BASIC ELECTRONICS

UNIT-3

5 MARKS OR 7 MARKS QUESTIONS

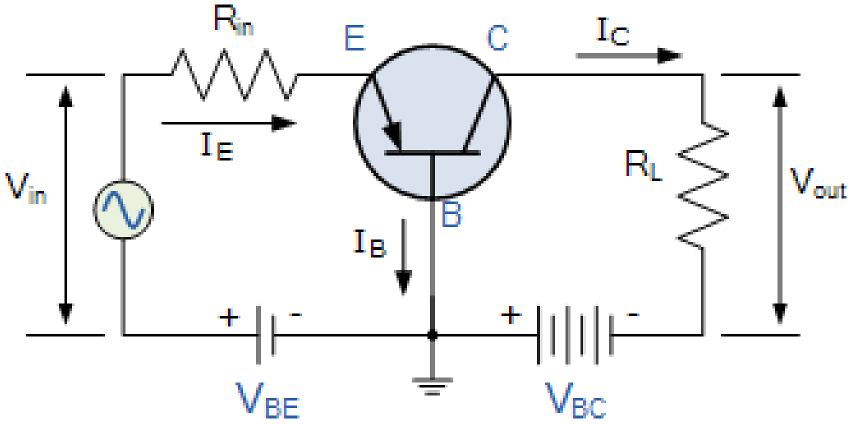
1) Draw and explain input and output characteristics of a Transistor in

a) CB configuration

Answer:

Common Base Configuration

Here, emitter-base circuit is forward biased with battery V_{BE} and Collector-Base circuit is reverse biased with battery V_{BC}. These transistors are used in high frequency circuits.

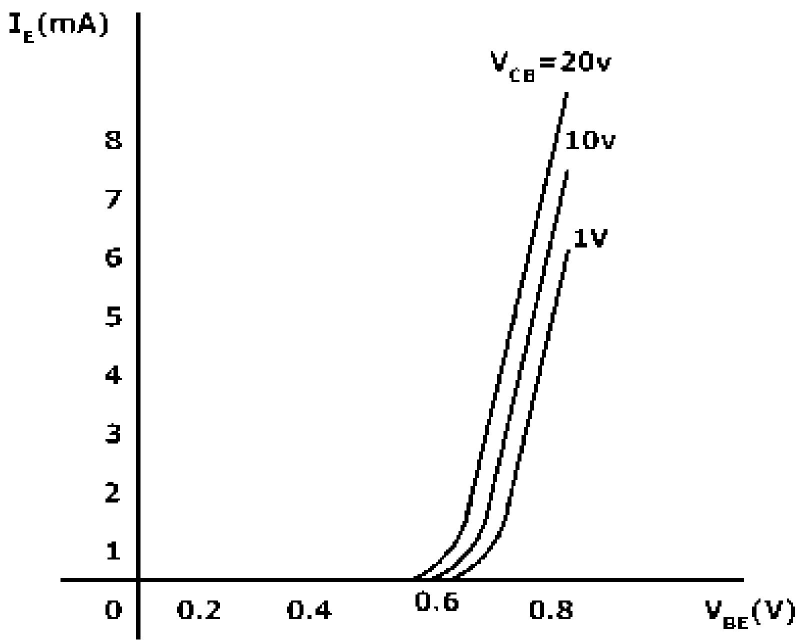


The Common Base characteristics of a transistor are of two types:

i. *Emitter or Input Characteristics:*

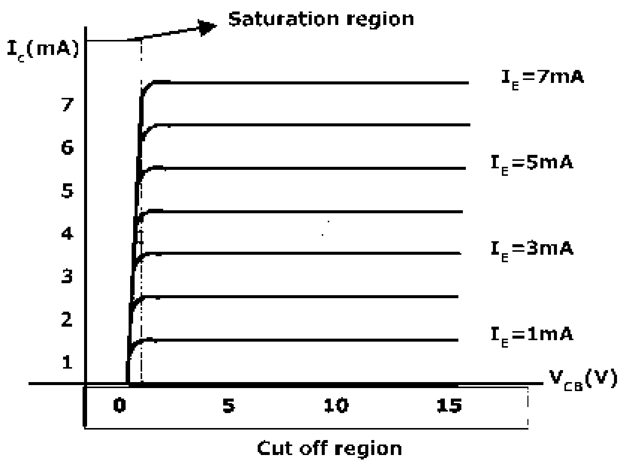
A graphical relation between the emitter voltage and emitter current at constant collector voltage, is called *emitter or input characteristics.* The graph is plotted between emitter current & corresponding emitter voltage.

$$R_{in} = \frac{\Delta V_{BE}}{\Delta I_E}$$



ii. *Collector or Output Characteristics:*

A graphical relation between the collector voltage and collector current at constant emitter current, is called *collector or output characteristics*. The graph is plotted between collector current and corresponding collector voltage.

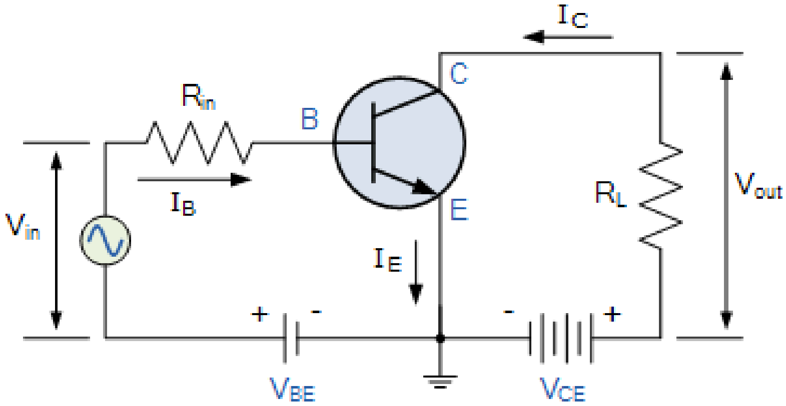


b) **CE configuration**

Answer:

Common Emitter Configuration

Here, Base-emitter circuit is forward biased with battery V_{BE} and Emitter-Collector circuit is reverse biased with battery V_{CE}. These are used in amplifiers.



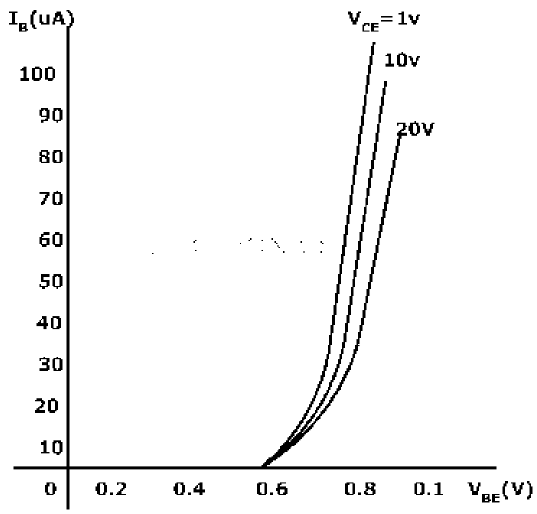
The two characteristics can be studied as shown below:

i. *Emitter or Input Characteristics:*

A graphical relation between the emitter voltage and emitter current by keeping collector voltage constant, is called *input characteristics of the transistor.*

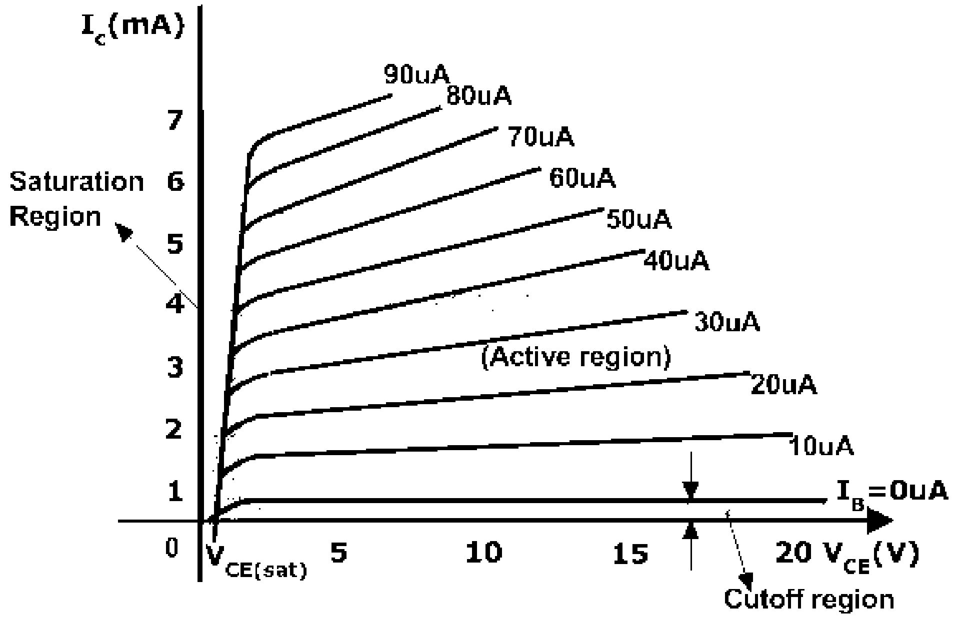
Input Resistance: It is defined as the ratio of change in base-emitter voltage (ΔV_{BE}) to the resulting change in the base current (ΔI_B) at reciprocal of slope of $I_{BE} - V_{BE}$ curve. Input resistance,

$$R_{in} = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE}=Constant}$$



ii. *Collector or Output Characteristics:*

A graphical relation between the collector voltage and collector current by keeping base current constant is called *output characteristics of the transistor.*

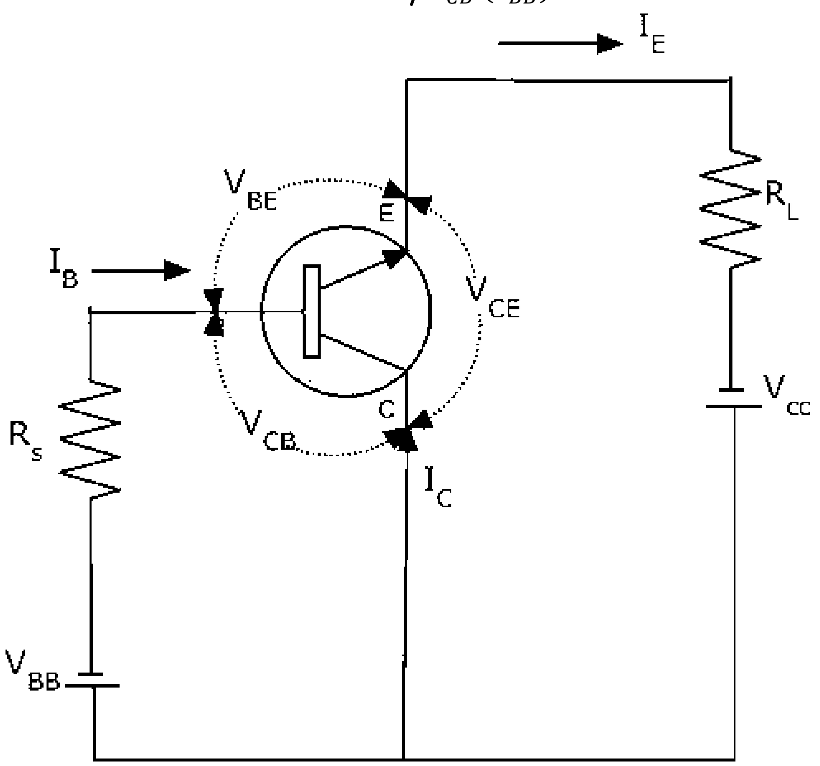


c) CC configuration

Answer:

Common Collector Configuration

Here, emitter-collector circuit is forward biased with battery $V_{CE}(V_{CC})$ and Collector-Base circuit is reverse biased with battery V_{CB} (V_{BB}). These are used in impendence matching.

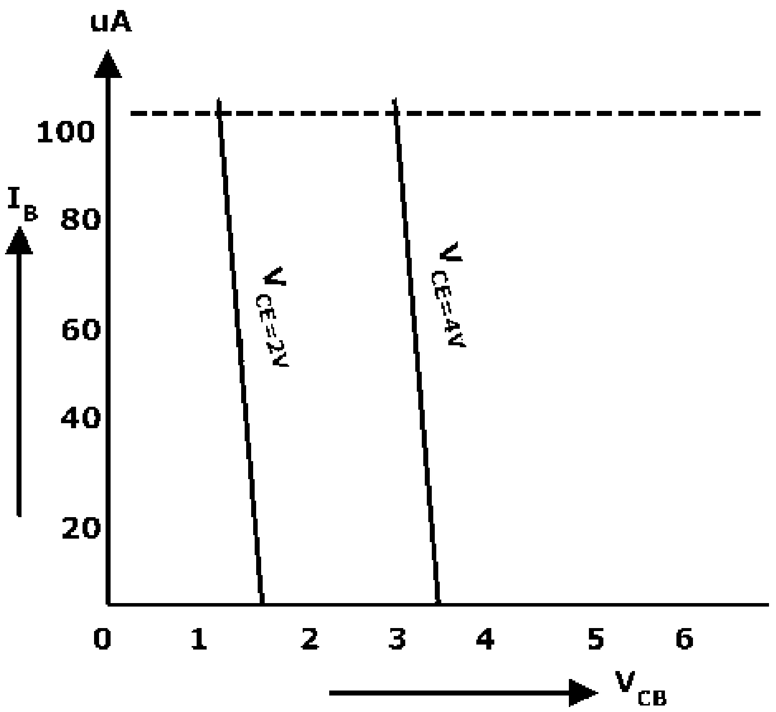


The Common Collector characteristics of a transistor are of two types:

i. *Input Characteristics:*

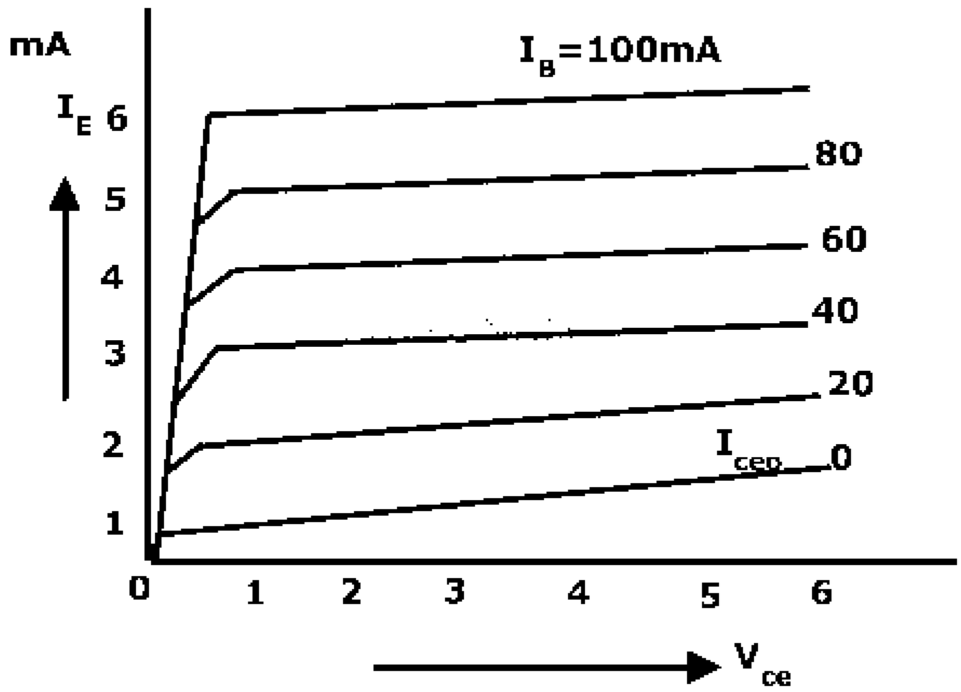
A graphical relation between input current I_B and the input voltage V_{CB} at constant output voltage V_{CE} is called *input characteristics.*

$$V_{CE} = V_{EB} + V_{BC}$$
$$V_{BE} = V_{CE} - V_{BC}$$



ii. *Output Characteristics:*

A graphical relation between the output voltage V_{CE} and output current I_E at constant input current I_B , is called *output characteristics*. In the operation of common collector circuit if the base current is zero then the emitter current also becomes zero. As a result, no current flows through the transistor.



2) Compare CB, CE, CC Configurations.

Answer:

The behaviour of these three different configurations of transistors with respect to gain is given below:

i. **Common Base (CB) Configuration:** No current gain but voltage gain.
ii. **Common Collector (CC) Configuration:** Current gain but no voltage gain.
iii. **Common Emitter (CE) Configuration:** Current gain & Voltage gain.

Parameters	Common-Emitter (CE) Amplifier	Common-Base (CB) Amplifier	Common-Collector (CC) Amplifier
Input resistance	Moderate βr_e	Low r_e	High βR_E
Output resistance	High R_C	High R_C	Low r_e
Voltage gain	High $\frac{r_L}{r_e}$	High $\frac{r_L}{r_e}$	About 1
Current gain	High β	Low, about 1	High $(1 + \beta)$
Power gain	High	Moderate	Low
Phase shift	180°	0°	0°

3) Explain about phototransistor with suitable diagrams.

Answer:

A **Phototransistor** is an electronic switching and current amplification component which relies on exposure to light to operate. When light falls on the junction, reverse current flows which are proportional to the luminance. Phototransistors are used extensively to detect light pulses and convert them into digital electrical signals. These are operated by light rather than electric current. Providing a large amount of gain, low cost and these phototransistors might be used in numerous applications.

It is capable of converting light energy into electric energy. Phototransistors are transistors with the base terminal exposed. Instead of sending current into the base, the photons from striking light activate the transistor. This is because a phototransistor is made of a bipolar semiconductor and focuses the energy that is passed through it. These are activated by light particles and are used in virtually all electronic devices that depend on light in some way. All silicon photosensors (phototransistors) respond to the entire visible radiation range as well as to infrared.

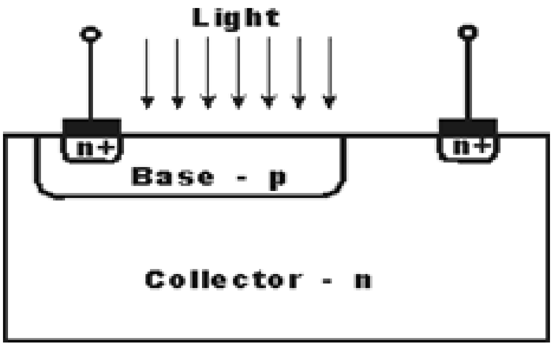
The **structure** of the **phototransistor** is specifically optimized for photo applications. Compared to a normal transistor, a phototransistor has a larger base and collector width and is made using diffusion or ion implantation.

CHARACTERISTICS:

- Low-cost visible and near-IR photodetection.
- Available with gains from 100 to over 1500.
- Moderately fast response times.
- Available in a wide range of packages including epoxy-coated, transfer-moulded and surface mounting technology.
- Electrical characteristics were similar to that of signal transistors.

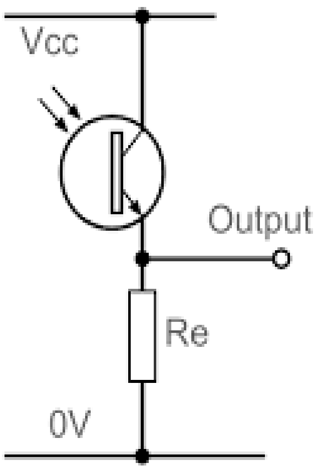
Photo Transistor Construction

With no light falling on the device there will be a small current flow due to thermally generated hole-electron pairs and the output voltage from the circuit will be slightly less than the supply value due to the voltage drop across the load resistor R. With light falling on the collector-base junction the current flow increases. With the base connection open circuit, the collector-base current must flow in the base-emitter circuit and hence the current flowing is amplified by normal transistor action. The collector-base junction is very sensitive to light. Its working condition depends upon the intensity of light. The base current from the incident photons is amplified by the gain of the transistor, resulting in current gains that range from hundreds to several thousand. A phototransistor is 50 to 100 times more sensitive than a photodiode with a lower level of noise.



A phototransistor works just like a normal transistor, where the base current is multiplied to give the collector current, except that in a phototransistor, the base current is controlled by the amount of visible or infrared light where the device only needs 2 pins.

Phototransistor Circuit:



In the **simple circuit**, assuming that nothing is connected to V_{OUT}, the base current controlled by the amount of light will determine the collector current, which is the current going through the resistor. Therefore, the voltage at V_{OUT} will move high and low based on the amount of light. We can connect this to an op-amp to boost the signal or directly to an input of a microcontroller. The output of a phototransistor is dependent upon the wavelength of the incident light. These devices respond to light over a broad range of wavelengths from the near UV, through the visible and into the near IR part of the spectrum. For a given light source illumination level, the output of a phototransistor is defined by the area of the exposed collector-base junction and the dc current gain of the transistor.

Phototransistors available different configurations like optoisolator, optical switch, retro sensor. Optoisolator is similar to a transformer in that the output is electrically isolated from the input. An object is detected when it enters the gap of the optical switch and blocks the light path between the emitter and detector. The retro sensor detects the presence of an object by generating light and then looking for its reflectance off of the object to be sensed.

ADVANTAGES OF PHOTOTRANSISTORS:

Phototransistors have several important advantages that separate them from another optical sensor some of them are mentioned below:

- Phototransistors produce higher current than photodiodes.
- Phototransistors are relatively inexpensive, simple, and small enough to fit several of them onto a single integrated computer chip.
- Phototransistors are very fast and are capable of providing nearly instantaneous output.
- Phototransistors produce a voltage, that photo-resistors cannot do so.

DISADVANTAGES OF PHOTOTRANSISTORS:

- Phototransistors that are made of silicon are not capable of handling voltages over 1,000 Volts.
- Phototransistors are also more vulnerable to surges and spikes of electricity as well as electromagnetic energy.
- Phototransistors also do not allow electrons to move as freely as other devices do, such as electron tubes.

APPLICATIONS OF PHOTOTRANSISTORS

The Areas of application for the Phototransistor include:

- Punch-card readers.
- Security systems
- Encoders – measure speed and direction
- IR detectors photo
- electric controls
- Computer logic circuitry.
- Relays
- Lighting control (highways etc)
- Level indication
- Counting systems

4) Explain different techniques used for Transistor biasing in detail with suitable diagrams.

Answer:

The biasing in transistor circuits is done by using two DC sources V_{BB} and V_{CC}. It is economical to minimize the DC source to one supply instead of two which also makes the circuit simple.

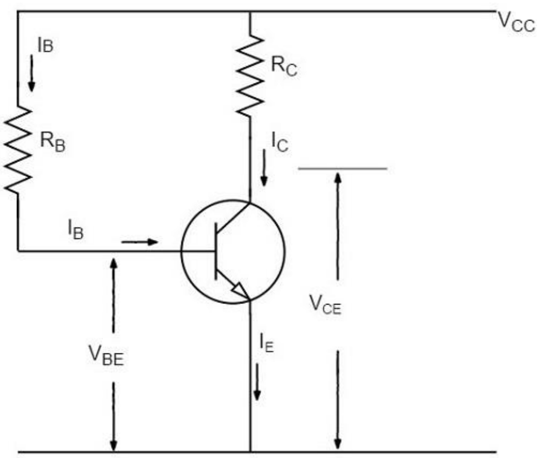
The commonly used methods/techniques of transistor biasing are

- Base Resistor method
- Collector to Base bias
- Biasing with Collector feedback resistor
- Voltage-divider bias

All of these methods have the same basic principle of obtaining the required value of I_B and I_C from V_{CC} in the zero signal conditions.

BASE RESISTOR METHOD

In this method, a resistor R_B of high resistance is connected in base, as the name implies. The required zero signal base current is provided by V_{CC} which flows through R_B. The base emitter junction is forward biased, as base is positive with respect to emitter.



The required value of zero signal base current and hence the collector current (as $I_C = \beta I_B$) can be made to flow by selecting the proper value of base resistor RB. Hence the value of R_B is to be known. The figure below shows how a base resistor method of biasing circuit looks like.

Let I_C be the required zero signal collector current. Therefore,

$$I_B = \frac{I_C}{\beta}$$

Considering the closed circuit from V_{CC}, base, emitter and ground, while applying the Kirchhoff's voltage law, we get,

$$V_{CC} = I_B R_B + V_{BE}$$

Or

$$I_B R_B = V_{CC} - V_{BE}$$

Therefore,

$$R_B = V_{CC} - V_{BE} I_B$$

Since V_{BE} is generally quite small as compared to V_{CC}, the V_{BE} can be neglected with little error. Then,

$$R_B = V_{CC} I_B$$

We know that V_{CC} is a fixed known quantity and I_B is chosen at some suitable value. As R_B can be found directly, this method is called as **fixed bias method**.

Stability factor

$$S = \frac{\beta + 1}{1 - \beta\left(\frac{dI_B}{dI_C}\right)}$$

In fixed-bias method of biasing, I_B is independent of I_C so that,

$$\frac{dI_B}{dI_C} = 0$$

Substituting the above value in the previous equation,

Stability factor, $S = \beta + 1$

Thus, the stability factor in a fixed bias is (β+1) which means that I_C changes (β+1) times as much as any change in I_{CO}.

ADVANTAGES

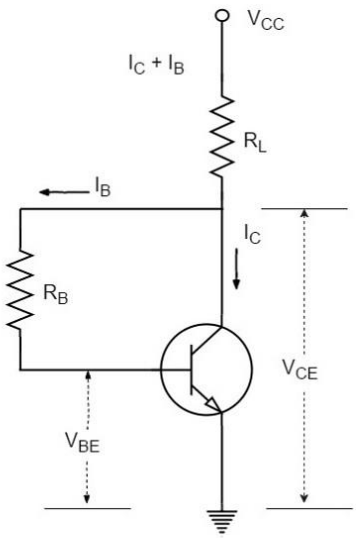
- The circuit is simple.
- Only one resistor R_E is required.
- Biasing conditions are set easily.
- No loading effect as no resistor is present at base-emitter junction.

DISADVANTAGES

- The stabilization is poor as heat development can't be stopped.
- The stability factor is very high. So, there are strong chances of thermal run away.

Hence, this method is rarely employed.

COLLECTOR TO BASE BIAS



The collector to base bias circuit is same as base bias circuit except that the base resistor R_B is returned to collector, rather than to V_{CC} supply as shown in the figure.

This circuit helps in improving the stability considerably. If the value of I_C increases, the voltage across R_L increases and hence the V_{CE} also increases. This in turn reduces the base current I_B. This action somewhat compensates the original increase.

The required value of R_B needed to give the zero-signal collector current I_C can be calculated as follows.

Voltage drop across R_L will be

$$R_L = (I_C + I_B) R_L \cong I_C R_L$$

From the figure,

$$I_C R_L + I_B R_B + V_{BE} = V_{CC}$$

Or

$$I_B R_B = V_{CC} - V_{BE} - I_C R_L$$

Therefore

$$R_B = \frac{V_{CC} - V_{BE} - I_C R_L}{I_B}$$

Or

$$R_B = \frac{(V_{CC} - V_{BE} - I_C R_L)\beta}{I_C}$$

Applying KVL we have

$$(I_B + I_C)R_L + I_B R_B + V_{BE} = V_{CC}$$

Or

$$I_B(R_L + R_B) + I_C R_L + V_{BE} = V_{CC}$$

Therefore

$$I_B = \frac{V_{CC} - V_{BE} - I_C R_L}{R_L + R_B}$$

Since V_{BE} is almost independent of collector current, we get

$$\frac{dI_B}{dI_C} = -\frac{R_L}{R_L + R_B}$$

We know that,

$$S = \frac{1+\beta}{1 - \beta\left(\frac{dI_B}{dI_C}\right)}$$

Therefore

$$S = \frac{1+\beta}{1 + \beta\left(\frac{R_L}{R_L + R_B}\right)}$$

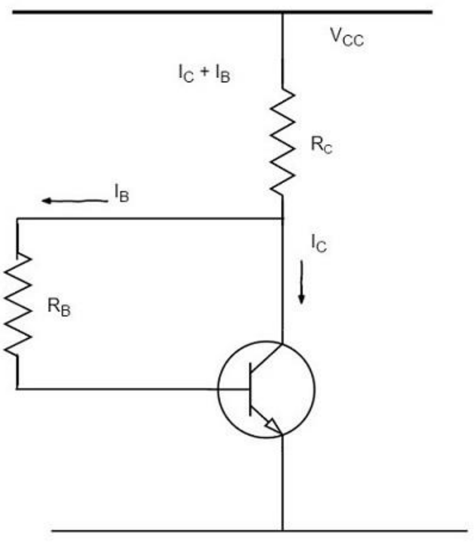
This value is smaller than (1+β) which is obtained for fixed bias circuit. Thus, there is an improvement in the stability.

This circuit provides a negative feedback which reduces the gain of the amplifier. So, the increased stability of the collector to base bias circuit is obtained at the cost of AC voltage gain.

BIASING WITH COLLECTOR FEEDBACK RESISTOR

In this method, the base resistor R_B has its one end connected to base and the other to the collector as its name implies. In this circuit, the zero-signal base current is determined by V_{CB} but not by V_{CC}.

It is clear that V_{CB} forward biases the base-emitter junction and hence base current I_B flows through R_B. This causes the zero-signal collector current to flow in the circuit. The below figure shows the biasing with collector feedback resistor circuit.



The required value of R_B needed to give the zero-signal current I_C can be determined as follows.

$$V_{CC} = I_C R_C + I_B R_B + V_{BE}$$

Or

$$R_B = \frac{V_{CC} - V_{BE} - I_C R_C}{I_B} = \frac{V_{CC} - V_{BE} - \beta I_B R_C}{I_B}$$

Since $I_C = \beta I_B$

Alternatively,

$$V_{CE} = V_{BE} + V_{CB}$$

Or

$$V_{CB} = V_{CE} - V_{BE}$$

Since,

$$R_B = \frac{V_{CB}}{I_B} = \frac{V_{CE} - V_{BE}}{I_B}$$

Where

$$I_B = \frac{I_C}{\beta}$$

Mathematically,
Stability factor, $S < (\beta + 1)$
Therefore, this method provides better thermal stability than the fixed bias.
The Q-point values for the circuit are shown as

$$I_C = \frac{V_{CC} - V_{BE}}{\frac{R_B}{\beta} + RC}$$

$$V_{CE} = V_{CC} - I_C R_C$$

ADVANTAGES

- The circuit is simple as it needs only one resistor.
- This circuit provides some stabilization, for lesser changes.

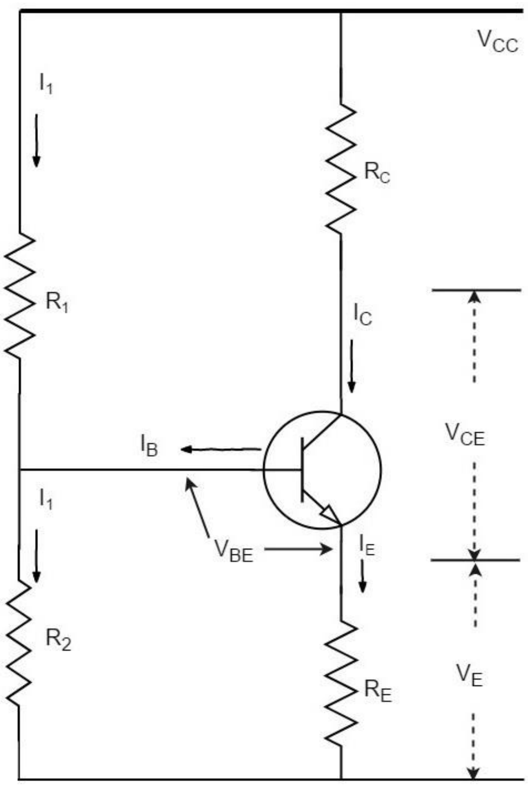
DISADVANTAGES

- The circuit doesn't provide good stabilization.
- The circuit provides negative feedback.

VOLTAGE DIVIDER BIAS METHOD

Among all the methods of providing biasing and stabilization, the **voltage divider bias method** is the most prominent one. Here, two resistors R_1 and R_2 are employed, which are connected to V_{CC} and provide biasing. The resistor R_E employed in the emitter provides stabilization.

The name voltage divider comes from the voltage divider formed by R_1 and R_2. The voltage drop across R_2 forward biases the base-emitter junction. This causes the base current and hence collector current flow in the zero signal conditions. The figure below shows the circuit of voltage divider bias method.



Suppose that the current flowing through resistance R_1 is I_1. As base current I_B is very small, therefore, it can be assumed with reasonable accuracy that current flowing through R_2 is also I_1.

Now let us try to derive the expressions for collector current and collector voltage.

COLLECTOR CURRENT, I_C

From the circuit, it is evident that,

$$I_1 = \frac{V_{CC}}{R_1 + R_2}$$

Therefore, the voltage across resistance R_2 is

$$V_2 = \left(\frac{V_{CC}}{(R_1 + R_2)}\right) R_2$$

Applying Kirchhoff's voltage law to the base circuit,

$$V_2 = V_{BE} + V_E$$

$$V_2 = V_{BE} + I_E R_E$$

$$I_E = \frac{V_2 - V_{BE}}{R_E}$$

Since $I_E \approx I_C$,

$$I_C = \frac{V_2 - V_{BE}}{R_E}$$

From the above expression, it is evident that I_C doesn't depend upon β. V_{BE} is very small that I_C doesn't get affected by V_{BE} at all. Thus, I_C in this circuit is almost independent of transistor parameters and hence good stabilization is achieved.

COLLECTOR-EMITTER VOLTAGE, V_{CE}

Applying Kirchhoff's voltage law to the collector side,

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

Since $I_E \cong I_C$

$$= I_C R_C + V_{CE} + I_C R_E$$
$$= I_C (R_C + R_E) + V_{CE}$$

Therefore,

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

R_E provides excellent stabilization in this circuit.

$$V_2 = V_{BE} + I_C R_E$$

Suppose there is a rise in temperature, then the collector current I_C decreases, which causes the voltage drop across R_E to increase. As the voltage drop across R_2 is V_2, which is independent of I_C, the value of V_{BE} decreases. The reduced value of I_B tends to restore I_C to the original value.

STABILITY FACTOR

The equation for **Stability factor** of this circuit is obtained as

$$Stability\ Factor\ = S = \frac{(\beta+1)(R_0+R_3)}{R_0+R_E+\beta R_E}$$

$$= (\beta+1) \times \frac{1+\frac{R_0}{R_E}}{\beta+1+\frac{R_0}{R_E}}$$

Where

$$R_0 = \frac{R_1 R_2}{R_1 + R_2}$$

If the ratio R_0/R_E is very small, then R0/RE can be neglected as compared to 1 and the stability factor becomes

$$Stability\ Factor\ = S = (\beta+1) \times \frac{1}{(\beta+1)} = 1$$

This is the smallest possible value of S and leads to the maximum possible thermal stability.

5) **Define Stability factor. How to obtain bias stability in CE configuration.**

Answer:

Stability factor (S): The rate of change of collector current with respect to collector leakage current at constant V_{BE} is known as *stability factor.*

$$\left[\!\left[S = \frac{\partial I_C}{\partial I_{CBO}} \right]\!\right] \Rightarrow \left[\!\left[S = \frac{dI_C}{dI_{CBO}} \right]\!\right] \Rightarrow \left[\!\left[S = \frac{\Delta I_C}{\Delta I_{CBO}} \right]\!\right] \cdots (1)$$

In common emitter configuration:

$$I_C = \beta I_B + I_{CBO}(1+\beta) \cdots (2)$$

Partial differentiating the above equation (2) with respect to I_C we get,

$$\frac{\partial I_C}{\partial I_C} = \beta \frac{\partial I_B}{\partial I_C} + \frac{\partial I_{CBO}}{\partial I_C}(1+\beta)$$

$$1 = \beta \frac{\partial I_B}{\partial I_C} + \frac{\partial I_{CBO}}{\partial I_C}(1+\beta)$$

$$1-\beta\frac{\partial I_B}{\partial I_C}=\frac{\partial I_{CBO}}{\partial I_C}(1+\beta)$$

$$1-\beta\frac{\partial I_B}{\partial I_C}=\frac{(1+\beta)}{S}\quad\cdots\left[Since,\frac{1}{S}=\frac{\partial I_{CBO}}{\partial I_C}\right]\ From\ eq(1)$$

$$\left[\!\left[S=\frac{(1+\beta)}{\left(1-\beta\frac{\partial I_B}{\partial I_C}\right)}\right]\!\right]$$

From the above equation it is clear that this Stability factor (S) should be as small as possible to have better thermal stability.

Stability Factor for Biasing Circuit:

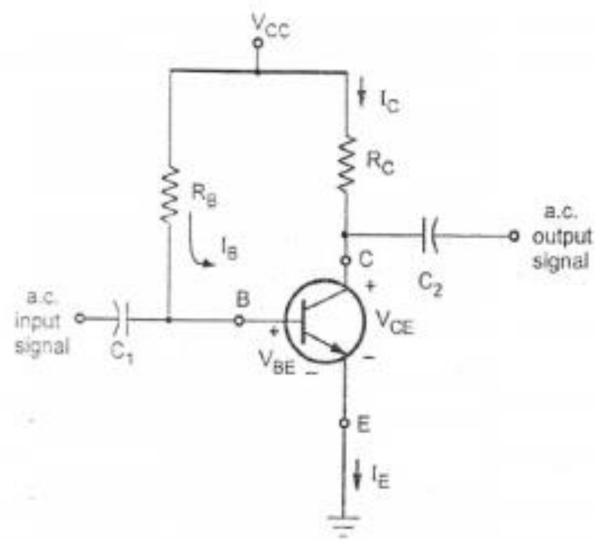
There are different biasing circuit those are:

i. Fixed bias circuit
ii. Collector to Base bias circuit
iii. Voltage divider (or) Self bias circuit

FIXED BIAS CIRCUIT:

Applying KVL for the circuit given, we get

$$-V_{CC}+I_BR_B+V_{BE}=0$$
$$V_{CC}=I_BR_B+V_{BE}$$
$$I_BR_B=V_{CC}-V_{BE}$$
$$I_B=\frac{V_{CC}-V_{BE}}{R_B}$$



Partial Differentiating the above equation with respect to I_C, we get

$$\frac{\partial I_B}{\partial I_C}=\frac{\partial}{\partial I_C}\left(\frac{V_{CC}-V_{BE}}{R_B}\right)$$
$$\frac{\partial I_B}{\partial I_C}=0$$

We know that, Stability Factor

$$S=\frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_C}\right)}$$

$$[\![S=1+\beta]\!]$$

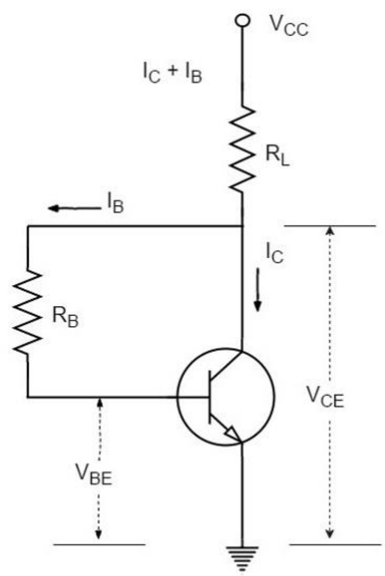
COLLECTOR TO BASE BIAS CIRCUIT:

Applying KVL for the circuit given, we get

$$-V_{CC}+(I_C+I_B)R_C+I_BR_B+V_{BE}=0$$
$$V_{CC}-V_{BE}=I_CR_C+I_B(R_C+R_B)$$

Partial Differentiating the above equation with respect to I_C, we get

$$\frac{\partial}{\partial I_C}(I_CR_C)+\frac{\partial I_B}{\partial I_C}(R_C+R_B)=\frac{\partial}{\partial I_C}(V_{CC}-V_{BE})$$
$$R_C+\frac{\partial I_B}{\partial I_C}(R_C+R_B)=0$$
$$\frac{\partial I_B}{\partial I_C}=\frac{-R_C}{(R_C+R_B)}$$



We know that, Stability Factor,

$$S=\frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_C}\right)}$$

$$S=\frac{1+\beta}{1-\beta\left(\frac{-R_C}{(R_C+R_B)}\right)}$$

$$S = \frac{1+\beta}{1+\frac{\beta R_C}{(R_C+R_B)}} = \frac{1+\beta}{\frac{R_C+R_B+\beta R_C}{(R_C+R_B)}}$$

$$S = \frac{(1+\beta)(R_C+R_B)}{R_C(1+\beta)+R_B}$$

$$S = \frac{(1+\beta)(R_C+R_B)}{(1+\beta)+\frac{R_B}{R_C}}$$

If $\frac{R_B}{R_C} \ll 1$, then $\frac{R_B}{R_C}$ is negligible.

So,

$$S = \frac{1+\beta}{1+\beta} \Rightarrow S = 1$$

VOLTAGE DIVIDER CIRCUIT:

Applying KVL for the circuit given, we get

$$-V_B + I_B R_B + V_{BE} + (I_C + I_B)R_E = 0$$

$$R_B I_B + (I_C + I_B)R_E = V_B - V_{BE}$$

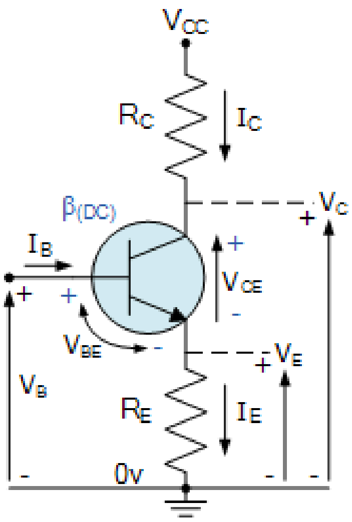
$$(R_B + R_E)I_B + R_E I_C = V_B - V_{BE}$$

Partial Differentiating the above equation with respect to I_C, we get

$$\frac{\partial I_B}{\partial I_C}(R_B + R_E) + \frac{\partial I_C}{\partial I_C}R_E = \frac{\partial}{\partial I_C}(V_B - V_{BE})$$

$$R_E + \frac{\partial I_B}{\partial I_C}(R_B + R_E) = 0$$

$$\frac{\partial I_B}{\partial I_C} = \frac{-R_E}{(R_B + R_E)}$$



We know that, Stability Factor

$$S = \frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_C}\right)}$$

$$S = \frac{1+\beta}{1-\beta\left(\frac{-R_E}{(R_B+R_E)}\right)}$$

$$S = \frac{1+\beta}{1+\frac{\beta R_E}{(R_E+R_B)}} = \frac{1+\beta}{\frac{R_E+R_B+\beta R_E}{(R_E+R_B)}}$$

$$S = \frac{(1+\beta)(R_E+R_B)}{R_E(1+\beta)+R_B}$$

$$S = \frac{(1+\beta)(R_E+R_B)}{(1+\beta)+\frac{R_B}{R_E}}$$

If $\frac{R_B}{R_E} \ll 1$, then $\frac{R_B}{R_E}$ is negligible.

So,

$$S = \frac{1+\beta}{1+\beta} \Rightarrow S = 1$$

1 MARK OR 2 MARKS QUESTIONS

1) Define α.

Answer:

$\propto$ is the ratio between collector current to the Emitter current

Generally,

$$\propto = \frac{I_c}{I_E}$$

2) Define β.

Answer:

The β is the current gain defined as the ratio between collector current to the Base current

$$\beta = \frac{I_c}{I_B}$$

3) Give the relationship between α and β.

Answer:

We know that,

$$I_C = \propto I_E$$

And,

$$I_C = \beta I_B$$

So,

$$\propto I_E = \beta I_B$$

But, $I_E = I_B + I_C$

$$\propto (I_B + I_C) = \beta I_B$$

$$\propto + \frac{I_C}{I_B} = \beta$$

$$\propto + \propto \beta = \beta$$

Finally,

$$\propto = \frac{\beta}{1+\beta}$$

Or

$$\beta = \frac{\propto}{\propto - 1}$$

4) Define Stability factor(S).

Answer:

Stability factor (S): The rate of change of collector current with respect to collector leakage current at constant V_{BE} is known as *stability factor.*

$$\left[\!\left[S = \frac{\partial I_C}{\partial I_{CBO}}\right]\!\right]$$

OR

$$\left[\!\left[S = \frac{dI_C}{dI_{CBO}}\right]\!\right]$$

OR

$$\left[\!\left[S = \frac{\Delta I_C}{\Delta I_{CBO}}\right]\!\right]$$

5) What do you mean by transistor biasing?

Answer:

The basic purpose of a transistor biasing is to keep the base-emitter junction properly forward bias and Collector junction reverse bias during the application of the input signal.

In order to achieve the faithful amplification, emitter junction is forward biased and collector junction is reversed biased. And this process is called as transistor biasing.

5 MARKS OR 7 MARKS QUESTIONS

1) Design full adder using (1) basic gates (2) exclusive OR gates.

Answer:

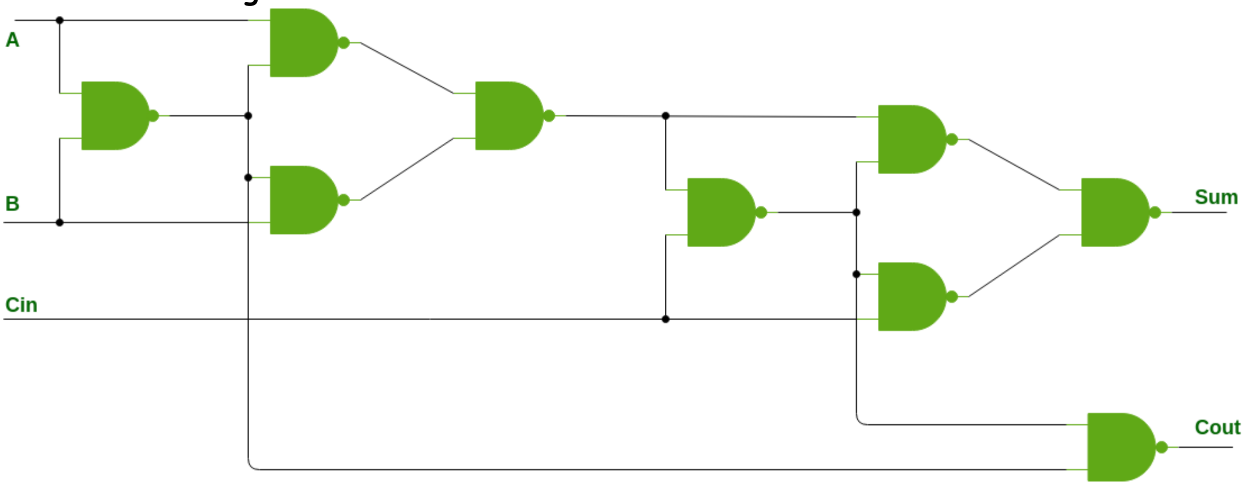
Full adder is a combinational circuit that performs the addition of three binary digits.

It has 3 inputs A, B, C and two outputs Sum and Carry.

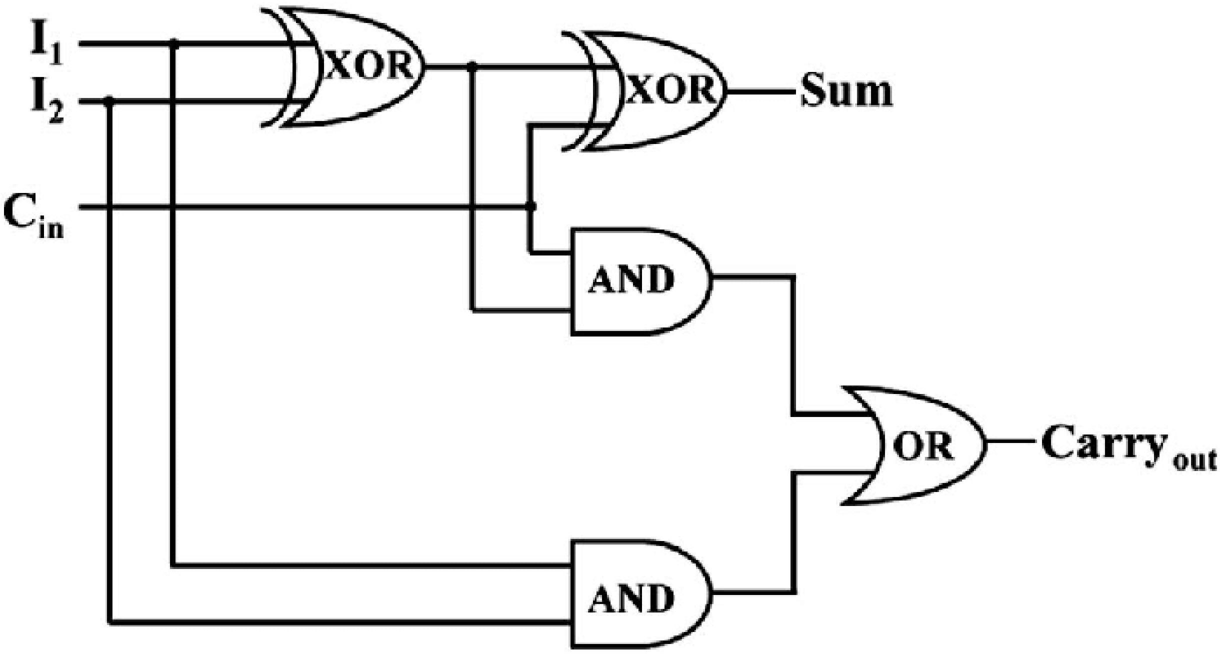
Truth Table:

Inputs			Outputs	
A	B	C_{in}	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Implementation Using Basic Gate:



Implementation Using Exclusive OR Gate:



2) Design half adder using (1) basic gates (2) exclusive OR gates.

Answer:

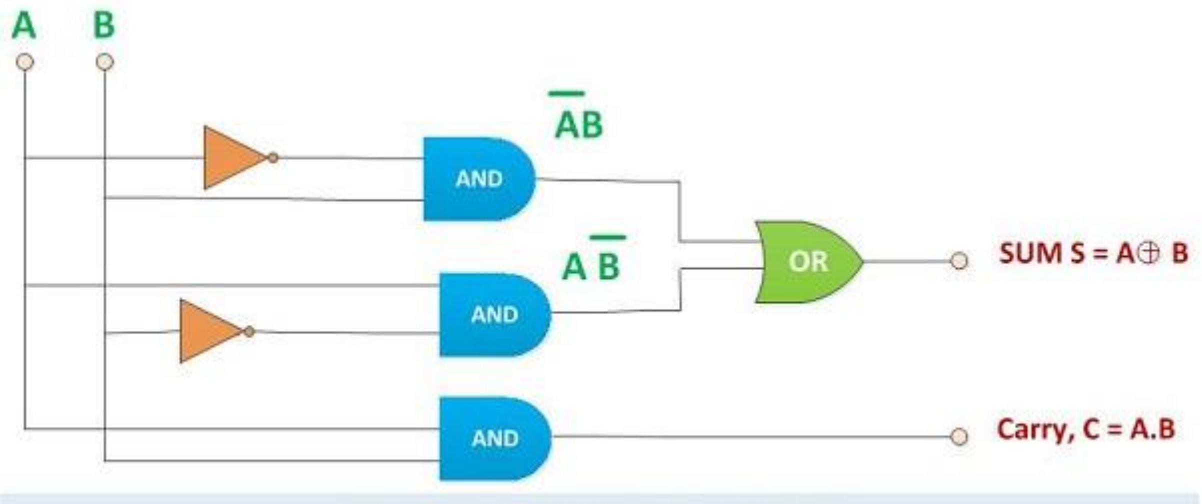
The most common arithmetic operation in digital system is the addition of two binary digits. The combinational circuit that performs this operation is called *Half Adder*.

It has two inputs A, B each input is a 1-bit number and it produce sum, carry as the outputs.

Truth Table:

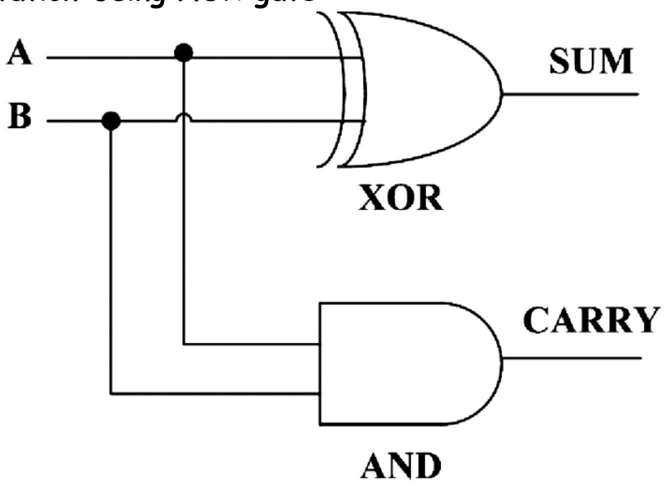
Input		Output	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Implementation Using Basic Gates:



Half Adder Using Basic Gates

Implementation Using XOR gate:



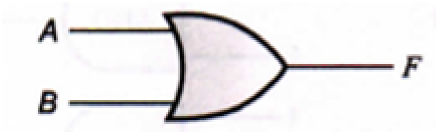
3) **Draw and explain two input OR gate using transistors.**

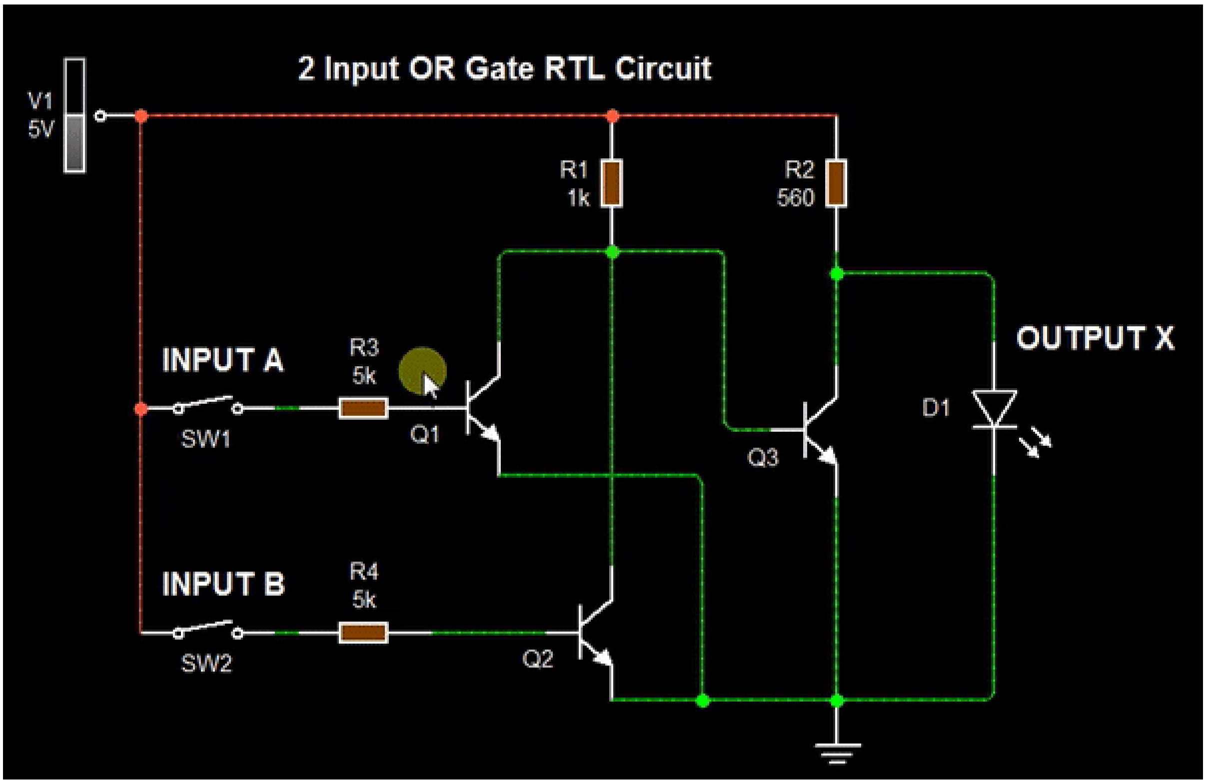
Answer:

2 Input OR Gate using Transistor:

Two input OR gate uses 3 transistors Q_1, Q_2, Q_3. The input A, B are applied to base terminal of transistors Q_1 & Q_2 through resistor and output X is taken at collector terminal of transistor Q_3.

Logic Symbol:





Operation:

i. When both inputs are low i.e. A=B=0V then both transistors Q_1, Q_2 are OFF and the resultant transistor Q_3 becomes ON, So the output is $V_{CE} = 0.3V$ i.e. X=0.

ii. When A is low and B is high i.e. A=0V & B=5V (A=0, B=1) then transistor Q_1 is OFF & transistor Q_2 is ON. So, the resultant transistor Q_3 is OFF so the output voltage is same as supply voltage $V_{CC} = 5V$ i.e. X=1.

iii. When A is high and B is low i.e. A=5V & B=0V (A=1, B=0) then transistor Q_1 is ON & transistor Q_2 is OFF. So, the resultant transistor Q_3 is OFF so the output voltage is same as supply voltage $V_{CC} = 5V$ i.e. X=1.

iv. When A is high and B is high i.e. A=5V & B=5V (A=1, B=1) then transistor Q_1 is ON & transistor Q_2 is ON. So, the resultant transistor Q_3 is OFF so the output voltage is same as supply voltage $V_{CC} = 5V$ i.e. X=1.

Functional Table:

A	B	Q1	Q2	Q3	X=A+B
0	0	OFF	OFF	ON	0
0	1	OFF	ON	OFF	1
1	0	ON	OFF	OFF	1
1	1	ON	ON	OFF	1

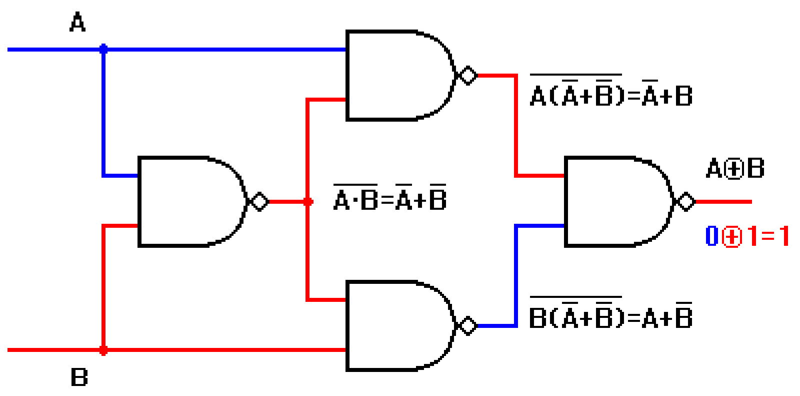
Truth Table:

X	Y	F
0	0	0
0	1	1
1	0	1
1	1	1

4) **Design X-OR and X-NOR gate using NAND Gate.**

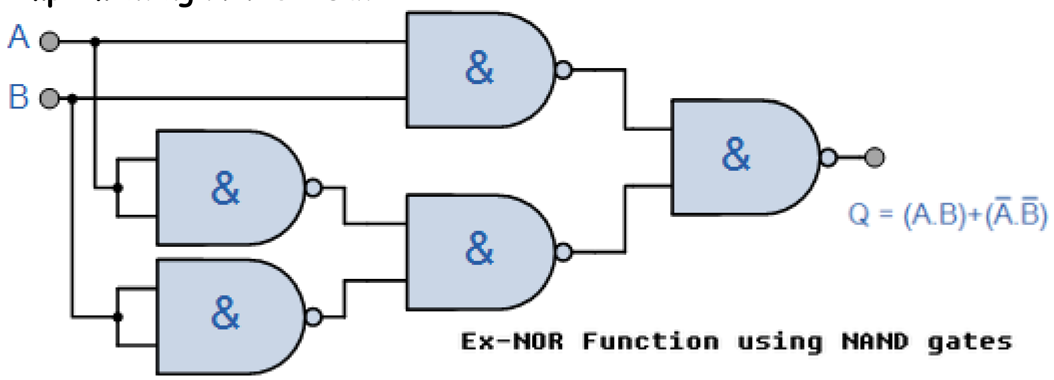
Answer:

Implementing X-OR Gate:



X-OR gate is replaced by 4 NAND gates.

Implementing X-NOR Gate:



Ex-NOR Function using NAND gates

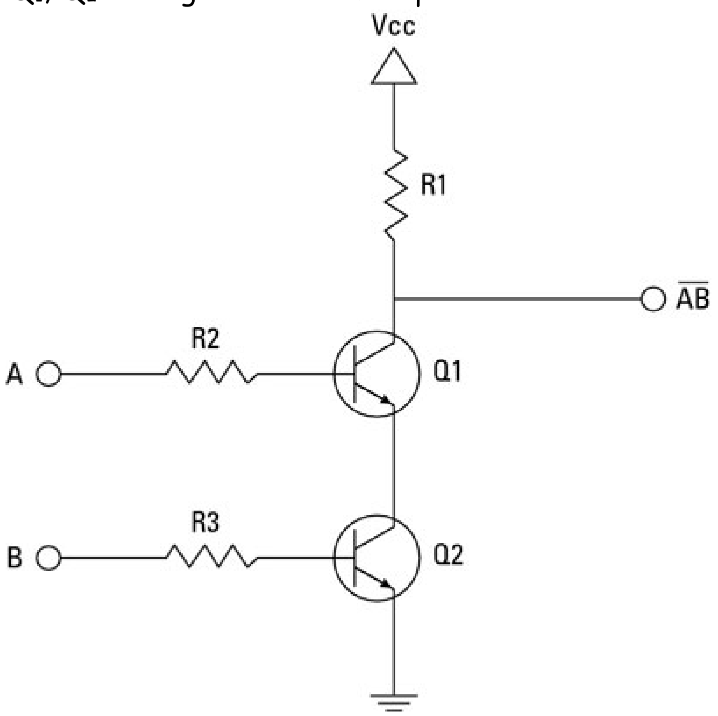
X-NOR gate is replaced by 5 NAND gates.

5) **Draw and explain two input NAND gate using transistors.**

Answer:

2 Input NAND gate using Transistors:

Two input NAND uses two transistors inputs are A, B which are applied to base terminal of transistor Q_1, Q_2 through resistor & output X is taken at collector terminal of transistor Q_1.



Operation:

i. When both inputs are low i.e. A=B=0V then both transistors Q_1, Q_2 are OFF, So the output is $V_{CE} = 5V$ i.e. X=1.

ii. When A is low and B is high i.e. A=0V & B=5V (A=0, B=1) then transistor Q_1 is OFF & transistor Q_2 is ON. So, the output voltage is same as supply voltage $V_{CC} = 5V$ i.e. X=1.

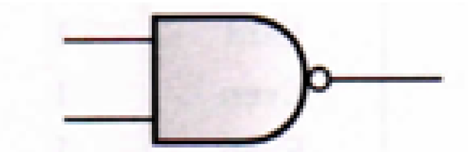
iii. When A is high and B is low i.e. A=5V & B=0V (A=1, B=0) then transistor Q_1 is ON & transistor Q_2 is OFF. So, the output voltage is same as supply voltage $V_{CC} = 5V$ i.e. X=1.

iv. When A is high and B is high i.e. A=5V & B=5V (A=1, B=1) then transistor Q_1 is ON & transistor Q_2 is ON. So, the output voltage $V_{CC} = 0.3V$ i.e. X=0.

Truth Table:

X	Y	F
0	0	1
0	1	1
1	0	1
1	1	0

Logic Symbol:



6) State and Explain Demorgan's Theorems.

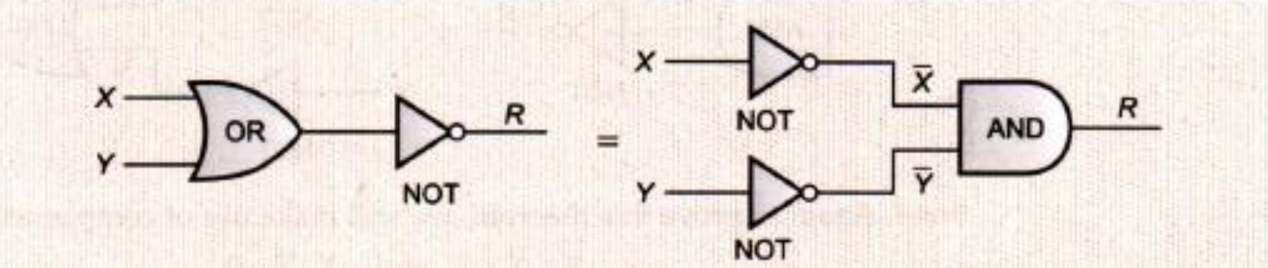
Answer:

DEMORGAN'S THEOREMS

One of the most powerful identities used in boolean algebra is DeMorgan's theorem. *Augustus DeMorgan* had paved the way to boolean algebra by discovering these two important theorems. This section introduces these two theorems of DeMorgan.

DeMorgan's First Theorem

It states that $\overline{X+Y} = \overline{X}\,\overline{Y}$



Proof. To prove this theorem, we need to recall complementarity laws, which state that

$$X + \overline{X} = 1 \quad \text{and} \quad X \, . \, \overline{X} = 0$$

i.e., a logical variable/expression when added with its complement produces the output as 1 and when multiplied with its complement produces the output as 0.

Now to prove DeMorgan's first theorem, we will use complementarity laws.

Let us assume that $P = X + Y$ where, P, X, Y are logical variables. Then, according to complementation law

$$P + \overline{P} = 1 \quad \text{and} \quad P . \overline{P} = 0.$$

That means, if P, X, Y are boolean variables then this complementarity law must hold for variable P. In other words, if $\overline{P}$ *i.e.*, if $\overline{X+Y} = \overline{X}\,\overline{Y}$ then

$(X+Y) + \overline{X}\,\overline{Y}$ must be equal to 1. *(as* $X + \overline{X} = 1$*)*

and $(X+Y) . \overline{X}\,\overline{Y}$ must be equal to 0. *(as* $X . \overline{X} = 0$*)*

Let us first prove the first part, *i.e.*,

$$(X+Y) + (\overline{X}\,\overline{Y}) = 1$$

$$(X+Y) + \overline{X}\,\overline{Y} = ((X+Y) + \overline{X}).((X+Y) + \overline{Y}) \qquad (ref.\ X + YZ = (X+Y)(X+Z))$$

$$= (X + \overline{X} + Y).(X + Y + \overline{Y})$$

$$= (1 + Y).(X + 1) \qquad (ref.\ X + \overline{X} = 1)$$

$$= 1.1 \qquad (ref.\ 1 + X = 1)$$

$$= 1$$

So first part is proved.

Now let us prove the second part *i.e.*,

$$(X+Y) . \overline{X}\,\overline{Y} = 0$$

$$(X+Y) . \overline{X}\,\overline{Y} = \overline{X}\,\overline{Y}.(X+Y) \qquad (ref.\ X(YZ) = (XY)Z)$$

$$= \overline{X}\,\overline{Y}\,X + \overline{X}\,\overline{Y}\,Y \qquad (ref.\ X(Y+Z) = XY + XZ)$$

$$= X\,\overline{X}\,\overline{Y} + \overline{X}\,Y\,\overline{Y}$$

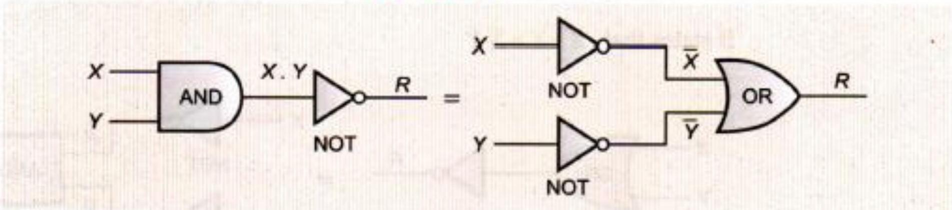
$$= 0 . Y + \overline{X} . 0 \qquad (ref.\ X . \overline{X} = 0)$$

$$= 0 + 0 = 0$$

So, second part is also proved, thus : $\overline{X+Y} = \overline{X}\,\overline{Y}$

DeMorgan's Second Theorem

This theorem states that : $\overline{X.Y} = \overline{X} + \overline{Y}$



Proof. Again to prove this theorem, we will make use of complementarity law *i.e.*,

$$X + \overline{X} = 1 \quad \text{and} \quad X . \overline{X} = 0.$$

If XY's complement is $\overline{X} + \overline{Y}$ then it must be true that

(*a*) $XY + (\overline{X} + \overline{Y}) = 1$ and

(*b*) $XY(\overline{X} + \overline{Y}) = 0$

To prove the *first part*

$$\text{L.H.S} = XY + (\overline{X} + \overline{Y})$$

$$= (\overline{X} + \overline{Y}) + XY \qquad (ref.\ X + Y = Y + X)$$

$$= (\overline{X} + \overline{Y} + X).(\overline{X} + \overline{Y} + Y) \qquad (ref.\ (X+Y)(X+Z) = X + YZ)$$

$$= (X + \overline{X} + \overline{Y}).(\overline{X} + Y + \overline{Y})$$

$$= (1 + \overline{Y}).(\overline{X} + 1) \qquad (ref.\ X + \overline{X} = 1)$$

$$= 1.1 \qquad (ref.\ 1 + X = 1)$$

$$= 1 = \text{R.H.S}$$

Now the *second part* i.e.,

$$XY.(\overline{X} + \overline{Y}) = 0$$

$$\text{L.H.S} = XY.(\overline{X} + \overline{Y})$$

$$= XY\overline{X} + XY\overline{Y} \qquad (ref.\ X(Y+Z) = XY + XZ)$$

$$= X\overline{X}Y + XY\overline{Y}$$

$$= 0 . Y + X . 0 \qquad (ref.\ X . \overline{X} = 0)$$

$$= 0 + 0 = 0 = \text{R.H.S.}$$

$$\therefore\ XY . (\overline{X} + \overline{Y}) = 0$$

and $XY + (\overline{X} + \overline{Y}) = 1$

$\Rightarrow$ $\overline{XY} = \overline{X} + \overline{Y}$. Hence the theorem.

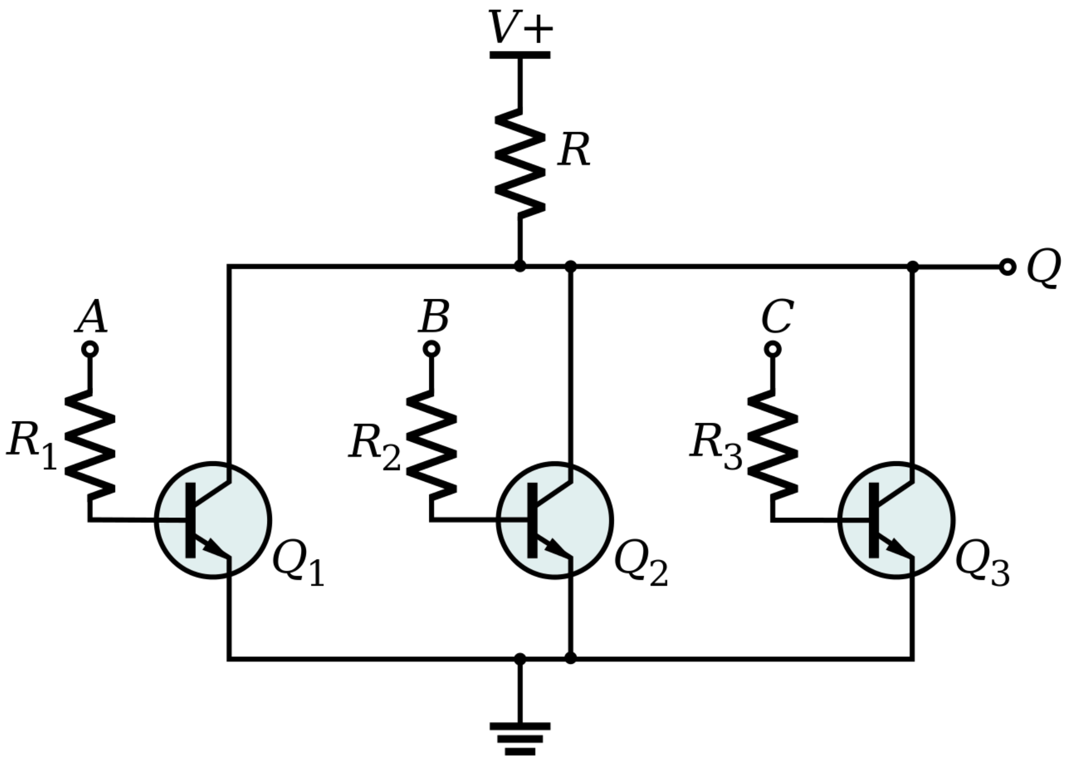
7) Draw and explain 3 input NOR gate using transistors.

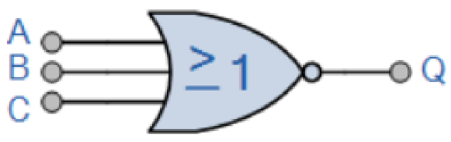
Answer:

3 Input NOR gate using Transistors:

Three input NOR gate uses 3 transistors inputs are A, B & C which are applied to base terminal of transistor Q_1, Q_2 & Q_3 through resistors & output Q is taken at collector terminal.

Circuit Diagram:



<table>
<tr><th>Symbol</th><th colspan="4">Truth Table</th></tr>
<tr><td rowspan="9">

3-input NOR Gate</td><td>C</td><td>B</td><td>A</td><td>Q</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>Boolean Expression $Q = \overline{A+B+C}$</td><td colspan="4">Read as A OR B OR C gives NOT Q</td></tr>
</table>

Operation:

i. When all inputs are low i.e. A=B=C=0V (A=0, B=0, C=0) then all transistors Q_1, Q_2 & Q_3 are OFF, So the output is $V_{CE} = 5V$ i.e. Q=1.

ii. When A is high, B is low and C is also low i.e. A=5V, B=0V & C=0V (A=1, B=0, C=0) then transistor Q_1 is ON, Q_2 is OFF & transistor Q_3 is also OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

iii. When A is low, B is high and C is low i.e. A=0V, B=5V & C=0V (A=0, B=1, C=0) then transistor Q_1 is OFF, Q_2 is ON & transistor Q_3 is OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

iv. When A is high, B is high and C is low i.e. A=5V, B=5V & C=0V (A=1, B=1, C=0) then transistor Q_1 is ON, Q_2 is ON & transistor Q_3 is OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

v. When A is low, B is also low and C is high i.e. A=0V, B=0V & C=5V (A=0, B=0, C=1) then transistor Q_1 is OFF, Q_2 is OFF & transistor Q_3 is also ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

vi. When A is high, B is low and C is high i.e. A=5V, B=0V & C=5V (A=1, B=0, C=1) then transistor Q_1 is ON, Q_2 is OFF & transistor Q_3 is ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

vii. When A is low, B is high and C is high i.e. A=0V, B=5V & C=5V (A=0, B=1, C=1) then transistor Q_1 is OFF, Q_2 is ON & transistor Q_3 is ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

viii. When A is high, B is high and C is high i.e. A=5V, B=5V & C=5V (A=1, B=1, C=1) then transistor Q_1 is ON, Q_2 is ON & transistor Q_3 is also ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

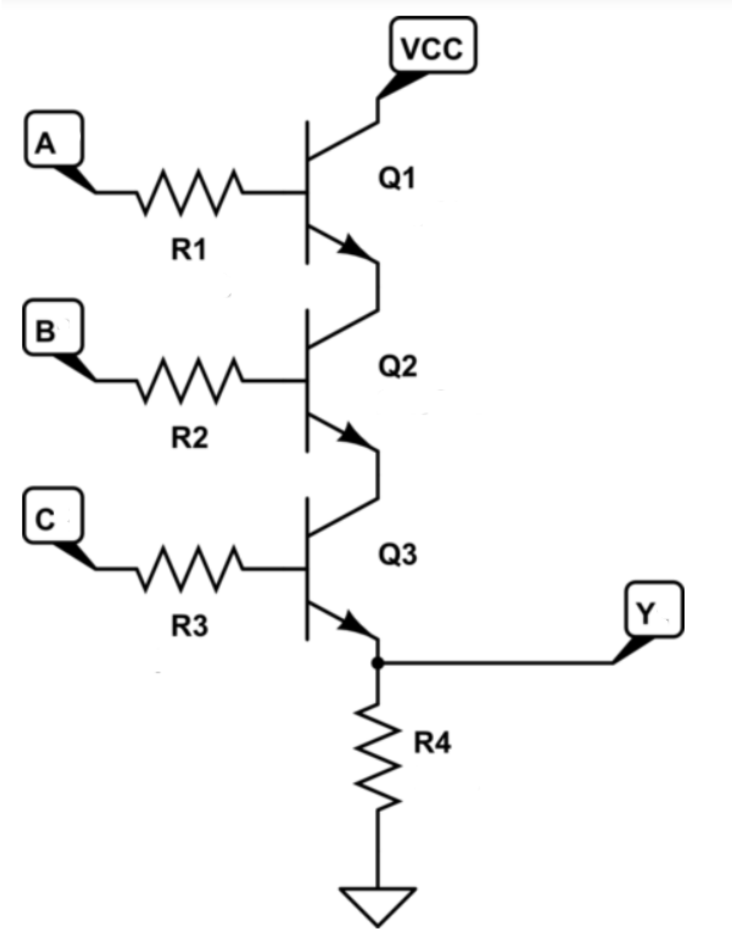
8) Draw and explain 3 input AND gate using transistors.

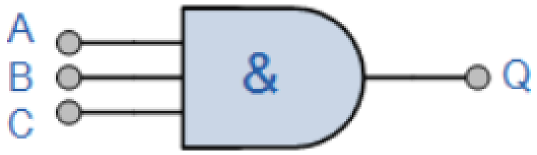
Answer:

3 Input AND gate using Transistors:

Three input AND gate uses 3 transistors inputs are A, B & C which are applied to base terminal of transistor Q_1, Q_2 & Q_3 through resistors & output Q is taken at collector terminal.

Circuit Diagram:



Symbol	Truth Table			
 3-input AND Gate	C	B	A	Q
	0	0	0	0
	0	0	1	0
	0	1	0	0
	0	1	1	0
	1	0	0	0
	1	0	1	0
	1	1	0	0
	1	1	1	1
Boolean Expression **Q = A.B.C**	Read as A **AND** B **AND** C gives Q			

Operation:

i. When all inputs are low i.e. A=B=C=0V (A=0, B=0, C=0) then all transistors Q_1, Q_2 & Q_3 are OFF, So the output is $V_{CE} = 0.2V$ i.e. Q=0.

ii. When *A* is high, B is low and *C* is also low i.e. *A*=5V, B=0V & *C*=0V (*A*=1, B=0, *C*=0) then transistor Q_1 is ON, Q_2 is OFF & transistor Q_3 is also OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

iii. When *A* is low, B is high and *C* is low i.e. *A*=0V, B=5V & *C*=0V (*A*=0, B=1, *C*=0) then transistor Q_1 is OFF, Q_2 is ON & transistor Q_3 is OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

iv. When *A* is high, B is high and *C* is low i.e. *A*=5V, B=5V & *C*=0V (*A*=1, B=1, *C*=0) then transistor Q_1 is ON, Q_2 is ON & transistor Q_3 is OFF. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

v. When *A* is low, B is also low and *C* is high i.e. *A*=0V, B=0V & *C*=5V (*A*=0, B=0, *C*=1) then transistor Q_1 is OFF, Q_2 is OFF & transistor Q_3 is also ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

vi. When *A* is high, B is low and *C* is high i.e. *A*=5V, B=0V & *C*=5V (*A*=1, B=0, *C*=1) then transistor Q_1 is ON, Q_2 is OFF & transistor Q_3 is ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

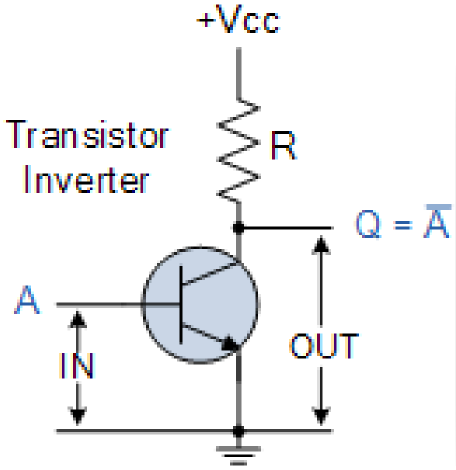
vii. When *A* is low, B is high and *C* is high i.e. *A*=0V, B=5V & *C*=5V (*A*=0, B=1, *C*=1) then transistor Q_1 is OFF, Q_2 is ON & transistor Q_3 is ON. So, the output voltage is $V_{CC} = 0.2V$ i.e. Q=0.

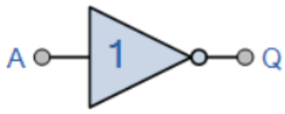
viii. When *A* is high, B is high and *C* is high i.e. *A*=5V, B=5V & *C*=5V (*A*=1, B=1, *C*=1) then transistor Q_1 is ON, Q_2 is ON & transistor Q_3 is also ON. So, the output voltage is $V_{CC} = 5V$ i.e. Q=1.

9) Draw and explain inverter using transistor.

Answer:

NOT gate uses only one transistor (Q). Here the input is A which is connected to base terminal of the transistor through resistor R, the output is taken at the collector terminal which is Q.



Symbol	Truth Table	
	A	Q
 Inverter or NOT Gate	0	1
	1	0
Boolean Expression **Q = not A or $\overline{A}$**	Read as inverse of **A** gives Q	

Operation:

i. When input is low i.e. A=0 (0V) then transistor is in cut of region then there is no current flow through the collector terminal i.e. $I_C = 0$. So, the output is same as the supply voltage i.e. 5V and Q=1.

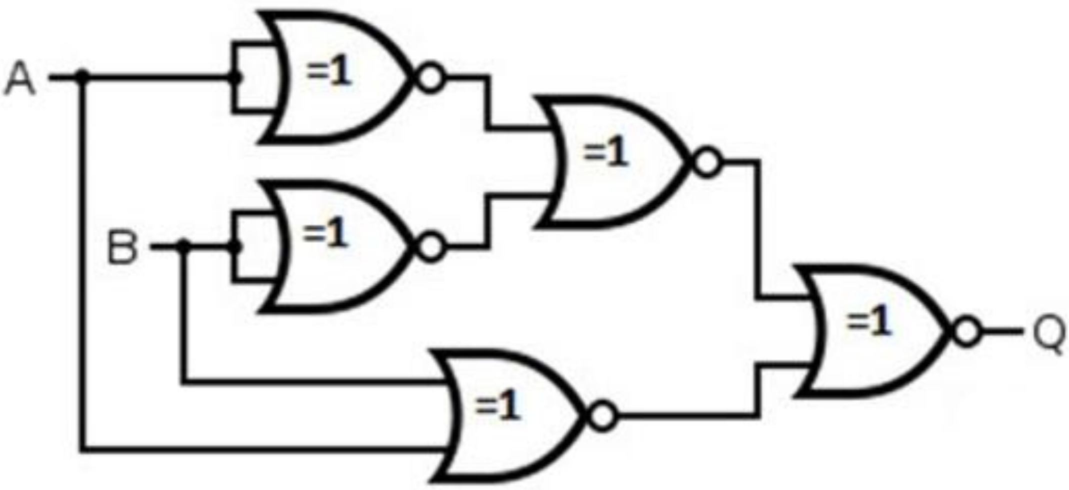
ii. When input is high i.e. A=1 (5V) then transistor is in saturation region and maximum collector current flows. So, the output is $V_{CE} = 0.3V$ i.e. Q=0.

10) Design X-OR and X-NOR gate using NOR Gate.

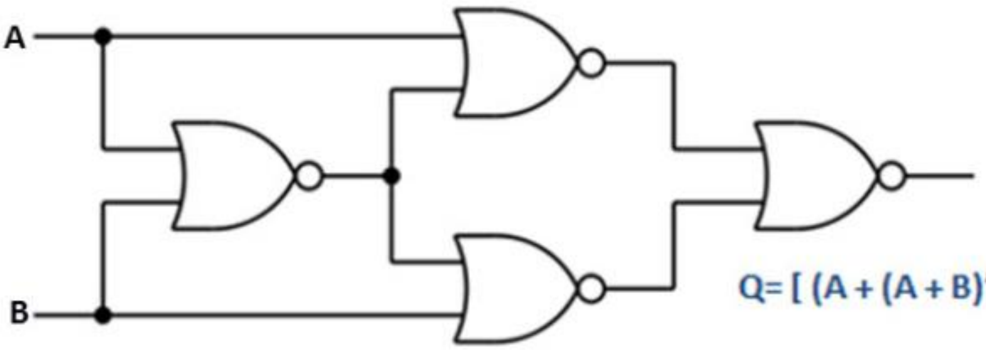
Answer:

X-OR Gate using NOR gate:

$$Q = ((A' + B')' + (A + B)')'$$



X-NOR Gate using NOR gate:



Q= [(A + (A + B)')' + (B + (A + B)')']'

1 MARK OR 2 MARKS QUESTIONS

1) **Why NAND and NOR gates are used as universal gates?**

Answer:

The NAND and NOR gates are said to be universal gates because using these gates any logical operations can be designed and also, they can perform all logical operation of basic gate i.e. they can perform AND, OR, NOT.

2) **Define Logic Gate.**

Answer:

A logic gate is a basic electronic circuit which operates on one or more signals to produce an output signal. And in computers, Boolean operations are performed by logic gates. Logic Gates are digital (two-state 0 or 1) circuits because the input and output signals are either low voltage (*denotes 0*) or high voltage (*denotes 1*). Logic Gates are often called *logic circuits* because they can be analysed with Boolean algebra

3) **Define X-OR Gate and draw truth table.**

Answer:

XOR Gate (Exclusive OR Gate)

The **XOR Gate** can also have two or more inputs but produces one output signal. Exclusive-OR gate is different from OR gate. OR gate produces output 1 for any input combination having one or more 1's, but XOR gate produces output 1 for only those input combinations that have odd number of 1's.

In Boolean algebra (+) sign stands for XOR operation. Thus, *A XOR B* can be written as A (+) B.

Following Truth Tables illustrate XOR operation:

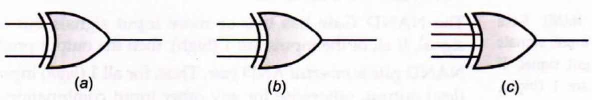
Table 2-input XOR gate

No. of 1's even/odd	X	Y	F
Even	0	0	0
Odd	0	1	1
Odd	1	0	1
Even	1	1	0

Table 3-input XOR gate

No. of 1's	X	Y	Z	F
Even	0	0	0	0
Odd	0	0	1	1
Odd	0	1	0	1
Even	0	1	1	0
Odd	1	0	0	1
Even	1	0	1	0
Even	1	1	0	0
Odd	1	1	1	1

The symbols of XOR gates are given below :



(*a*) 2-input XOR gate (*b*) 3-input XOR gate (*c*) 4-input XOR gate.

XOR addition can be summarised as follows :

$0 \oplus 0 = 0$, $0 \oplus 1 = 1$, $1 \oplus 0 = 1$, $1 \oplus 1 = 0$

XOR gate XOR gate produces output 1 for only those input combinations that have odd number of 1's.

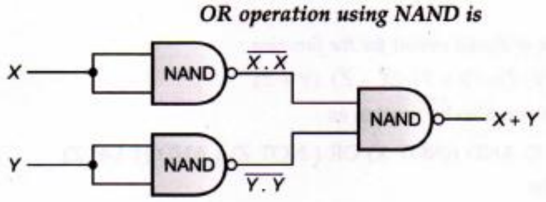
NOTE

Remember odd number of 1's produce output 1.

4) **Design OR gate using NAND gate.**

Answer:

OR operation using NAND is



OR operation NAND to NAND logic.

$X + Y = (X \text{ NAND } X) \text{ NAND } (Y \text{ NAND } Y)$

Proof. X NAND X

$= \overline{X.X}$

$= \overline{X} + \overline{X}$ (*DeMorgan's Second Theorem*)

$= \overline{X}$ $(X + X = X)$

Similarly, Y NAND Y $= \overline{Y}$

Therefore, (X NAND X) NAND (Y NAND Y)

$= \overline{X} \text{ NAND } \overline{Y}$

$= \overline{\overline{X}.\overline{Y}}$

$= \overline{\overline{X}} + \overline{\overline{Y}}$ (*De Morgan's Second Theorem*)

$= X + Y$ (*i.e.*, X OR Y) $(\overline{\overline{X}} = X, \overline{\overline{Y}} = Y)$

5) **Classify the logic gates.**

Answer:

Logic gates are classified into 3 basic gates and 2 universal gates and 2 Additional gates.

3 Basic Gates:

i. AND
ii. NOT
iii. OR

2 Universal Gates:

i. NAND
ii. NOR

2 Additional Gates:

i. X-OR
ii. X-NOR

6) **Define NAND gate and draw truth table.**

Answer:

NAND Gate

The **NAND Gate** has two or more input signals but only one output signal. If all of the inputs are 1 (high), then the output produced is 0 (low).

NAND *gate is inverted* AND *gate*. Thus, for all 1 (*high*) inputs, it produces 0 (*low*) output, otherwise for any other input combination, it produces a 1 (*high*) output. NAND gate can also have as many inputs as desired. NAND action is illustrated in following Truth Tables:

Table *2-input NAND gate*

X	Y	F
0	0	1
0	1	1
1	0	1
1	1	0

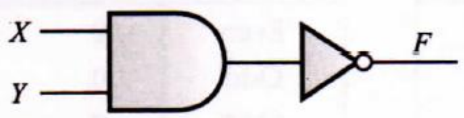
$F = \overline{XY}$

Table *3-input NAND gate*

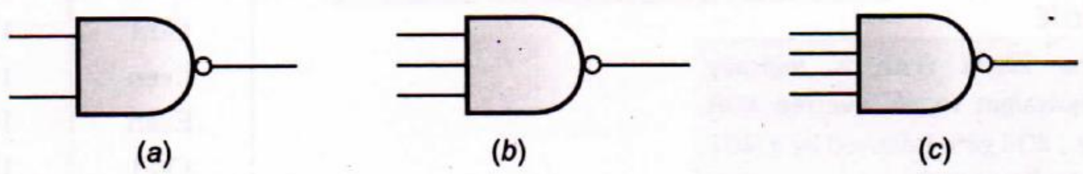
X	Y	Z	F
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

$F = \overline{XYZ}$

The logical meaning of NAND gate can be shown as follows :



The symbols of 2, 3, 4 input NAND gates are given below :



(*a*) 2-input NAND gate (*b*) 3-input NAND gate (*c*) 4-input NAND gate.

NAND Gate The NAND Gate has two or more input signals but only one output signal. If all of the inputs are 1 (high), then the output produced is 0 (low).

7) Define OR gate and draw truth table.

Answer:

OR Gate

The OR Gate has two or more input signals but only one output signal.
If any of the input signals is 1 (high), the output is 1 (high).
If all inputs are 0 then output is also 0. If one or more inputs are 1, then output is 1.

OR Gate The **OR Gate** has two or more input signals but only one output signal. If any of the input signals is 1 (high), the output signal is 1 (high).

An OR gate can have as many inputs as desired. No matter how many inputs are there, the action of OR gate is the same: one or more 1 (high) inputs produce output as 1.

Following tables show OR action

Table *Two input OR gate*

X	Y	F
0	0	0
0	1	1
1	0	1
1	1	1

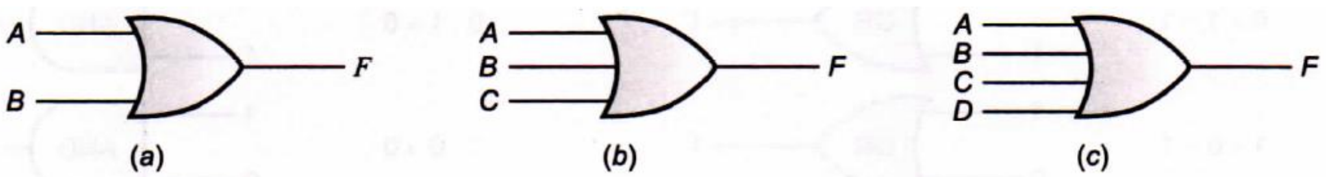
$F = X + Y$

Table *Three input OR gate*

X	Y	Z	F
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

$F = X + Y + Z$

The symbol for OR gate is given below :



(*a*) Two input OR gate (*b*) Three input OR gate (*c*) Four input OR gate.

8) Write the distributive law.

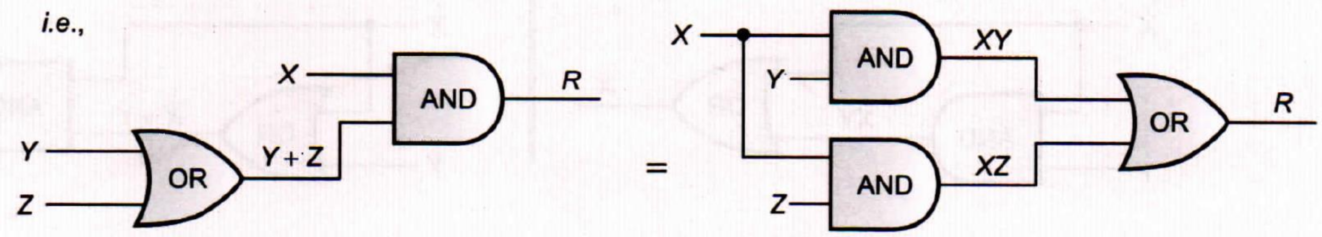
Answer:

Distributive Law

This law states that

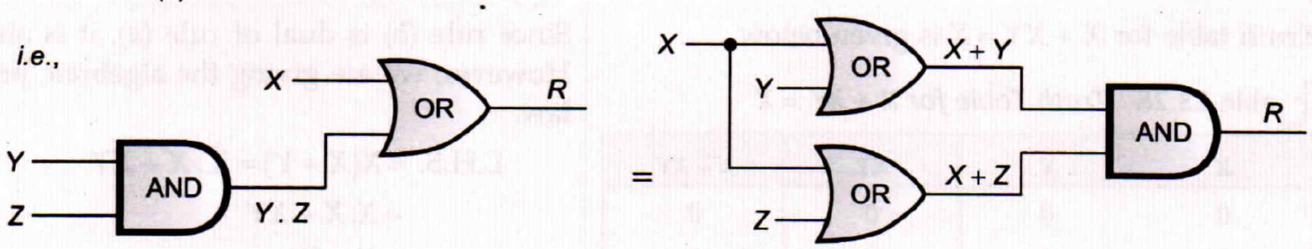
(*a*) $X(Y+Z) = XY + XZ$

i.e.,



(*b*) $X + YZ = (X+Y)(X+Z)$

i.e.,



9) Design inverter using NOR gate.

Answer:

Inverter or NOT gate is one input and one output gate. We know that the purpose of invertor is to invert the input signal and generate output signal.

So, if input A=1 then output Q=0.

And if input A=0 then output Q=1.

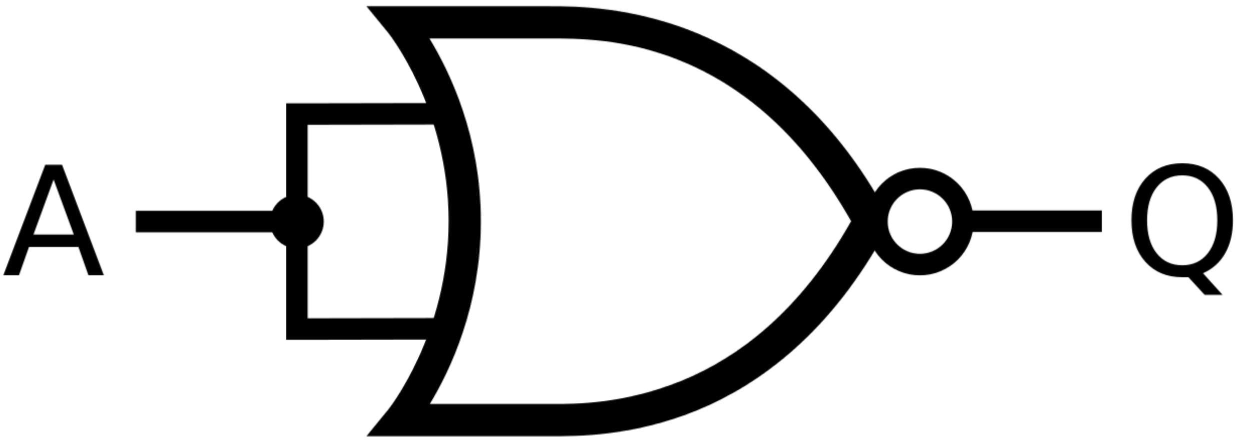
So, the NOR gate takes two or more inputs and generates one output and the output is determined as:

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

So, if we divide the single input A into two parts and send it to NOR gate it will generate A'.

Explanation:

$$Q = \overline{A + A} = \bar{A}.\bar{A} = \bar{A}$$



10) Define X-NOR Gate and draw truth table.

Answer:

XNOR Gate (Exclusive NOR Gate)

The **XNOR Gate** is logically equivalent to an inverted XOR *i.e.*, XOR gate followed by a NOT gate (inventor). Thus, XNOR produces 1 (high) output when the input combination has even number of 1's.

XNOR gate XNOR gate produces output 1 for only those input combinations that have even number of 1's.

Following tables illustrate XNOR action:

Table *2-input XNOR gate*

No. of 1's	X	Y	F
Even	0	0	1
Odd	0	1	0
Odd	1	0	0
Even	1	1	1

Table *3-input XNOR gate*

No. of 1's	X	Y	Z	F
Even	0	0	0	1
Odd	0	0	1	0
Odd	0	1	0	0
Even	0	1	1	1
Odd	1	0	0	0
Even	1	0	1	1
Even	1	1	0	1
Odd	1	1	1	0

NOTE

The XNOR Gate is logically equivalent to an inverted XOR *i.e.*, XOR gate followed by a NOT gate (inventor).

UNIT-5

1 MARK OR 2 MARKS QUESTIONS

1) Definition of sensor.

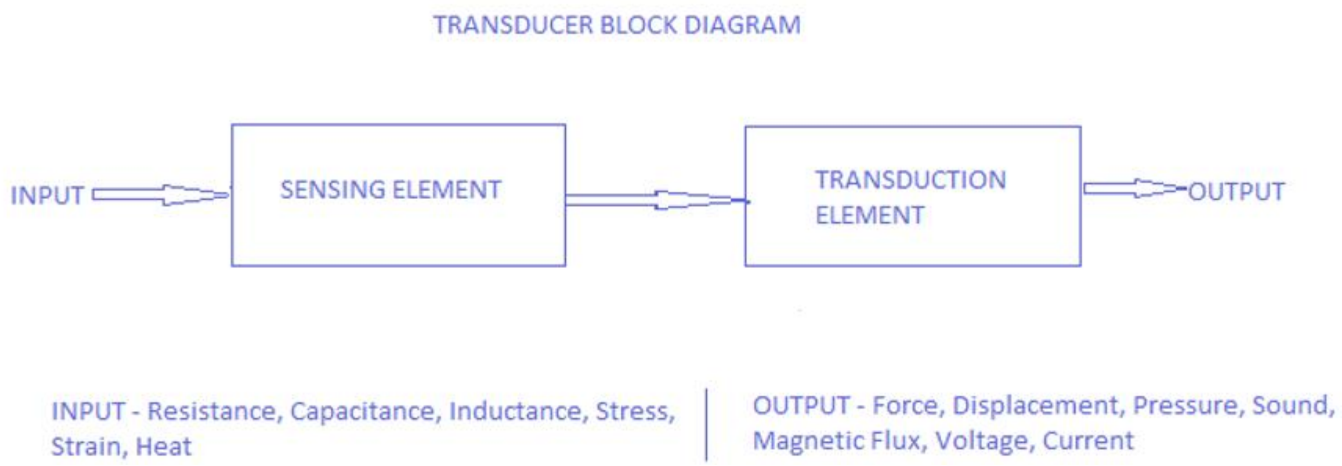
Answer:

A **sensor** is a device that measures physical input from its environment and converts it into data that can be interpreted by either a human or a machine. Most **sensors** are electronic (the data is converted into electronic data), but some are simpler, such as a glass thermometer, which presents visual data.

In the broadest definition, a *sensor* is a device, module, machine or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics.

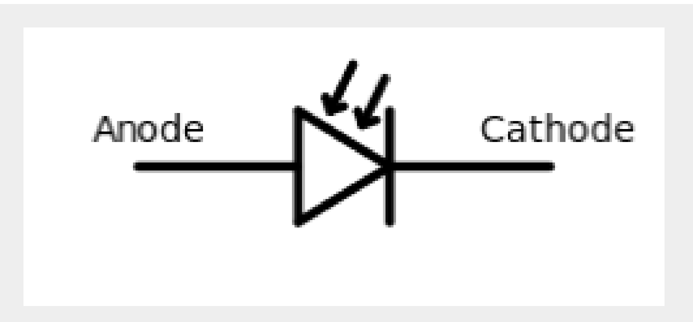
2) Draw the block diagram of transducer.

Answer:



3) Draw the symbol of photo diode.

Answer:



— Photo diode symbol

4) Write the applications of current sensor.

Answer:

Applications of Current Sensors:

i. Open loop current sensor using TLE4998S.

ii. Current sensor using TLE4998S in range selection mode.

5) What is function of photo detector?

Answer:

A **photodiode** is a semiconductor device that converts light into an electrical current. The current is generated when photons are absorbed in the **photodiode**. **Photodiodes** may contain optical filters, built-in lenses, and may have large or small surface areas.

Working principle: Converts light into current

Pin configuration: anode and cathode

6) **Define quantum efficiency, responsivity and dark current of a photo diode.**

Answer:

Quantum Efficiency: It is defined as fraction of incident photons contributing to photo current. It is unit less as it is a fraction.

$$P = \frac{N_E}{N_{Photons}}$$

Where N_E is the number of $\frac{generated\ carriers}{unit\ \ time}$

And $N_{Photons}$ is the number of $\frac{incident\ photos}{unit\ time}$

Responsivity: It is defined as the ratio of photo generated current to incident light power. It is measured in units of $\frac{amp}{watt}$.

$$Responsivity\ R = \frac{I_S}{P_{in}}$$

Where, I_S is the photo current

Dark Current: The current through the photodiode in the absence of light, when it is operated in photoconductive mode. The dark current includes photocurrent generated by background radiation and the saturation current of the semiconductor junction.

The relation between the Responsivity and quantum efficiency is given as:

$$Q = \frac{R \times h \times v}{e} \quad and \quad R = \frac{I_S}{P_{in}}$$

7) **What is the function of resistive level sensor?**

Answer:

Resistive Level Sensor detects level changes by the change in resistance of a partially submerged electrical element.

8) **What are the types of temperature sensors?**

Answer:

Types of temperature Sensors:

i. Thermocouples
ii. Resistor temperature detectors
iii. Thermistors
iv. Infrared sensors
v. Semiconductor Sensor
vi. Thermometers

9) **What are voltage and current sensors?**

Answer:

Voltage Sensor: It is a sensor which is used to calculate and monitor the amount of voltage across and element. Voltage sensors can determine both the AC voltage and DC voltage level.

Current Sensor: A current sensor is a device that recognizes electrical current in a wire or a system whether it is high or low and creates an indicator relative to it. Current sensor is a device which detects and converts current to get an output voltage, which is directly proportional to the current in the designed path.

10) **Mention the types of photodiodes.**

Answer:

Types of Photodiodes:

i. PN junction photo diode
ii. Avalanche photo diode
iii. PIN photo diode

Normal PN junction photodiode is used in low frequency and low sensitive applications. When high frequency of operation and high sensitivity is needed avalanche photodiode or PIN photodiodes are used.

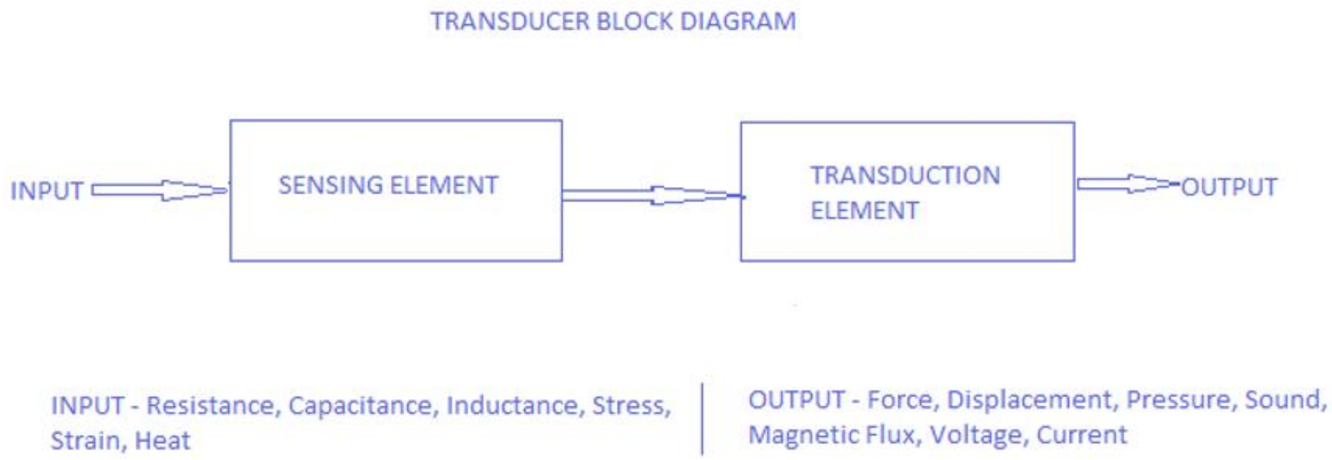
5 MARKS OR 7 MARKS QUESTIONS

1) Explain about the transducer block diagram in detail.

Answer:

A transducer is a device that is used to convert a physical quantity into its corresponding electrical signal.

In most of the electrical systems, the input signal will not be an electrical signal, but a non-electrical signal. This will have to be converted into its corresponding electrical signal if its value is to be measured using electrical methods.



A transducer will have basically two main components. They are

i. **Sensing Element:** The physical quantity or its rate of change is sensed and responded to by this part of the transistor.
ii. **Transduction Element:** The output of the sensing element is passed on to the transduction element. This element is responsible for converting the non-electrical signal into its proportional electrical signal.

There may be cases when the transduction element performs the action of both transduction and sensing. The best example of such a transducer is a thermocouple. A thermocouple is used to generate a voltage corresponding to the heat that is generated at the junction of two dissimilar metals.

2) Explain about resistive level sensor.

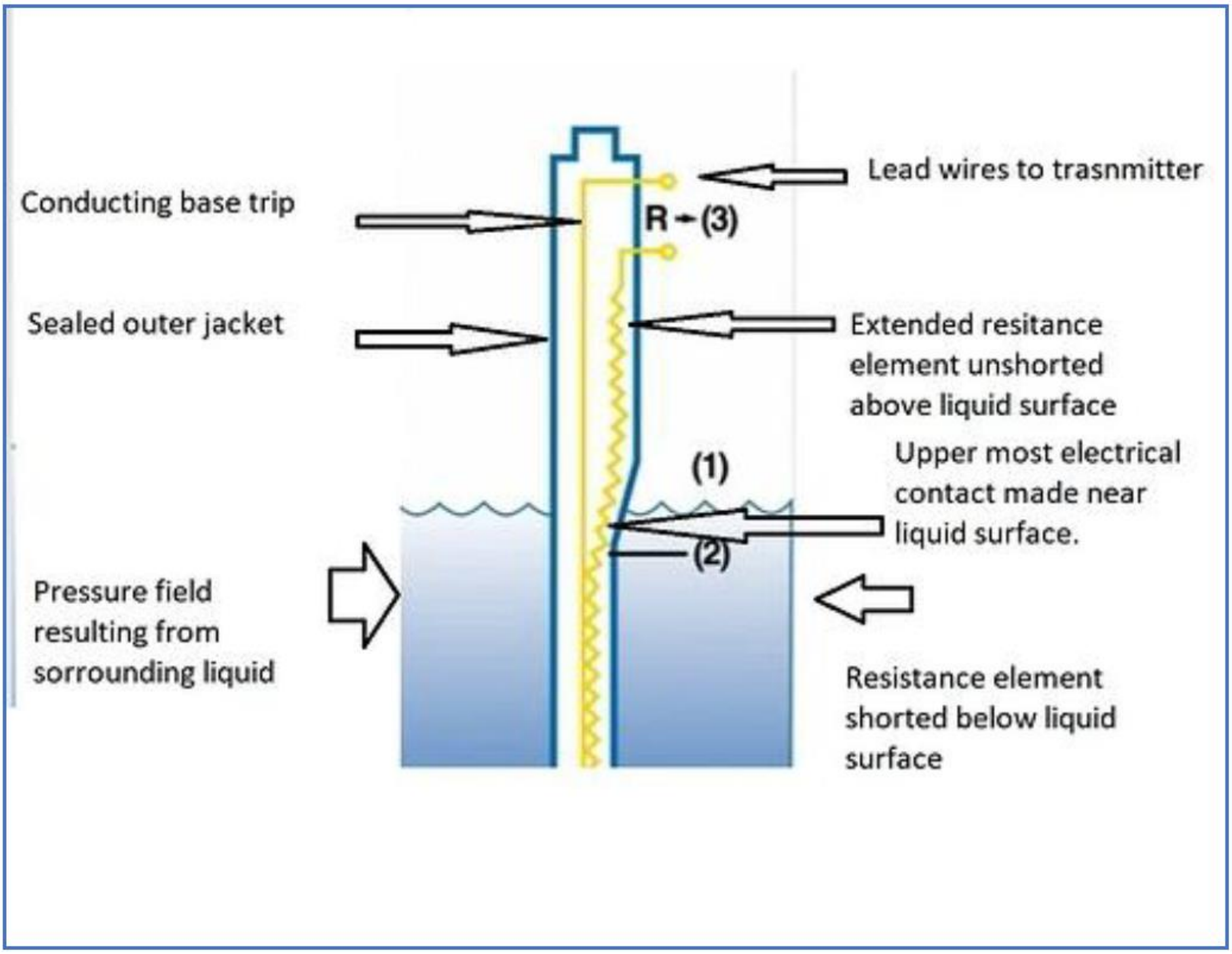
Answer:

Resistive level sensor: It detects level changes by the change in resistance of a partially submerged electrical element.

Construction of Resistance Level Detectors: The electrical sensing element consists of a precision-wound helix resistor that has about 28 contacts per foot. An outer jacket of flexible protective material also acts as a pressure receiving diaphragm.

Principle of Operation: Resistance Level Detector

- The pressure of the liquid in the tank acts upon the jacket-diaphragm and causes the resistance element to contact the steel base trip.
- Below the surface of the liquid, the resistor is shorted.
- The resistor remains un-shorted above the surface, and it is this portion that is metered to provide the level reading.
- Two wires from the sensor top transmit an electrical resistance signal that is related to the distance from the tank top to the surface of the liquid.
- Typically, 1 ohm is equal to 1 cm.



Advantages of Resistance of Level detector

- The sensor strip remains fixed in position, has no moving parts and provides a continuous indication of resistance.
- The windings these sensors are purely resistive, they cannot store or release electrical energy.
- Thus, resistance sensors qualify as intrinsically safe devices and can be used with explosive liquids and dust.

3) **Explain about the voltage sensors and types and explain anyone.**

Answer:

Voltage sensor: A voltage sensor is a sensor which is used to calculate and monitor the amount of voltage across an element.

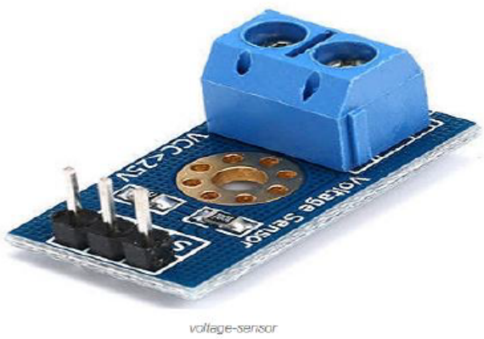
Voltage sensors can determine both the AC voltage and DC voltage level. The input of this sensor can be the voltage whereas the output is the switches, analog voltage signal, a current signal, an audible signal, etc

Advantages of Voltage sensor

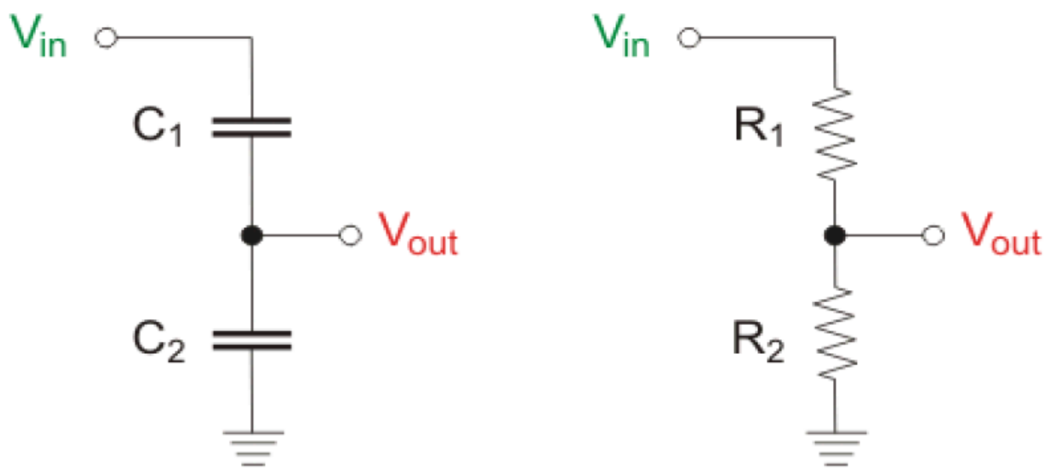
- Small in weight and size.
- Personnel safety is high.
- Degree of accuracy is very high.
- It is non-saturable.
- Wide dynamic range.
- Eco-friendly.
- It is possible to combine both the voltage and current measurement into a single physical device with small and compact dimensions.

Types of voltage sensors

1. A voltage sensor can in fact determine, monitor and can measure the supply of voltage. It can measure:
   i. AC voltage level
   ii. DC voltage level.
2. The input to the voltage sensor is the voltage itself and the output can be:
   i. Analog voltage signals
   ii. Switches
   iii. Audible signals
   iv. Analog current level
   v. Frequency
   vi. Even frequency modulated outputs.
3. Some voltage sensors can provide sine or pulse trains as output and others can produce:
   i. Amplitude Modulation outputs.
   ii. Pulse Width Modulation outputs.
   iii. Frequency Modulation outputs.
4. In voltage sensors, the measurement is based on a voltage divider. There are two main types of voltage sensors are available-
   i. Capacitive type voltage sensor
   ii. Resistive type voltage sensor



Fig(a)Capacitor



$$V_{out} = \frac{C_1}{C_1 + C_2} \times V_{in}$$

$$V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}$$

Fig(a)Capacitor voltage sensor (b)Resistor voltage sensor

I. Capacitive Voltage Sensor

As we know that a capacitor comprises of two conductors or simply two plates and in between these plates, a non-conductor is kept. That non-conducting material is termed as dielectric.

When an AC voltage is provided across these plates current will start to pass owing to either the attraction or the repulsion of electrons by means of the voltage present on the opposite plate.

The field among the plates will create a complete AC circuit without any hardware connection. This is how a capacitor works.

Usually in series circuits, high voltage will develop across the component which is having high impedance.

In the case of capacitors, conductance and impedance (capacitive reactance) are always inversely proportional.

$$X_C = \frac{1}{2\pi f C}$$

The relation between voltage and capacitance is

$$V = \frac{Q}{C}$$

Q → Charge (Coulomb)

C → Capacitance (Farad)

X_C → Capacitive reactance (Ω)

f → Frequency (Hertz)

From the above two relations, we can clearly state that the highest voltage will build up across smallest capacitor.

II. Resistor Voltage Sensor

This sensor mainly includes two circuits like a voltage divider & bridge circuit. The resistor in the circuit works as a sensing element.

The voltage can be separated into two resistors like a reference voltage & variable resistor to make a circuit of the voltage divider.

A voltage supply is applied to this circuit. The output voltage can be decided by the resistance used in the circuit. So, the voltage change can be amplified.

The bridge circuit can be designed with four resistors. One of these resistors can be subjected to the voltage detector device. The change in voltage can be directly exhibited. This difference alone can be amplified but the difference within the voltage divider circuit not only amplified.

Applications:

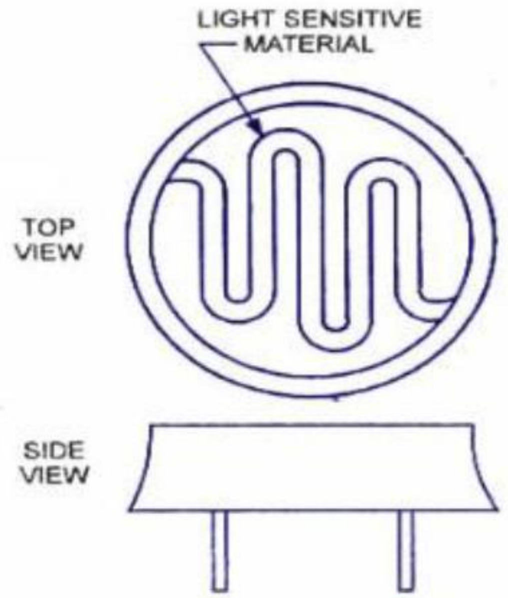
- Detection of power failure
- Detecting of load
- Safety switching
- Controlling temperature
- Controlling of power demand
- Detection of fault
- Variation of load measurement of Temperature

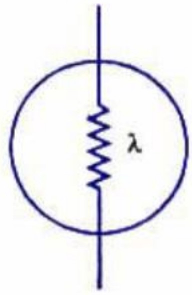
4) Write short notes on Photoconductive detectors and their characteristics.

Answer:

Photoconductive detectors: Photoconductive detectors are a type of photo detectors. Here, the absorption of incident light creates non-equilibrium electrical carriers, and that reduces the electrical resistance across two electrodes. There are also some exotic cases with negative photo conductivity, i.e., with an increase of resistance caused by illumination. Alternative, terms for photoconductive detectors are *photo resistors*, *light-dependent resistors* and *photocells*.

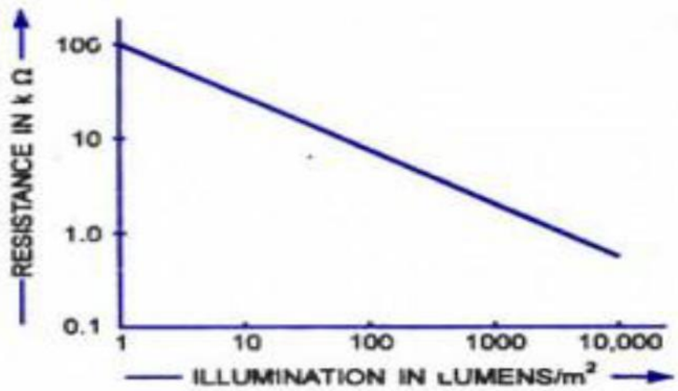
However, *photoconductors* are the devices without a p–n junction. The electrical characteristics are profoundly different from those of photodiodes. For example, one obtains a substantial dependence of the photocurrent on the applied bias voltage.
The *photoconductive cell* is a two terminal semiconductor device whose terminal resistance will vary (linearly) with the intensity of the incident light. For obvious reasons, it is frequently called a *photo resistive device.* The photoconductive materials most frequently used include cadmium sulphide (CdS) and cadmium selenide (CdSe). The resistance of cadmium sulphide remains relatively stable. The *spectral response* of a cadmium sulphide cell closely matches that of the human eye, and the cell is therefore often used in applications where human vision is a factor, such as street light control or automatic iris control for cameras. The circuit symbol and construction of a typical photoconductive cell are shown. Light sensitive material is arranged in the form of a long strip, zigzagged across a disc shaped base with protective sides. For added protection, a glass or plastic cover may be included. The two ends of the strip are brought out to connecting pins below the base.





Circuit Symbol

Characteristics of a Photoconductive cell:
Sensitivity: The sensitivity of a photodetector is the relationship between the light falling on the device and the resulting output signal. In the case of a photocell, one is dealing with the relationship between the incident light and the corresponding resistance of the cell.



Illumination Characteristic of a Typical Photoconductive Cell

The illumination *characteristics of a typical photoconductive* cell are shown from which it is obvious that when the cell is not illuminated its resistance may be more than 100 kilo ohms. This resistance is called the *dark resistance*. When the cell is illuminated, the resistance may fall to a few hundred ohms. Note that the scales on the illumination characteristic are logarithmic to cover a wide range of resistance and illumination that are possible. Cell sensitivity may be expressed in terms of the cell current for a given voltage and given level of illumination.

The *major drawback* of the photoconductive cells is that temperature variations cause substantial variations in resistance for a particular light intensity. Therefore, such a cell is unsuitable for analog applications.

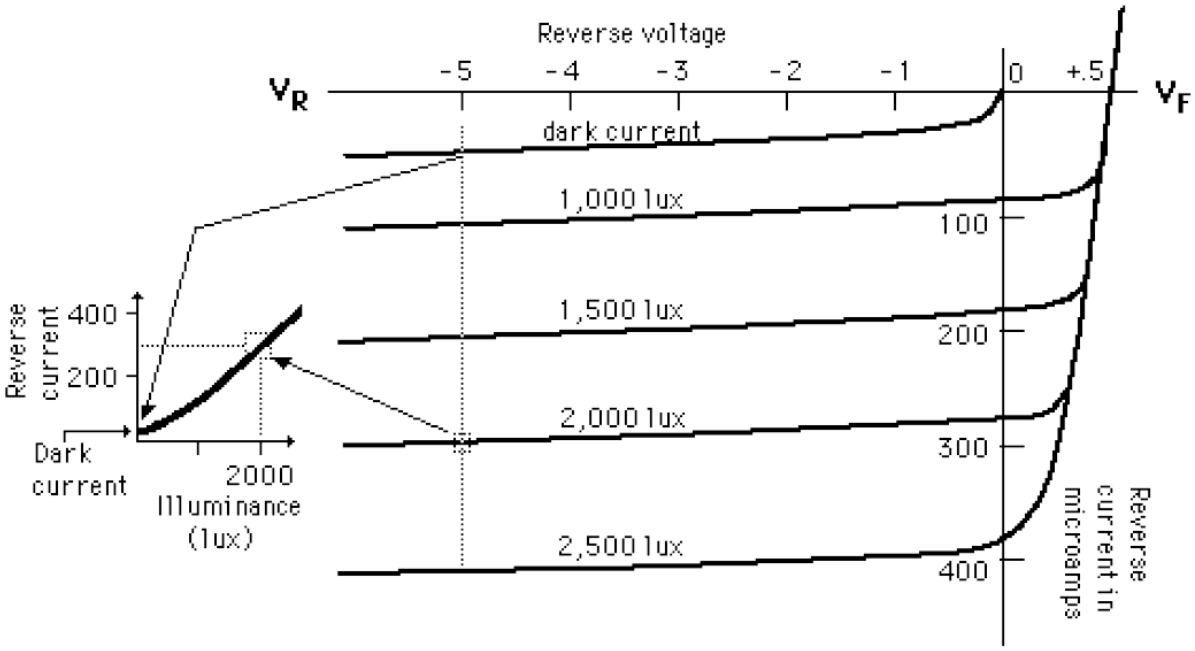
Some of its *applications* include camera light meters, street lights, clock radios, light beam alarms, reflective smoke alarms, and outdoor clocks.

5) Explain the working principle and characteristics of Photodiode.

Answer:

Photodiodes are semiconductor devices with a p–n junction or p–i–n structure (i = intrinsic material) (p–i–n photodiodes), where light is absorbed in a depletion region and generates a photocurrent. Such devices can be very compact, fast, highly linear, and exhibit a high quantum efficiency (i.e., generate nearly one electron per incident photon) and a high dynamic range, provided that they are operated in combination with suitable electronics. A particularly sensitive type is that of avalanche photodiodes, which are sometimes used even for photon counting.

V-I characteristics of photo diode:



6) Illustrate principle of Current Sensor.

Answer:

Current Sensor:

A sensor is a unit that can determine a physical phenomenon and compute the latter, in other words it gives a measurable demonstration of the wonder on a particular scale or range.

A current sensor is a device that recognizes electrical current in a wire or a system whether it is high or low and creates an indicator relative to it. It might be then used to presentation the measured current in an ammeter or might be archived for further classification in a data acquisition system or might be used for control purpose. Current sensor is "disturbing" as it is an incorporation of some of the sensor, which may cause system performance.

There are a wide variety of current sensors to monitor alternating or direct the current and its measurement is required in many applications be it in industrial, automotive or household fields.

Principle:

Current sensor is a device which detects and converts current to get an output voltage, which is directly proportional to the current in the designed path. When current is passing through the circuit, a voltage drops across the path where the current is flowing. Also, a magnetic field is generated near the current carrying conductor. These above phenomena are used in the current sensor design technique.

7) **Explain the principle of thermocouple and RTDs.**

Answer:

Thermocouples:

Thermocouple sensor is the most commonly used temperature sensor and it is abbreviated as TC. This sensor is extremely rugged, low-cost, self-powered and can be used for long distance. There are many types of temperature sensors that have a wide range of applications.

A thermocouple is a voltage device that indicates temperature by measuring a change in the voltage. It consists of two different metals: opened and closed. These metals work on the principle of thermo-electric effect. When two dissimilar metals produce a voltage, then a thermal difference exists between the two metals. When the temperature goes up, the output voltage of the thermocouple also increases. This thermocouple sensor is usually sealed inside a ceramic shield or a metal that protects it from different environments. Some common types of thermocouples include K, J, T, R, E, S, N, and B. The most common type of thermocouples is J, T and K type thermocouples, which are available in pre-made forms. The most important property of the thermocouple is nonlinearity – the output voltage of the thermocouple is not linear with respect to temperature. Thus, to convert an output voltage to a temperature, it requires mathematical linearization.

Resistor Temperature Detector (RTD): RTD sensor is one of the most accurate sensors. In a resistor temperature detector, *the resistance is proportional to the temperature*. This sensor is made from platinum, nickel, and copper metals. It has a wide range of temperature measurement capabilities as it can be used to measure temperature in the range between -270oC to +850oC. RTD requires an external current source to function properly. However, the current produces heat in a resistive element causing an error in the temperature measurements. The error is calculated by this formula: $\boldsymbol{\delta T = P \times S}$

There are different types of techniques to measure temperature by using this RTD. They are two wired, three-wired and four-wired method. In a two-wired method, the current is forced through the RTD to measure the resulting voltage. This method is very simple to connect and implement; and, the main drawback is – the lead resistance is the part of the measurement which leads to erroneous measurements. Three-wired method is similar to the two-wired method, but the third wire compensates for the lead resistance. In a four-wired method, the current is forced on one set of the wires and the voltage is sensed on the other set of wires. This four-wired method completely compensates for the lead resistance.

8) **Explain the principle of thermometers and semiconductor sensors.**

Answer:

Thermometers: A thermometer is a device used to measure the temperature of solids, liquids, or gases. The name thermometer is a combination of two words: thermo – means heat, and meter means to measure. Thermometer contains a liquid, which is mercury or alcohol in its glass tube. The volume of the thermometer liquid is linearly proportional to the temperature – when the temperature increases, the volume of the thermometer also increases.

When the liquid is heated it expands inside the narrow tube of the thermometer. This thermometer has a calibrated scale to indicate the temperature. The thermometer has numbers marked alongside the glass tube to indicate the temperature when the line of mercury is at that point. The temperature can be recorded in these scales: Fahrenheit, Kelvin or Celsius. Therefore, it is always desirable to note for which scale the thermometer is calibrated.

Semiconductor Sensors: Semiconductor sensors are the devices that come in the form of ICs. Popularly, these sensors are known as an IC temperature sensor. They are classified into different types: Current output temperature sensor, Voltage output temperature sensor, Resistance output silicon temperature sensor, Diode temperature sensors and Digital output temperature sensor. Present semiconductor temperature sensors offer high linearity and high accuracy over an operating range of about 55°C to +150°C. However, AD590 and LM35 temperature sensors are the most popular temperature sensors

9) **Explain about current sensing methods.**

Answer:

Two methods of current sensing:

1. Direct current sensing:

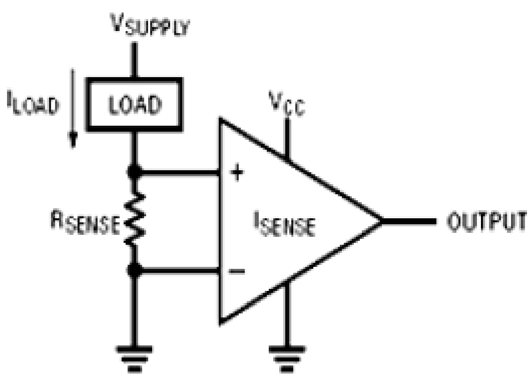
Direct current sensing is dependent upon Ohm's law. By putting a shunt resistor in arrangement with the system load, a voltage is generated across the shunt resistor that is proportional to the system load current. The voltage over the shunt could be measured by differential amplifiers for example current shunt amplifiers, operational amplifiers or difference amplifiers. It is typically implemented for load currents <100A.

2. Indirect current sensing:

Indirect current sensing is dependent upon Ampere's and Faraday's laws. By putting a loop around a current carrying conductor, a voltage is induced over the loop that is proportional to the current. This type sensing method is utilized for 100A – 1000A load currents

Low-Side Current Sensing:

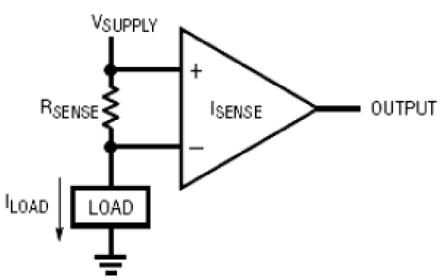
It is a low input common mode voltage. Low-side current sensing connects the sensing resistor between the load and ground. This is desirable because the common-mode voltage is near ground, which takes into consideration the utilization of single-supply, rail to rail input /output op-amps. Load is given to the single supply and resistance is grounded. The drawbacks to low-side sensing are disturbances to the system load's ground potential and the inability to detect load shorts.



High Side Current Sensing:

High-side current sensing connects the sensing resistor between the power supply and load.

High-side sensing is desirable because it directly monitors the current delivered by the supply, which considers the identification of load shorts. The test is that the amplifier's input common mode voltage range must have as a feature the load's supply voltage. Finally, out is measured across the current sensed device, and load is grounded.



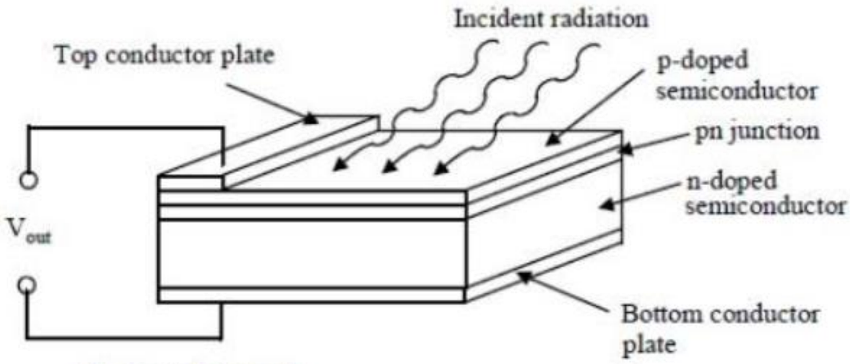
10) Explain the working principle of Photo voltaic detector.

Answer:

Photo voltaic detectors: An important type of photo detector is the photovoltaic cell, which generates a voltage that is proportional to the incident EM radiation intensity. These sensors are called photovoltaic cells because of their voltage-generating capacity, but the cells actually convert EM energy into electrical energy. Photovoltaic cells are very important in *instrumentation* and control applications because they are used both as light detectors and in power sources that convert solar radiation into electrical power for remote-measuring systems.

Working principle

The operating principle of the photovoltaic cell is illustrated in Figure below. The cell is a large exposed diode that is constructed using a p-n junction between appropriately doped semiconductors. Photons hitting the cell pass through the thin p-doped upper and are absorbed by electrons in the n-doped layer. This causes conduction electrons and holes to be created. The upper terminal is positive and the lower negative. In general, the open-circuit voltage V that is developed on a photovoltaic cell varies logarithmically with the incident radiation intensity according to the following equation:



Photovoltaic cell

$$V = V_o \ln(I_r)$$

where

I_r = the radiation intensity in W/m2

V_o = the calibration voltage in volts

V = the unloaded output voltage in volts