0, 0 and 0. Boolean algebra is based on three basic operations.

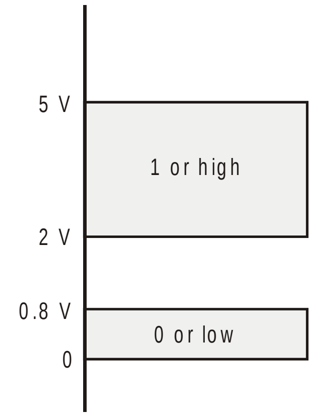
- ♦ AND operation
- ♦ OR operation
- ♦ NOT operation

These operations are implemented in the study of logic states.

Q.13 Describe the fundamental logic gates.

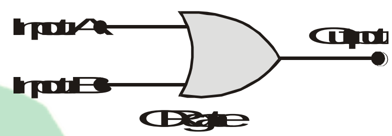
Ans. **FUNDAMENTAL LOGIC GATES**

The electronic circuit which implement the various logic operation are known as logic gates. In these gates, high and low states, 1 and 0 states are supposed by certain voltage levels. One particular voltage level represent a high (1) and another voltage level represent a low (0). For example figure show the range 1 and zero level for a certain type of digital gates. Thus, if voltage of 3.5 volt is applied to a gate. It will accept it as high or 1 and if a voltage of 0.5 volt is applied to a gate will accept it as low or 0.



OR Gate

It is symbolically represent as shown



It has two or more inputs and a signal output X. The output have value 1 when at least one of its inputs A and B is at one. Thus output will be 0 only when both the inputs are zero. Thus it implements the truth table of OR operation as shown. The mathematical notation for OR operation is

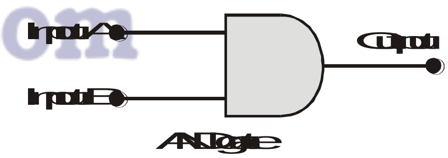
$$X = A + B$$

TRUTH TABLE

A	B	Output X
0	0	0
1	0	1
0	1	1
1	1	1

AND Gate

The AND gate is symbolically written as shown



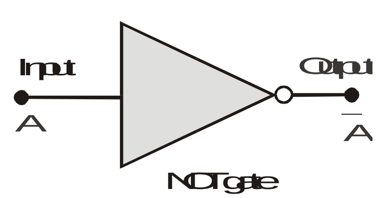
It has two or more inputs and single output. It is designed in such that it implements of truth table of AND operation i.e., its output is only one when both of its inputs are at 1 and for all other combination of the values of inputs, and the output is zero. The mathematical expression for AND gate is

$$X = A . B$$

A	B	Output X
0	0	0
1	0	0
0	1	0
1	1	1

NOT Gate

It performs the operation of inversion or complementation that is why it is also known as inverter. It changes a logic level to its opposite level i.e., it changes 1 to zero (0) and zero (0) to 1. The symbolic representation of NOT gate is shown in figure.



Whenever a bar is placed on any variable. This shows that value of variable have been inverted. For example,

$$\overline{1} = 0 \quad \text{or} \quad \overline{0} = 1$$

The bubble (0) indicates the operation of inversion. Mathematical symbol for NOT gate is

$$X = \overline{A}$$

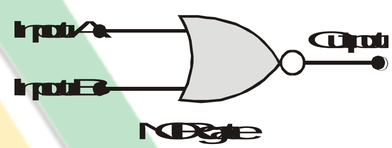
The truth table for NOT gate are as shown.

TRUTH TABLE	
A	**Output**
1	0
0	1

Q.14 Draw the symbols of logic gates for the following Boolean functions. Write their respective truth labels $X = \overline{A + B}$, $X = \overline{A \cdot B}$.

Ans. **OTHER LOGIC GATES**

NOR Gate

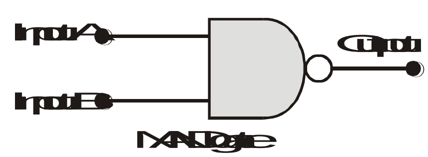


In NOR gate, the output of OR gate is inverted. Its symbol is shown in figure. And its truth table is as given, the mathematical symbol for NOR operation is

$$X = \overline{A + B}$$

TRUTH TABLE		
A	**B**	**Output X**
0	0	0
1	0	0
0	1	0
1	1	1

NAND Gate



In NAND gate the output of AND gate is inverted. Its symbol is shown in figure. The bubble shown in figure tells that output of AND gate is inverted. The truth table implemented by it shown. The mathematical symbol of NAND operation is that

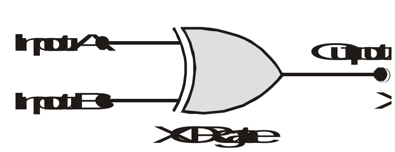
$$X = \overline{A \cdot B}$$

TRUTH TABLE		
A	**B**	**Output X**
0	0	1
0	1	1
1	0	1
1	1	0

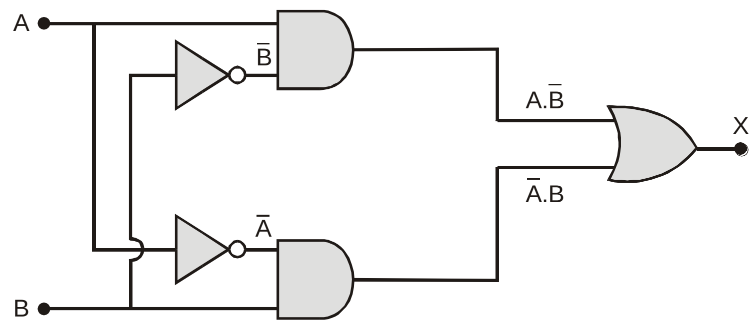
Exclusive OR Gate

Consider, a boolean function X of a variable A and B such that

$$X = A\overline{B} + \overline{A}B$$



The first term of function X is obtained by ANDing the variable A with NOT of B. The second term is NOT of A and AND of B. The function X is obtained by ORing these two term. It can be constructed by combining OR, AND and NOT gate according to figure. The value of function X is obtained by drawing truth table which gives the value of X for value of variable A and B.



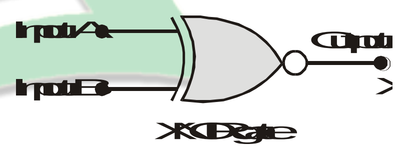
Making an XOR gate

The value of X is zero then the output have the same values and it is 1 when input have different values. It can be verified that the above circuit implement the truth table.

TRUTH TABLE		
A	**B**	**Output**
0	0	0
1	0	1
0	1	1
1	1	0

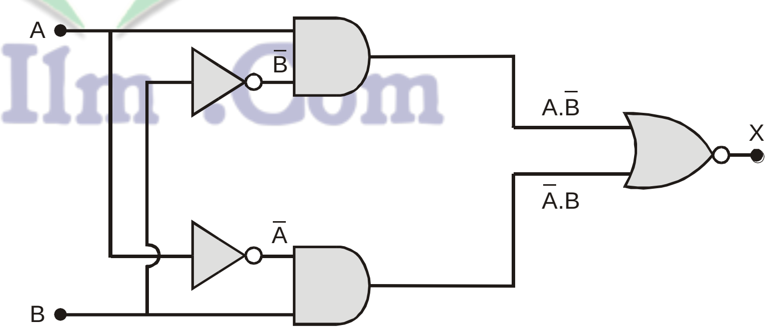
Exclusive-NOR Gate (XNOR)

The exclusive NOR gate is obtained by inverting the output of a XOR gate. Its symbol is shown in figure. The bubble shown at the output in this figure shows that the output of XOR gate has been inverted. So its Boolean expression is given by



$$X = \overline{A\overline{B} + \overline{A}B}$$

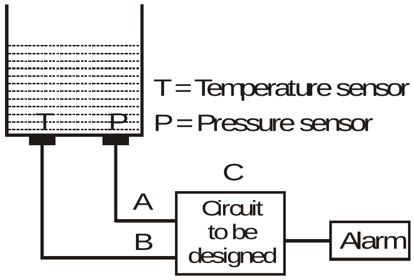
The truth table of XNOR gate is given in the table. Its output is 1 when its two inputs are identical and 0 when the two inputs are different. Like XOR gate, it is also constructed by a combination of NOT, AND and NOR gates by the sc in figure.



TRUTH TABLE		
A	**B**	**Output**
0	0	1
0	1	0
1	0	0
1	1	1

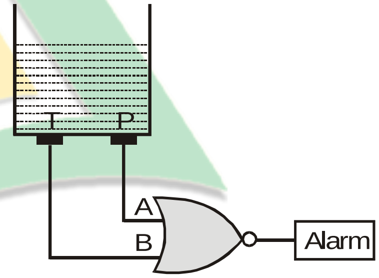
APPLICATIONS OF GATES IN CONTROL SYSTEMS

Gates are widely used in control systems. They control the function of the system by monitoring some physical parameter such as temperature, pressure or some other physical quantity of the system. As gates operate with electrical voltages only, so some devices are required which can convert various physical quantities into electric voltage. These devices are known as sensors. For example, in the example of night switch, Light Dependent Resistance (LDR) is a sensor for light because it can convert changes in the intensity of light into electric voltage. A thermister is a sensor for temperature. A microphone is a sound sensor. Similarly there are level sensors which give an electrical signal when the level of liquid in a vessel attains a certain limit. One such application is described here. For example sensors are used to monitor the pressure and temperature of a chemical solution stored in a vat. The circuitry for each sensor is such that it produces a HIGH, i.e., 1 when either the temperature or pressure exceeds a specified value. A circuit is to be designed which will ring an alarm when either the temperature or pressure or both cross the maximum specified limit. The alarm requires a LOW (0) voltage for its activation.



(i)

TABLE		
A	**B**	**C**
0	0	1
0	1	0
1	0	0
1	1	0



(ii)

The block diagram of the problem is shown in figure in which C is the circuit to be designed. Its inputs A and B are fed by the temperature and pressure sensors T and P fitted into the vat. Whenever output of the circuit C is LOW, the alarm is activated. So the circuit C should be such that its output is 0 as soon as the limit for temperature or pressure is exceeded, i.e., when A = 0, B = 1 or when A = 1, B = 0 or when A = B = 1. The output of C should be HIGH when temperature and pressure are within the specified limit, i.e., when A = B = 0. This gives the truth table which the circuit C has to implement. It can be seen that it is the truth table of NOR gate. So the circuit C in figure should be a NOR gate as shown in figure (ii).

SOLVED EXAMPLES

EXAMPLE 18.1

In a certain circuit, the transistor has a collector current of 10 mA and base current of 40 μA. What is the current gain of the transistor?

Data

Collector current = I_C = 10 mA

= 10×10^{-3} A

Base current = I_B = 40 μA

= 40×10^{-6} A

To Find

Current gain = β = ?

SOLUTION

By formula

$$\beta = \frac{I_C}{I_B} = \frac{10 \times 10^{-3}}{40 \times 10^{-6}} = 250$$

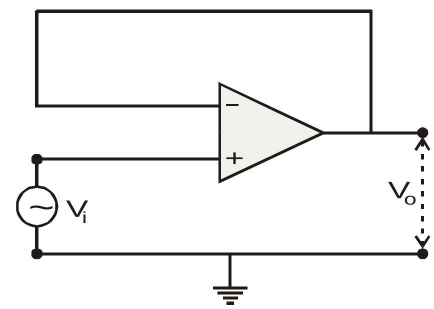
Result

Current gain = 250

EXAMPLE 18.2

Find the gain of the circuit as shown in figure.

SOLUTION



As the input signal V_i is connected to non-inverting input (+), so op-amp used as a non-inverting amplifier thus $R_1 = \infty$ and R = 0

By formula

$$\text{Gain} = 1 + \frac{R_2}{R_1} = 1 + \frac{0}{\infty}$$

$$= 1 + 0 = 1$$