ELECTRONIC DEVICES AND CIRCUITS

IMPORTANT QUESTIONS, NOTES

UNIT - I

2 - Mark

1. What is diffusion current in PN junction diode ?

Ans.:

When a semiconductor is nonuniformly doped, then there exists concentration gradient. On one side there is high carrier concentration while on the other there is low carrier concentration. Due to this, charges start moving from higher to lower concentration area. This process is called diffusion. When the charges move due to diffusion, the current gets established in a semiconductor which is called a diffusion current.

2. What is peak inverse voltage?

Ans.:

In reverse biased, opposite polarity voltage appears across diode. The maximum reverse voltage which diode can withstand without breakdown is called peak inverse voltage.

3. What is meant by Zener breakdown?

Ans.:

When a p-n junction is heavily doped the depletion region is very narrow. So under reverse bias conditions, the electric field across the depletion layer is very intense. Electric field is voltage per distance and due to narrow depletion region and high reverse voltage, it is intense. Such an intense field is enough to pull the electrons out of the valence bands of the stable atoms. Such a creation of free electrons is called Zener effect. These minority carriers constitute very large current to cause the breakdown and the mechanism is called Zener breakdown.

4. Define knee voltage or a cut-in voltage of a diode.

   Ans.:

   When diode is forward biased, some voltage is necessary to overcome barrier potential, to make diode conduct. This is called its cut-in voltage. The minimum voltage at which the diode starts conducting and current starts increasing exponentially is called cut-in voltage, offset voltage, break-point voltage, threshold voltage or knee voltage. It is denoted as V, and its, value is 0.2 V for Germanium while 0.6 V for Silicon. Below this voltage, the diode current is very very small and practically considered to be zero.

5. Derive the ripple factor of FWR.

   Ans.:

   The ripple factor is given by,

$$\gamma = \sqrt{\left[\frac{I_{R.M.S.}}{I_{D.C.}}\right]^2 - 1}$$

For FWR, $I_{R.M.S.} = I_m/\sqrt{2}$ and $I_{D.C.} = 2\,I_m / \pi$

$$\gamma = \sqrt{\left[\frac{I_m}{\sqrt{2}\left(\frac{2\,I_m}{\pi}\right)}\right]^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1}$$

$$= 0.48$$

6. What is a rectifier? List its types.

   Ans.:

   A rectifier is a device which converts a.c. voltage to pulsating d.c. voltage, using one or more p-n junction diodes. The various types of rectifiers are,

   i) Half wave ii) Full wave and iii) Bridge type

13 - Mark

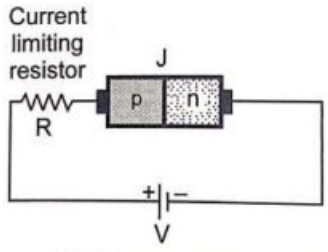
1. Forward Biasing of P-N Junction Diode

Ans:

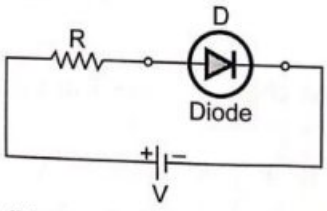
- If an external d.c. voltage is connected in such a way that the p-region terminal is connected to the positive of the d.c. voltage and the n-region is connected to the negative of the d.c. voltage, the biasing condition is called forward biasing. The p-n junction is said to be forward biased.

Key Point: Forward biasing means connecting p-region to +ve and n-region to -ve of the battery.

- The following figure (a) shows the connection of forward biasing of a p-n junction. To limit the current, practically a current limiting resistor is connected in series with the p-n junction diode. The following figure (b) shows the symbolic representation of forward biased diode.



(a) Forward biasing



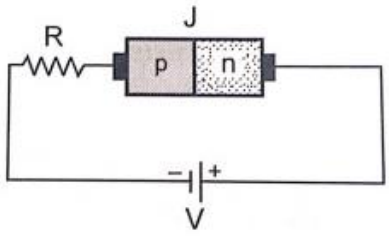
(b) Symbolic representation

2. Reverse Biasing of P-N Junction Diode

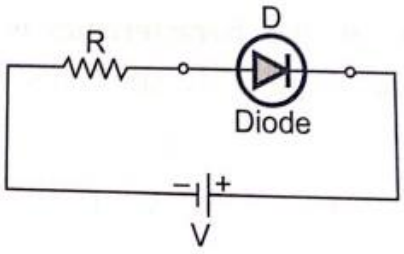
- If an external d.c. voltage is connected in such a way that the p-region terminal of a p-n junction is Electron Device connected to the negative of the battery and the n-region terminal of a p-n junction is connected to the positive terminal of the battery, the biasing condition is called reverse biasing of a p-n junction.

Key Point: Reverse biasing means connecting p-region to -ve and n-region to +ve of the battery.

The following figure (a) shows the connection of a reverse biasing of a p-n junction while the following figure (b) shows the symbolic representation of a reverse biased diode



(a) Reverse biasing



(b) Symbolic representation

3. A silicon diode conducts 5 mA at room temperature in forward bias condition at 0.7 V. Calculate its reverse saturation current. If the forward voltage is increased to 0.75 V calculate the new current through the diode. (Take η = 2 and V_T =26 mV) at room temperature.

Ans: I1 = 5 mA, V1 = 0.7 V, η = 2, VT = 26 mV

$$I = I_0 [e^{V/\eta V_T} - 1] \text{ ... Diode equation}$$

$$\therefore \quad I_1 = I_0 [e^{V1/\eta V_T} - 1]$$

$$\text{i.e.} \quad 5\times10^{-3} = I_0 [e^{0.7/2\times26\times10^{-3}} - 1]$$

$$\therefore \quad I_0 = 7.1235 \text{ nA}$$

... Reverse saturation current.

Now the voltage is changed to V_2 = 0.75 V

$I = 7.1235 \times 10^{-9} [e^{0.75/2 \times 26 \times 10^{-3}} - 1]$

= 13.0784 mA ... New current

4. Diffusion Capacitance

Ans:

- During forward biased condition, an another capacitance comes into existence called diffusion capacitance or storage capacitance, denoted as CD.
- In forward biased condition, the width of the depletion region decreases and holes from p side get diffused in n side while electrons from n side move into the p side. As the applied voltage increases, concentration of injected charged particles increases. This rate of change of the injected charge with applied voltage is defined as a capacitance called diffusion capacitance.

$$C_D = \frac{dQ}{dV} \quad \ldots (1,12.1)$$

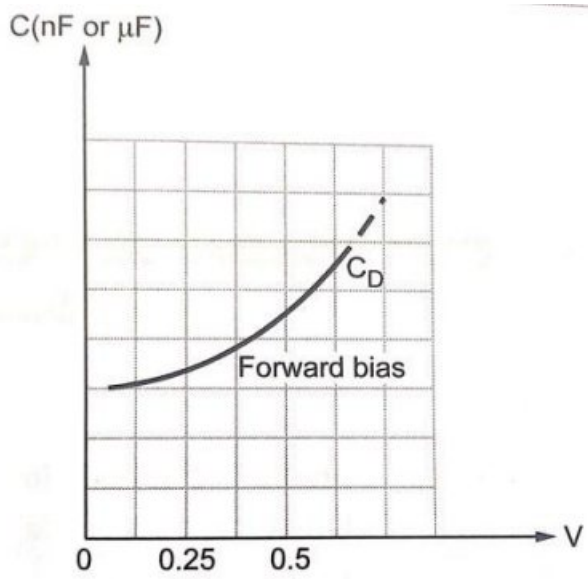
- The diffusion capacitance can be determined by the expression,

$$C_D = \frac{\tau I}{\eta V_T} \quad \ldots (1,12.2)$$

where τ = Mean life time for holes.

- So, diffusion capacitance is proportional to the current. For forward biased condition, the value of diffusion capacitance is of the order of nano farads to micro farads while transition capacitance is of the order of pico farads. So, C_D is much larger than C_T
- However, in forward biased condition, C_D appears in parallel with the forward resistance which is very very small. Hence the time constant which is function of product of the forward resistance and C_D is also very small for ordinary signals.

Key Point: Hence for normal signals CD has no Practical significance but for fast signals Cp must be considered.



Diffusion capacitance versus applied forward biased voltage

- The graph of C_D against the applied forward voltage is shown in the given figure

5. Laser Diode

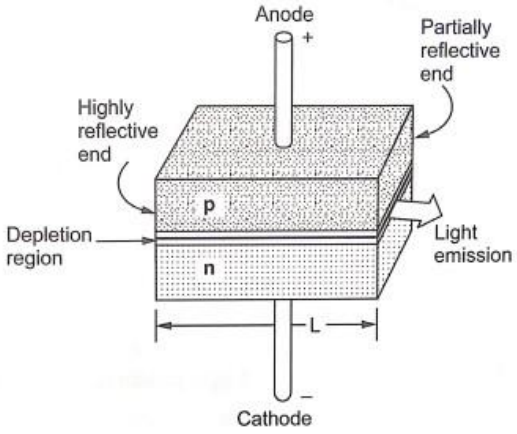
Ans:

- The term laser stands for light amplification by stimulated emission of radiation.
- Laser light is referred to as coherent light which means that a light with a single wavelength. This is opposite to the incoherent light, which has wide band of wavelengths.
- The light emitted by LED is an incoherent light whereas light emitted by laser diode is a coherent light

Construction and Symbol

- The following figure shows the symbol and basic construction of laser diode.
- It consists of p-n junction formed by two doped gallium arsenide layers. The two ends of the structure are flat and parallel with one end mirrored and one partially reflective.
- The length (L) of the junction is precisely related to the wavelength of the light to be emitted.

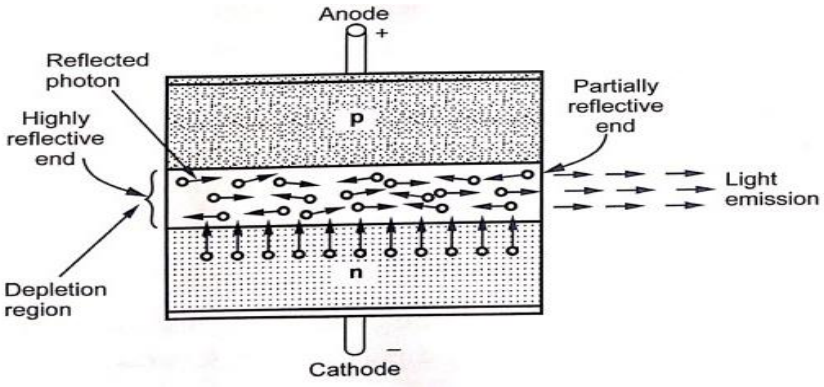
(a) Symbol



(b) Construction of laser diode

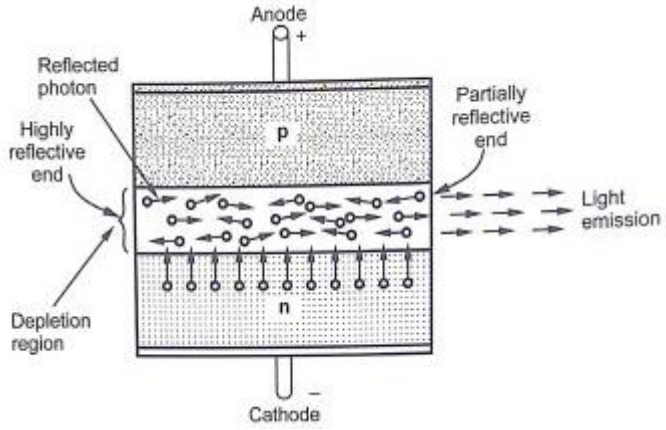
Operation

- The operation of laser diode is illustrated in the following figure.
- When the p-n junction is forward biased by an external voltage source, the electrons move through the junction and recombines as in an ordinary diode.
- When electrons recombine with holes, photons are released. These photons strikes atoms, causing more photons to be released the following figure Operation



Random emission and laser action region within Depletion

- As the forward bias current is increased, more electrons enter the depletion region and cause more photons to be emitted.



Random emission and laser action region

within depletion

- Eventually some of the photons that are randomly drifting within the depletion region strike the reflected surfaces perpendicularly, so that they are reflected back along their original path. These reflected photons are then reflected back again from the other end of the junction.
- This movement of photons from one end to another end continues for thousands of times. During this movement, photons strike more atoms and release additional photons due to the avalanche effect.
- This activity of reflection and generation of increasing number of photons results in a very intense, focused and pure beam of laser light which is formed by the photons that pass through the partially reflective end of the pn junction.
- Each photon produced in such an emission process is identical to the other photons in energy level, phase relationship, and frequency. Thus, emission process gives a intense beam of laser light with a single wavelength.
- To produce a beam of laser light it is necessary to have a current through the laser diode above certain threshold level. The current below threshold level forces diode to behave as LED, emitting incoherent light.

UNIT - II

2 - Mark

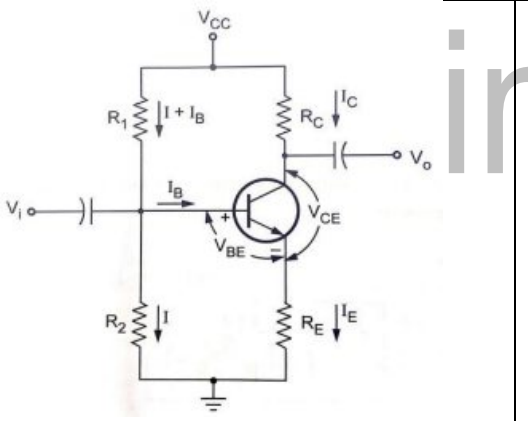
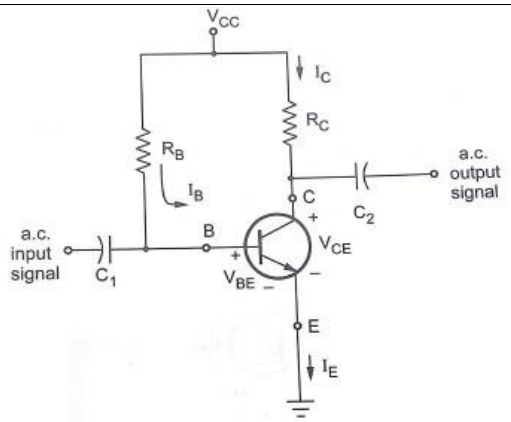
1. What is early effect?

Ans.:

When reverse bias voltage VCB increases, the width of depletion region also increases, which reduces the electrical base width. This effect is Effect' called as Early modulation'. Base or width

2. Draw the figure of self bias, and fixed bias circuits.

Ans:

Self bias	Fixed bias
	

3. Mention the disadvantage of FET compare to BJT

Ans.: Disadvantages of FET compared to BJT are :

1. Relationship between input and output is non-linear; whereas in case of BJT it is linear.
2. Gain-bandwidth product is less in FET than BJT.

4. Which MOSFET is called as normally ON MOSFET and Normally OFF MOSFET? Why?

Ans.:

In depletion type MOSFET, maximum current I_{DSS} flows through the channel when Ves = 0, i.e., MOSFET is ON. Thus, depletion type MOSFET is called Normally ON MOSFET.

For enhancement type MOSFET, the channel does not exists when $V_{GS} = 0$. Due to this I_D is almost zero and we can say that MOSFET is OFF. Thus, enhancement type MOSFET is also called Normally OFF MOSFET.

5. What is a thyristor? Mention two of them.

Ans.:

A thyristor is a semiconductor device whose switching action depends on internal regenerative feedback. Unlike BJTs and FETs, a thyristor can be operated only as a switch. A thyristor can be two terminal, three terminal or four terminal, unidirectional or bidirectional device.

The two thyristors are silicon controlled rectifier (SCR) and Triac.

6. Show how an SCR can be triggered on by the application of a pulse to the gate terminal.

Ans.:

When the pulse is applied to the gate terminal then the electrons from n-type cathode which are majority in number, cross the junction J3 to reach to positive of battery. While holes from p type move towards the negative of battery, constituting gate current.

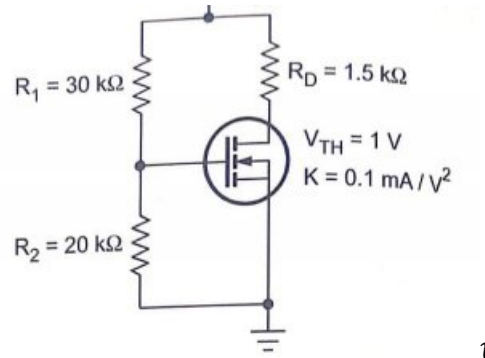
7. What is meant by latching in SCR.

Ans.:

There is minimum current for SCR which flows from anode to cathode when it goes from OFF to ON state. Once this current level is reached, SCR remains ON even gate bias is removed. This is called latching in SCR and this current is called latching current.

13 - Mark

1. Calculate the D.C. operating condition for the circuit shown in following diagram.



$v_\sigma \eta$

Sol. : We have

$$V_G = V_{GS}\left(\frac{R_2}{R_{1+}R_2}\right) V_{DD} = \left(\frac{20}{20+30}\right)10$$

= 4V

Assuming transistor is biased in the saturation, the drain current is

$I_D = K (V_{GS} - V_T)^2$

$= (0.1 \times 10^{-3}) \times (4 - 1)^2 = 0.9$ mA

$V_{DS} = V_{DD} - I_D R_D$

$= 10 - (0.9 \times 10^{-3})(1.5 \times 10^3)$

= 8.65 V

Comment: Because V_{DS} - 8.65 V > V_{DS} (sat)

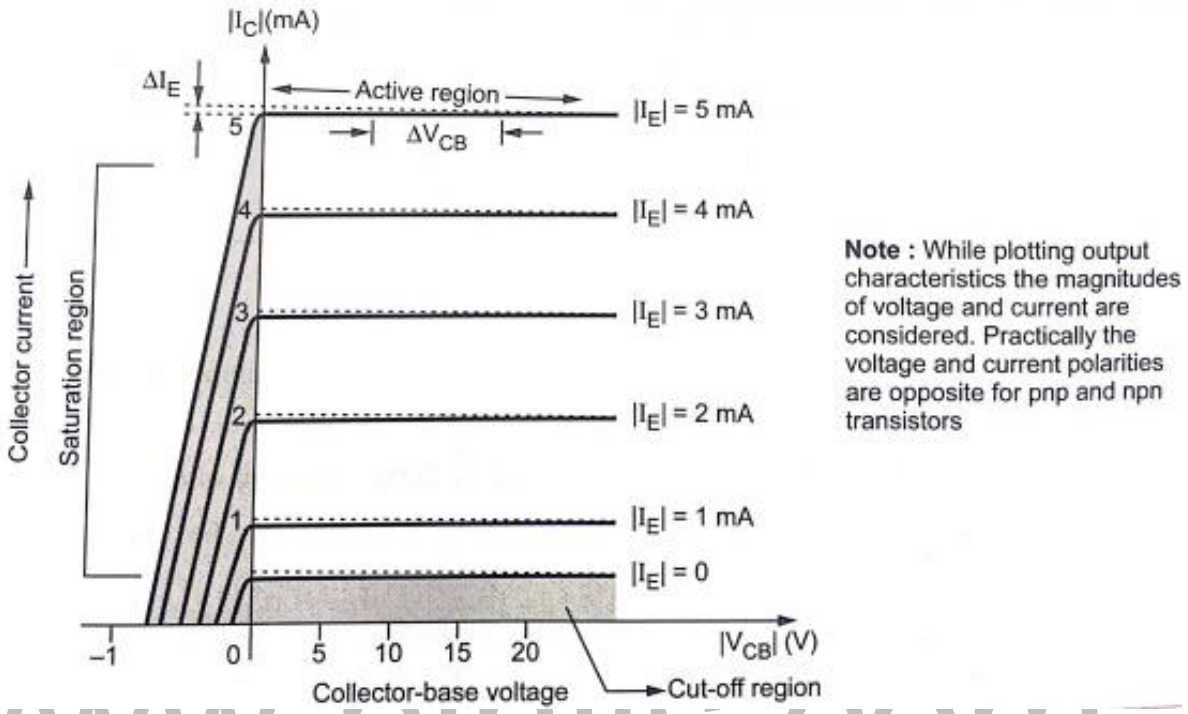
$= V_{GS} – V_T = 4 - 1 = 3$, the transistor is indeed biased in the saturation region and our analysis is valid .

2. Output Characteristics (Collector Curves)

Ans:

- It is the curve between collector current Ic and collector base voltage VCB at constant emitter current IF. The collector current is taken along Y-axis and collector-base

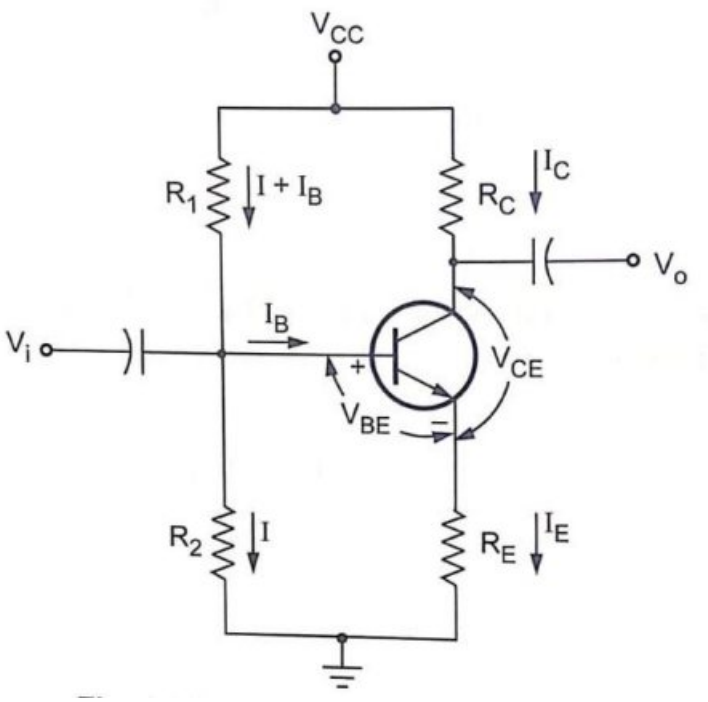
voltage magnitude along X-axis. The following figure shows the output characteristics of a typical transistor in common base configuration.



3. Explain self bias and its stability factors.

Ans:

- A circuit which is used to establish a stable operating point is the self-biasing circuit shown in the following figure. This circuit is also known as voltage divider bias circuit.



Voltage divider bias circuits

- In this circuit, the biasing is provided by three resistors: R_1, R_2 and R_E.
- The resistors R_1 and R_2 act as a potential divider giving a fixed voltage to point B which is base.
- If collector current increases due to change in temperature or change in β, the emitter current I_E also increases and the voltage drop across R_E increases, reducing the voltage difference between base and emitter (V_{BE}).
- Due to reduction in V_{BE}, base current I_B and hence collector current I_C also reduces. Therefore, we can say that negative feedback exists in the voltage divider bias circuit.
- This reduction in collector current I_C compensates for the original change in I_C.

Stability factor S

$$S = \left.\frac{\partial I_C}{\partial I_{CO}}\right|_{V_{BE},\,\beta\ \text{constant}} = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_E+R_B}\right)}$$

…for voltage divider bias

Stability factor S'

$$S' = \left.\frac{\partial I_C}{\partial V_{BE}}\right|_{I_{CO},\,\beta \text{ constant}} = \frac{-\beta}{R_B + (1+\beta)R_E}$$

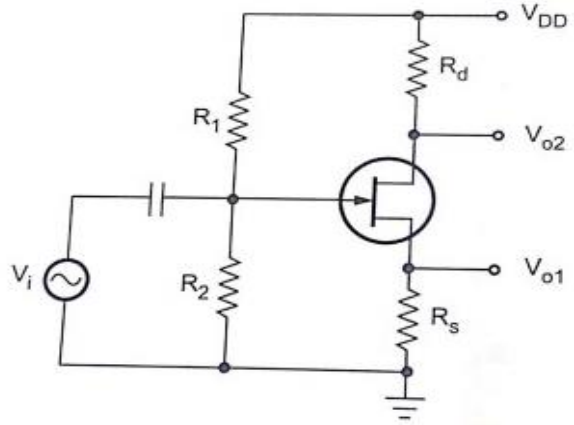
… for voltage divider bias

Stability factor S"

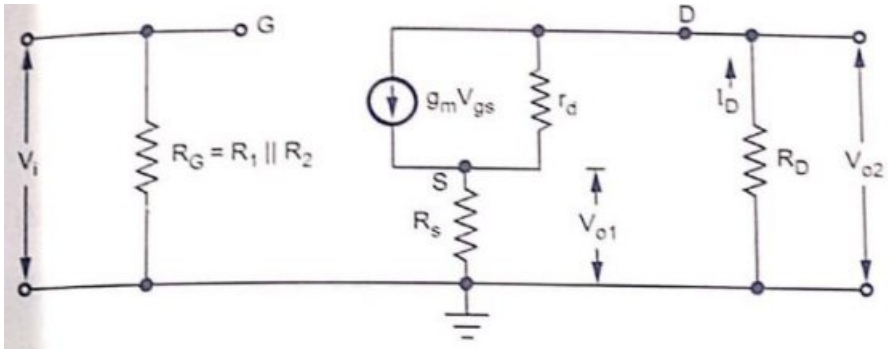
$$S'' = \left.\frac{\partial I_C}{\partial \beta}\right|_{I_{CO},\,V_{BE} \text{ constant}} = \frac{I_{C1}S_2}{\beta_1(1+\beta_2)}$$

where S_2 = S with $\beta = \beta_2$ … (2.8.5)

4. Draw the small signal equivalent circuit for FET of following figure and hence find V_{o1} / V_i and V_{o2} / V_i in terms circuit constants.



Ans:



Small signal equivalent circuit for given FET amplifier

Applying KVL to the output circuit we have,

$(I_d - g_m V_{gs}) r_d + I_d R_s + I_d R_D = 0$... (1)

We know that, $V_{gs} = V_{in} - I_d R_s$

Substituting value of V_{gs} in equation (1) we get,

$[I_d - g_m (V_i - I_d R_s)] r_d + I_d R_s + I_d R_D = 0$ ... (2)

$\therefore I_d r_d - g_m V_i r_d g_m I_d R_s r_d + I_d R_s + I_d R_D = 0$ ... (3)

$\therefore I_d (r_d + g_m + R_D + g_m R_s I_d) = g_m V_i r_d$ ... (4)

$$\therefore \quad I_d = \frac{g_m V_i r_d}{r_d + R_s + R_D + g_m R_s r_d} \quad \text{... (5)}$$

$$V_{o2} = -I_d R_D$$

$$= \frac{-g_m V_i r_d R_D}{r_d + R_s + R_D + g_m R_s r_d}$$

$$\therefore \quad \frac{V_{o2}}{V_i} = \frac{-g_m r_d R_D}{r_d + R_s + R_D + g_m R_s r_d}$$

$$V_{o1} = I_d R_s$$

$$= \frac{g_m V_i r_d R_s}{r_d + R_s + R_D + g_m R_s r_d}$$

$$\therefore \quad \frac{V_{o1}}{V_i} = \frac{g_m r_d R_s}{r_d + R_s + R_D + g_m R_s r_d}$$

5. Explain the construction, principles and characteristics of SCR

Ans:

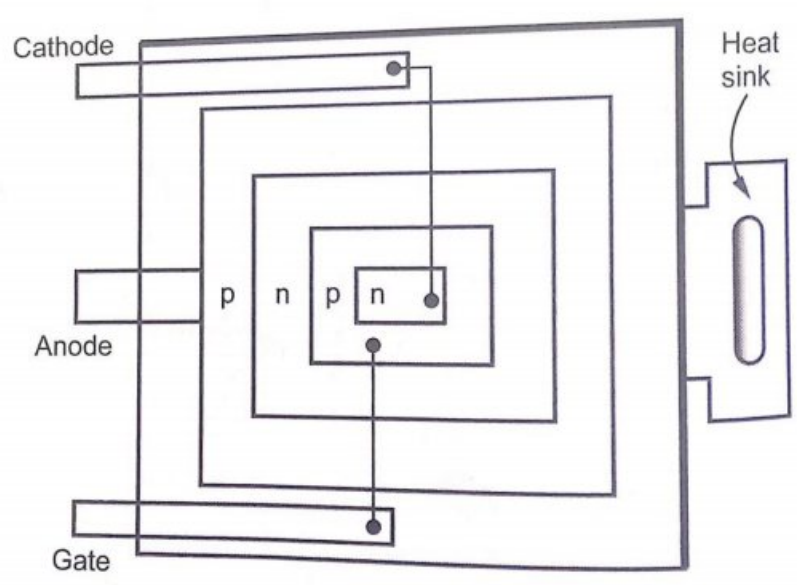
Types of Construction

- Three types of constructions are used to manufacture SCR,

1) Planar type 2) Mesa type 3) Press pack type.

4. Planar type:

This construction is used for low current SCRs. In this type, all the p-n junctions come to the same surface on the cathode side. This is shown in the following figure. All the junctions are diffused in this type of construction.

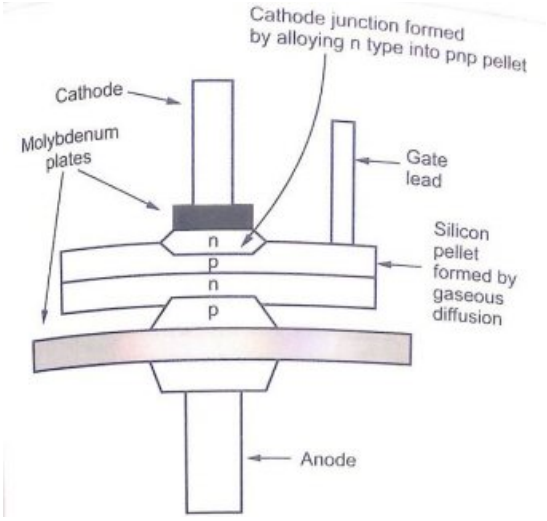


Planner type construction

- The disadvantage of this type is more silicon per ampere current is required. The advantage is that the mass production is possible and large number of SCRs can be manufactured with uniform characteristics.

Mesa type:

In this construction, the junction J_2 is diffused while the outer layers are alloyed to it. This is shown in the following figure.



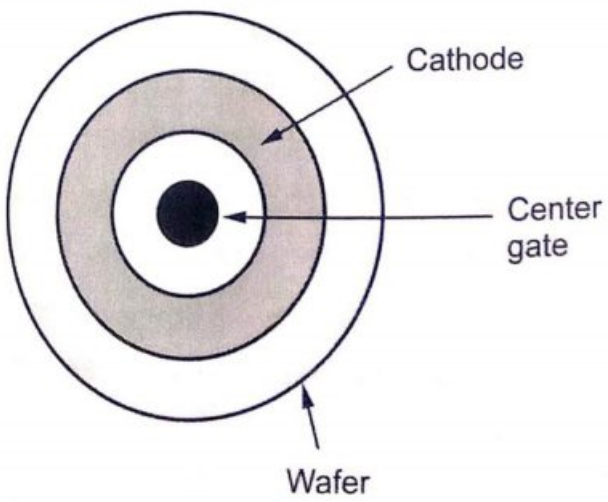
Mesa type construction

- To handle the large currents, the molybdenum or tungsten plates are braced to p-n-p-n silicon pellet. This provides the additional mechanical strength.

- In this construction, area around the gate is small hence this construction is not suitable for high di / dt ratings.

Press pack type: The construction is used for high power and center gate SCRs. A silicon wafer is used to make such a high power SCR.

- The entire circular area around the gate takes part in the initial conduction hence di/dt capability of such SCRs is large. This is shown in the following figure.



Press pack type construction

- This type of construction provides double sided cooling arrangement which is necessary for high power SCRs.

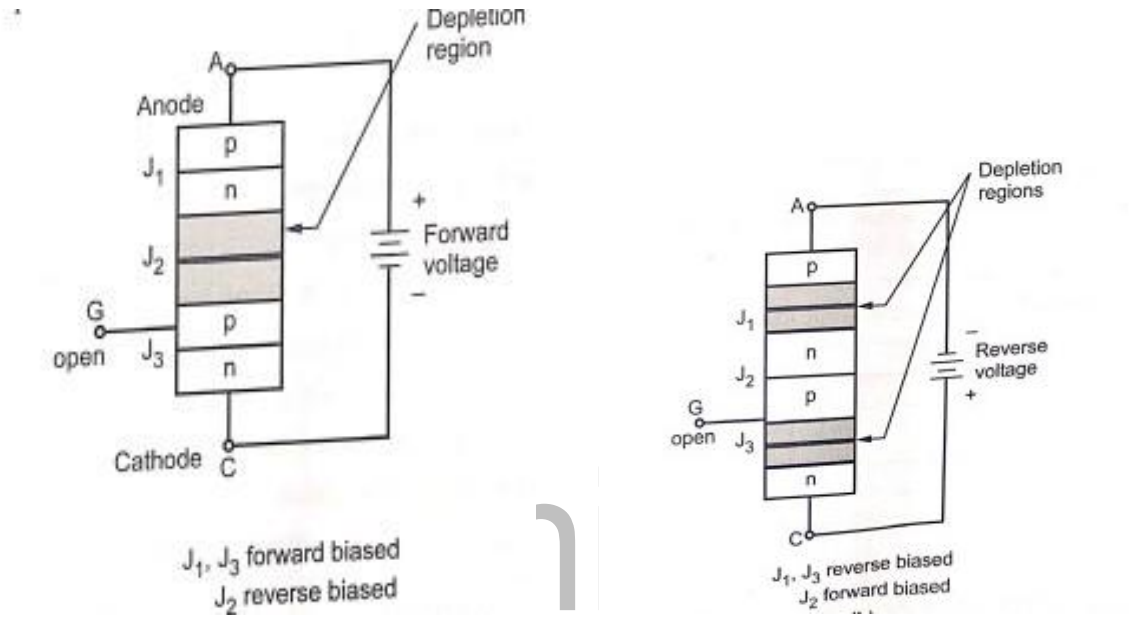
Working Principle

- The operation of SCR is divided into two categories,

i) When Gate is open, and ii) When Gate is closed.

- When gate is open: Consider that the anode is positive with respect to cathode and gate is open.
- The junctions J_1 and J_3 are forward biased and junction J_2 is reverse biased. There is depletion region around J_2 and only leakage current flows which is negligibly small.

- Practically the SCR is said to be OFF. This is called forward blocking state of SCR and voltage applied to anode and cathode with anode positive is called forward voltage. This is shown in the following figure (a).
- . With gate open, if cathode is made positive with respect to anode, the junctions Jy, J3 become gate current the regenerative action takes place and SCR conducts



(a)

Characteristics of SCR

- The characteristics are divided into two sections:

1. Forward characteristics:
   - It shows a forward blocking region, when IG = 0. It also shows that when forward voltage increases upto V_{BO}, the SCR turns ON and high current results. The drop across SCR reduces suddenly which is now the ohmic drop in the four layers. The current must be limited only by the external resistance inseries with the device.
   - It also shows that, if gate bias is used then as gate current increases, less voltage is required to turn ON the SCR.

- If the forward current falls below the level of the holding current IH, then depletion region begins to develop around J_2 and device goes into the forward blocking region.
- When SCR is turned ON from OFF state, the resulting forward current is called latching current It. The latching current is slightly higher than the holding current.

2. Reverse characteristics:
   - If the anode to cathode voltage is reversed, then the device enters into the reverse blocking region. The current is negligibly small and practically neglected.
   - If the reverse voltage is increased, similar to the diode, at a particular value avalanche breakdown occurs and a large current flow through the device. This is called reverse breakdown and the voltage at which this happens is called reverse breakdown voltage VBR.
   - The forward breakover voltage is greater than reverse breakover voltage.

UNIT- lll

2 - Mark

1. State Miller's theorem.

Ans.:

Miller's theorem states that, if Z is the impedance connected between two nodes, node 1 and node 2, it can be replaced by two separate impedances Z_1 and Z_2; where Z_1 is connected between node 1 and ground and Z_2 is connected between node 2 and ground. The V_i and V_o are the voltages at the node 1 and node 2 respectively. The values of Z_1 and Z_2 can be derived from the ratio of V_o and V_i (V_o / V_i), denoted as K. Thus, it is not necessary to know the values of V_i and V_o to calculate the values of Z_1 and Z_2. The values of impedances Z_1 and Z_2 are given as

$$Z_1 = \frac{Z}{I-K} \quad \text{and} \quad Z_2 = \frac{Z \cdot K}{K-I}$$

2. What is bandwidth of an amplifier?

Ans:

The bandwidth of the amplifier is defined as the difference between the lower cut-off frequency and the upper cut-off frequency.

$$BW = f_2 - f_1$$

3. An NPN common emitter amplifier circuit has the following parameters. h_{fe} =50, h_{ie} =1kΩ and R_c =3.3kΩ. Find the voltage gain of the amplifier.

Ans.:

$$A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_c}{h_{ie}}$$

$$= \frac{-50 \times 3.3}{1} = -165$$

4. Define the four h-parameters.

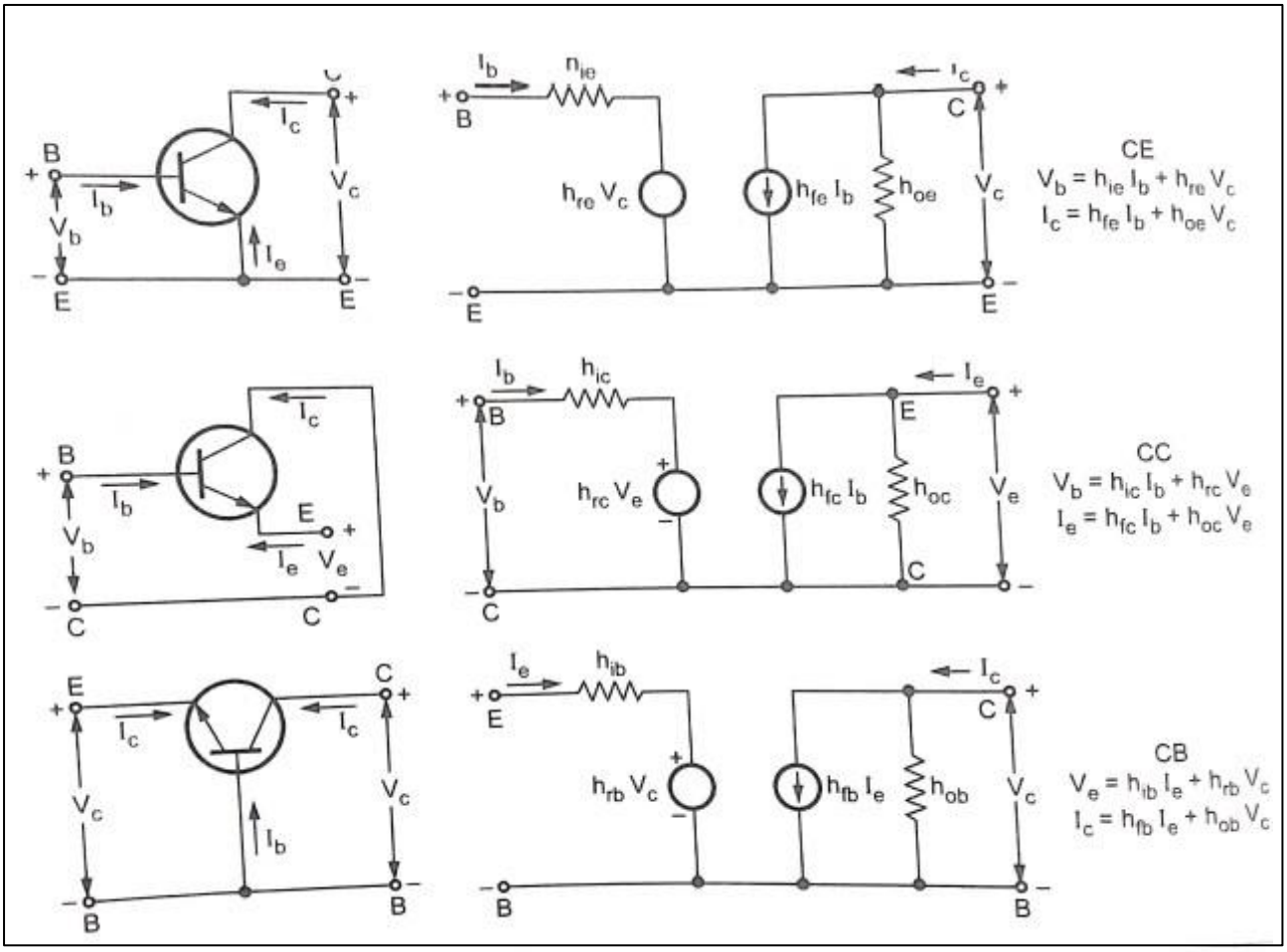
Ans:

- Thus we can write h-parameters as follows :

a) With output short circuited :	b) With input open circuited :
$h_{11} = h_i$: Input resistance.	$h_{12} = h_r$: Reverse voltage transfer ratio.
$h_{21} = h_f$: Short circuit current gain.	$h_{22} = h_o$: Output admittance.

5. Draw the hybrid small signal model of common base configuration.

Ans:



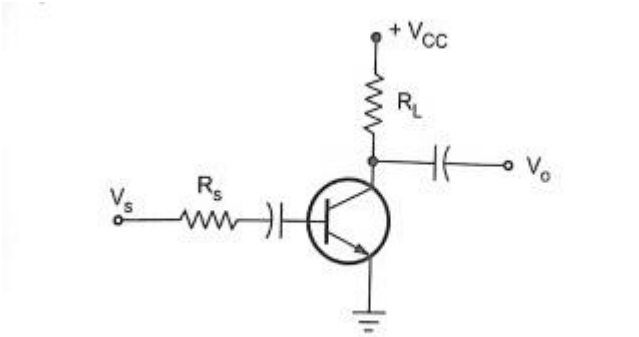
Transistor configuration and their hybrid model

13 - Mark

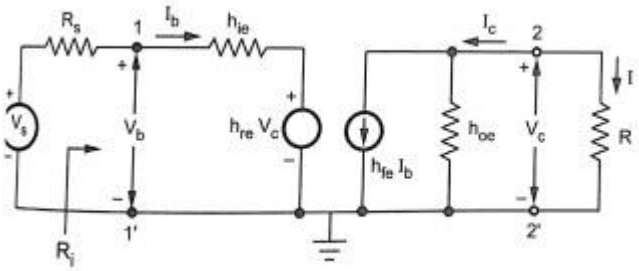
1. Derive the expressions for A, Ay, R; and Ro for CE amplifier using h-parameter model.

Ans:

The following figure shows the CE amplifier and its h-parameter equivalent circuit.



(a) CE amplifier



(b) CE amplifier in its h-parameter model

- Let us analyze hybrid model to find the current gain, the input resistance, the voltage gain, and the output resistance.

Step 1: Obtain expression for current gain (A_1)

$$\textbf{Current gain } (A_I) = \frac{I_L}{I_b} = -\frac{I_c}{I_b}$$

From the circuit of following figure (b) we have

$$I_c = h_{fe} I_b + h_{oe} V_c$$

$$= h_{fe} I_b + h_{oe} (-I_c R_L)$$

$$\because V_c = -I_c R_L \qquad \ldots (2)$$

$$\therefore (1 + h_{oe} R_L) I_c = h_{fe} I_b$$

$$\therefore \frac{I_c}{I_b} = \frac{h_{fe}}{1 + h_{oe} R_L}$$

$$\therefore A_I = -\frac{I_c}{I_b} = \frac{-h_{fe}}{1 + h_{oe} R_L} \qquad \ldots (3)$$

Step 2: Obtain expression for input resistance (R_i)

$$\text{Input resistance } (R_i) = \frac{V_b}{I_b} \quad \ldots (4)$$

From the input circuit of Fig. 6.4.5 (b) we have,

$$V_b = h_{ie} I_b + h_{re} V_c \quad \ldots (5)$$

and $$V_c = -I_c R_L = A_I I_b R_L$$

$$\therefore \quad R_i = \frac{h_{ie} I_b + h_{re} A_I I_b R_L}{I_b}$$

$$= h_{ie} + h_{re} A_I R_L \quad \ldots (6)$$

Substituting $$A_I = -\frac{h_{fe}}{1 + h_{oe} R_L}$$

We get, $$R_i = h_{ie} - \frac{h_{re} h_{fe} R_L}{1 + h_{oe} R_L} \quad \ldots (6(a))$$

Step 3: Obtain expression for voltage gain (A_V)

$$\text{Voltage gain } (A_V) = \frac{V_c}{V_b} = \frac{A_I I_b R_L}{V_b} = \frac{A_I R_L}{R_i}$$

$$\because \frac{I_b}{V_b} = \frac{1}{R_i} \quad \ldots (7)$$

Step 4: Obtain expression for out output admittance(Y_o)

Output admittance (Y_o) = $\frac{I_c}{V_c}$ with $V_s = 0$ … (8)

From equation (6.4.2), we have,

$$I_c = h_{fe} I_b + h_{oe} V_c$$

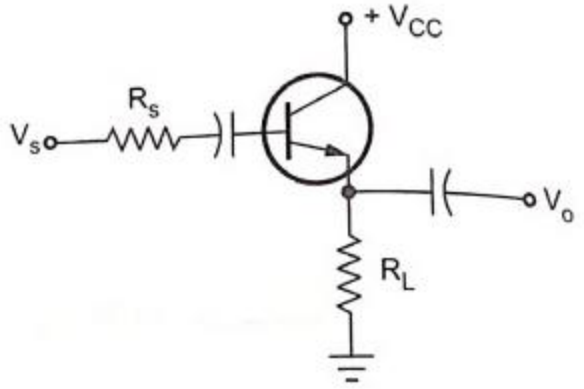
Dividing above equation by V_c we get,

$$Y_o = \frac{I_c}{V_c} = \frac{h_{fe} I_b}{V_c} + h_{oe}$$

2. Derive the expressions for current gain voltage gain, input impedance and output impedance for an emitter follower circuit.

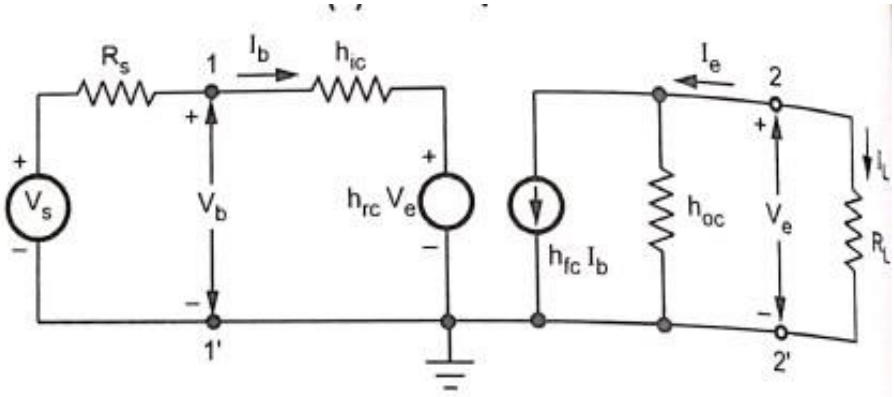
Ans.:

The Fig. 6.4.6 shows the emitter follower (CC) amplifier circuit and its h-parameter equivalent circuit.



(a) CC amplifier

Let us analyze hybrid model to find the current gain, the input resistance, the voltage gain and the output resistance.



(b) CC amplifier in its h-parameter model

$$\text{Current Gain } (A_i) = \frac{I_L}{I_b} = -\frac{I_e}{I_b} \quad \ldots (1)$$

From the circuit of given figure (b) we have,

$$I_e = h_{fc} I_b + h_{oc} V_e$$

$$= h_{fc} I_b + h_{oc} (- I_e R_L)$$

$$\therefore \quad V_e = -I_e R_L \qquad \ldots (2)$$

$$\therefore \quad (1 + h_{oc} R_L) I_e = h_{fc} I_b$$

$$\frac{I_e}{I_b} = \frac{h_{fc}}{1 + h_{oc} R_L} = 20.12\ \Omega$$

Where $R' = R_S \parallel R_1 \parallel R_2 = 833.33\Omega$

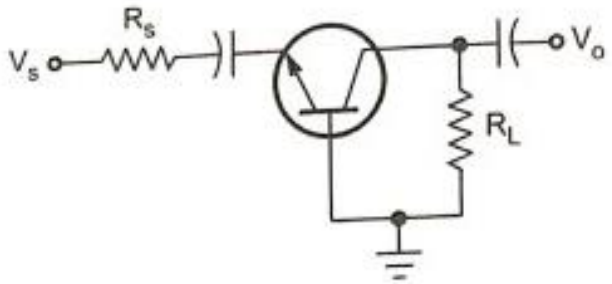
$$R_o = \frac{1}{25 \times 10^{-6} - \left(\frac{-101 \times 1}{1.2 + 83333}\right)} = 20.12\ \Omega$$

$$R'_o = R_o \parallel R'_L = 20.12 \parallel (5\ K \parallel 20\ K)$$

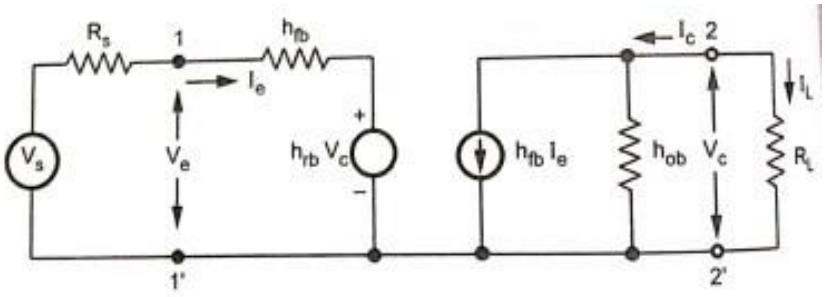
$$= \mathbf{20\ \Omega}$$

3. Derive the expressions for A_i, A_v R_i and R_O for CB amplifier using h-parameter model.

Ans: The Following figure shows the CB amplifier and its h-parameter equivalent circuit.



(a) CB amplifier



(b) h-parameter equivalent circuit for CB amplifier

$$\text{Current Gain } A_i = \frac{I_L}{I_e} = \frac{-I_c}{I_e}$$

From the circuit of following figure (b) we have

$$I_c = h_{fb} I_e + h_{ob} V_c$$

$$h_{fb} + I_b + h_{ob}(-I_c R_L)$$

$$\because V_C = -I_C R_L$$

$$\therefore \quad (1+h_{ob} R_L) I_c = h_{fc} I_e$$

$$\therefore \quad \frac{I_C}{I_e} = \frac{h_{fc}}{1 + h_{ob} R_L}$$

$$A_i = \frac{h_{fc}}{1 + h_{ob} R_L}$$

Input Resistance $\mathbf{R_i = \frac{V_e}{I_e}}$

from the input circuit of Fig. 6.4.8 (b) we have

$$V_e = h_{ib} I_e + h_{rb} V_c$$

And $$V_e = -I_c R_L = A_i I_e R_L$$

$$R_i = \frac{h_{ib} I_e + h_{rb} A_i I_e R_L}{I_e}$$

$$= h_{ib} + h_{rb} A_i R_L$$

$$\text{Voltage Gain } A_v = \frac{V_c}{V_e} = \frac{A_i I_e R_L}{V_e} = \frac{A_i R_L}{R_i}$$

$$\therefore \quad \frac{I_e}{V_e} = \frac{1}{R_i}$$

We have, $I_c = h_{fb} I_e + h_{ob} V_c$

Dividing above equation by V_c we get,

$$Y_o = \frac{I_c}{V_c} = \frac{h_{fb} I_e}{V_c} + h_{ob}$$

From the given figure (b) with $V_s = 0$ we can write

$$R_s I_e + h_{ib} I_e + h_{rb} V_c = 0$$

$$\therefore \quad (R_s + h_{ib}) I_e = -h_{rb} V_c$$

$$\therefore \quad \frac{I_e}{V_c} = \frac{-h_{rb}}{R_s + h_{ib}}$$

$$\therefore \quad Y_o = h_{ob} - \frac{h_{fb} h_{rb}}{R_s + h_{ib}} \quad \text{and} \quad R_o = \frac{1}{Y_o}$$

4. For a CB amplifier driven by voltage source of internal resistance R_s =1.2 kΩThe load impedeance is R_L = 1 kΩ. The h-parameters are h_{ib} = 22Ω, h_{rb}= 3 × 10^{-4} h_{fb}= −0.98 and h_{ob} = 0.5μ*A* / *V*. Estimate the current gain A_i input impedance $R_i$voltage gain A_v. overall current gain A_{is}, overall voltage gain A_{vs} and output impedance Z_o

Ans:

$$\text{Current gain,} \quad A_i = \frac{-I_c}{I_b} = \frac{-h_{fb}}{1 + h_{ob} R_L}$$

$$= \frac{-(-0.98)}{1 + 0.5 \times 10^{-6} \times 1 \times 10^{3}} = 0.9795$$

Input impedance,

$$R_i = h_{ib} + h_{rb}\, A_i R_L$$
$$= 22 + 3\times 10^{-4} \times (0.9795) \times 1\times 10^3$$
$$= \mathbf{22.29\,\Omega}$$

Voltage gain, $A_v = A_i \dfrac{R_L}{R_i} = 0.9795 \times \dfrac{1\times 10^3}{22.29} = \mathbf{43.94}$

$$Y_o = h_{ob} - \frac{h_{fb}h_{rb}}{h_{ib} + R_s}$$
$$= 0.5\times 10^{-6} - \frac{(-0.98)\,(3\times 10^{-4})}{22 + 1200}$$
$$= 7.4\times 10^{-7}$$
$$R_o = \frac{1}{Y_o} = \frac{1}{7.4\times 10^{-7}} = \mathbf{1.35\ M\Omega}$$
$$Z_o = R'_o = R_o \parallel R_L = 1.35\ M\Omega \parallel 1\ k\Omega$$
$$= \mathbf{999.26\ \Omega}$$

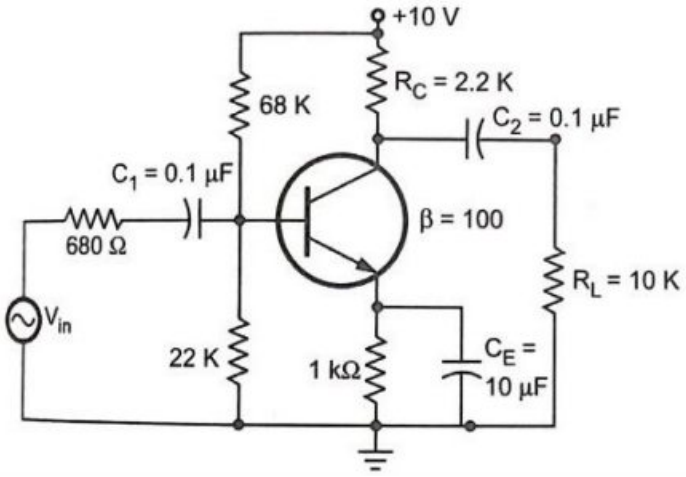
$$R_o = \frac{1}{Y_o} = \frac{1}{7.4\times 10^{-7}} = \mathbf{1.35\ M\Omega}$$
$$Z_o = R'_o = R_o \parallel R_L = 1.35\ M\Omega \parallel 1\ k\Omega$$
$$= \mathbf{999.26\ \Omega}$$

$$A_{vs} = A_v \frac{R_i}{R_i + R_s}$$
$$= 43.94 \times \frac{22.29}{22.29 + 1200} = \mathbf{0.8}$$
$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_C} \times \frac{I_C}{I_e} \times \frac{I_e}{I_S}$$

where $I_L = -I_C$ and $I_S = I_e$

$$= \frac{I_C}{I_S} = (-1) \times -(A_i) \times 1 = A_i = \mathbf{0.9795}$$

5. Ex. 6.9.3 Determine the low frequency response of the amplifier circuit shown in the following figure.



Ans.:

It is necessary to analyze each network to determine the critical frequency of the amplifier

1. Input RC network:

$$f_c \text{ (input)} = \frac{1}{2\pi[R_s+(R_1 \parallel R_2 \parallel h_{ie})]C_1}$$

$$= \frac{1}{2\pi[680+(68K \parallel 22K \parallel 1.1K)] \times 0.1 \times 10^{-6}}$$

$$= \frac{1}{2\pi[680+1031.7] \times 0.1 \times 10^{-6}} = \mathbf{929.8\ Hz}$$

2. Output RC network

$$f_{c\,(output)} = \frac{1}{2\pi(R_C + R_L)C_2}$$

$$= \frac{1}{2\pi(2.2K+10K) \times 0.1 \times 10^{-6}}$$

$$= \mathbf{130.45\ Hz}$$

c) Bypass RC network :

$$f_{c\,(bypass)} = \frac{1}{2\pi\left[\left(\frac{R_{TH} + h_{ie}}{\beta}\right) \| R_E\right] C_E}$$

$$R_{TH} = R_1 \| R_2 \| R_s = 68\ K \| 22\ K \| 680$$

$$= 653.28\ \Omega$$

$$f_{c\,(bypass)} = \frac{1}{2\pi\left[\left(\frac{653.28 + 1100}{100}\right) \| 1K\right] \times 10 \times 10^{-6}}$$

$$= \frac{1}{2\pi(17.23) \times 10 \times 10^{-6}} = \mathbf{923.7\ Hz}$$

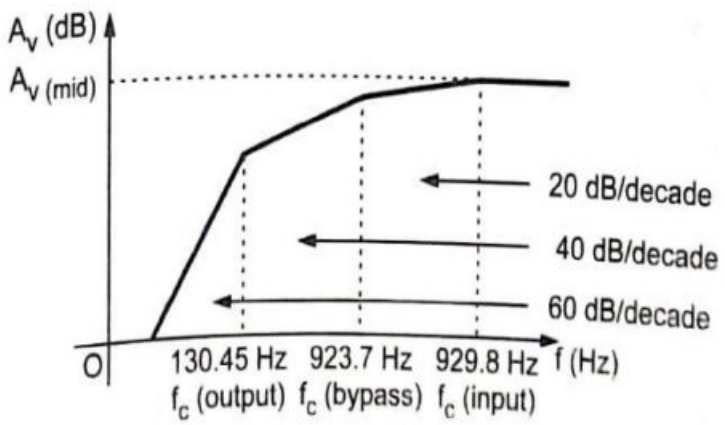
- We have calculated all the three critical frequencies:

  a) f_c (input) - 929.8 Hz

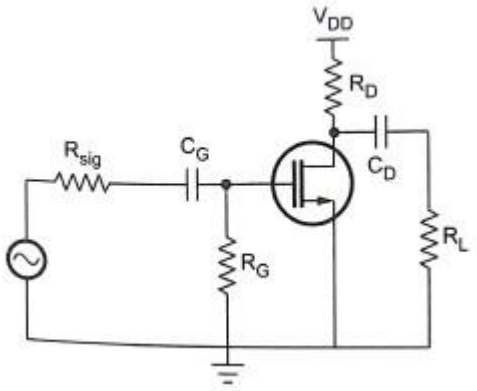
  b) f_c (output) - 130.45 Hz

  c) f_c (bypass) = 923.7 Hz

- The above analysis shows that the input network produces the dominant lower critical frequency. The following figure shows low frequency response of the given amplifier.



6. For CS MOSFET amplifier, R_{si} = 100 KΩ, R_G = 4.7 MΩ, R_D = 15 K, R_L = 15 K, g_m = 1 mA/V, r_o = 150 k32, C_{gs} = 1 pF and Cod = 0.4 pF. Find the midband gain A_M and the upper 3 dB frequency, f_H



Ans:

$$A_M = -\frac{R_G}{R_G + R_{si}} g_m R'_L$$

where $R'_L = r_o \| R_D \| R_L = 150 \| 15\,K \| 15\,K = 7.14\,k\Omega$

$$= -\frac{4.7 \times 10^6}{4.7 \times 10^6 + 100 \times 10^3} \times 1 \times 10^{-3} \times 7.14 \times 10^3 = -6.99$$

$$C_{eq} = (1 + g_m R'_L) C_{gd}$$

$$= (1 + 1 \times 10^{-3} \times 7.14 \times 10^3) \times 0.4 \times 10^{-12}$$

$$= \mathbf{3.256\ pF}$$

$$C_{in} = C_{eq} + C_{gs} = 3.256 + 1 = \mathbf{4.256\ pF}$$

$$f_H = \frac{1}{2\pi R'_{si} C_{in}}$$

where $R'_{si} = R_{si} \| R_G = 100\ K \| 4.7\ M = 97.92\ K$

$$= \frac{1}{2\pi \times 97.92 \times 10^3 \times 4.256 \times 10^{-12}}$$

$$= \mathbf{381.9\ kHz}$$

UNIT - IV

2 - Mark

1. What is the overall current gain for a cascode connection?

Ans.:

The overall current gain of cascode connection is

$$A_I = A_{I1} \times A_{I2}$$

where A_{I2} (Current gain of CB amplifier) $\rightarrow 1$

$\therefore$ $A_I \approx A_{I1}$ (Current gain of CE amplifier)

2. What is the coupling schemes used in multistage amplifiers?

Ans.:

The coupling schemes used in multistage amplifiers are:

1. RC coupling
2. Transformer coupling and
3. Direct coupling

3. Define CMRR. What is its ideal value?

Ans.:

The ability of a differential amplifier to reject a common mode signal is expressed by a ratio called common mode rejection ratio denoted as CMRR. It is defined as the ratio of the differential voltage gain Ad to common mode voltage gain Ac.

$\therefore$ $$\text{CMRR} = \rho = \left|\frac{A_d}{A_c}\right|$$

Its ideal vale is infinite (∞).

4. What is narrow band neutralization?

Ans.:

A process of canceling the instability effect due to the collector to base capacitance of the transistor in tuned circuits by introducing a signal which cancels the signal coupled through the collector to base capacitance is called narrow band neutralization.

5. What is the need for neutralization in tuned amplifiers?

Ans.:

In tuned RF amplifiers, at high frequencies centered around a radio frequency the inter junction capacitance between base and collector, Coc of the transistor becomes dominant, i.e., its reactance becomes low enough to be considered. As reactance of Coc at RF is low enough it provides the feedback path from collector to base. If this feedback is positive, the circuit is converted to an unstable one, generating its own oscillations and can stop working as an amplifier. In order to prevent oscillations without reducing the stage gain neutralization is used in tuned amplifiers.

6. Mention two applications of tuned amplifiers.

Ans.:

The important applications of tuned amplifiers are as follows:

1. Tuned amplifiers are used in radio receivers to amplify a particular band of frequencies for which the radio receiver is tuned.
2. Tuned class B and class C amplifiers are used as an output RF amplifier in radio transmitters to increase the output efficiency and to reduce the harmonics.
3. Tuned amplifiers are used in active filters such as low pass, high pass and band pass to allow amplification of signal only in the desired narrow band.

7. A tuned circuit has resonant frequency of 1600 kHz and bandwidth of 10 kHz. What is the value of its Q-factor?

Ans.:

Given: f_r =1600 kHz and BW = 10 kHz

$$Q = \frac{f_r}{BW} = \frac{1600}{10} = 160$$

13 - Mark

1. Ex. 8.10.11 The drain circuit of a FET tuned radio frequency amplifier has a 100 pF capacitor placed in parallel with an inductor L, whose unloaded Q-factor is 100. If the frequency of resonance is 1 MHz and the transistor output resistance is 20 KS calculate the loaded Q-factor, inductance and loaded bandwidth.

Ans.:

The total resistive loading on the tuned circuit consists of the transistor output impedance and the dynamic impedance in parallel R = RRp/(Rs + Rp). The dynamic impedance using the unloaded Q-factor is

$$R_p = \frac{Q_U}{\omega_0 C} = \frac{100}{2\pi(1\times10^6)(100\times10^{-12})}$$

$$= \frac{10^6}{2\pi} = 159\ \text{k}\Omega$$

The total resistance loading R is given by

$$R = R_o \parallel R_p$$

Where R_o is the transistor out put resistance

$$= \frac{20\ \text{K} + 159\ \text{K}}{(20\ \text{K} + 159\ \text{K})} = 17.76\ \text{k}\Omega$$

Since the unloaded Q-factor is greater than 10, the dynamic impedance

$R_p = Q_U^2 \, R_{coil}$

$$\therefore \quad R_{coil} = \frac{R_p}{Q_U^2} = \frac{159\times10^3}{(100)^2} = 15.9\ \Omega$$

The unload Q-factor is given by,

$$Q_L = \frac{Q_U}{1+R_p/R} = \frac{100}{1+(159\ K)\ /\ (17.76\ K)}$$

$$= 10$$

The unloaded Q-factor is given by,

$$Q_U = \frac{\omega_0 L}{R_{coil}}$$

$$\therefore \quad L = \frac{Q_U \times R_{coil}}{\omega_0} = \frac{100\times15.9}{2\pi(1\times10^6)}$$

$$= 0.253\ mH$$

The unloaded banwidth is given by

$$B_{WU} = \frac{f_0}{Q_U} = \frac{1\ MHz}{100} = 10\ kHz$$

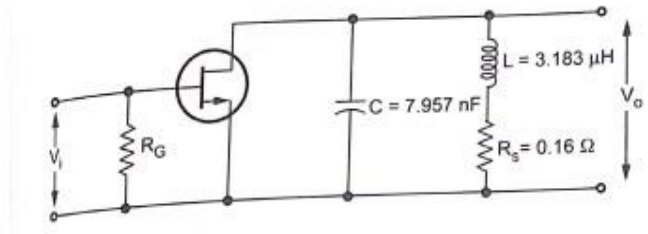
The loaded bandwidth is given by,

$$B_{WL} = \frac{f_0}{Q_L} = \frac{1\ MHz}{100} = 100\ kHz$$

Design a tuned amplifier using FET to have f_0 = 1 MHz, 3 dB bandwidth is 10 kHz and maximum gain is - 10 FET has g_m= 5 mA/V, r_d = 10 K.

Ans.:

The maximum gain of the amplifier is given by,



Tuned amplifier

$$A_{i(max)} = -g_m R$$

$$\therefore \quad R = -\frac{(-10)}{5\,mA/V} = 2\times 10^3\ \Omega$$

The 3 dB bandwidth of the amplifier is given by,

$$BW = \frac{1}{2\pi RC}$$

$$\therefore \quad C = \frac{1}{2\pi R\,BW} = \frac{1}{2\pi\times 2\times 10^3\times 10\times 10^3}$$

$$= \mathbf{7.957\ nF}$$

The resonant frequency is given by,

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\therefore \quad 1\times 10^6 = \frac{1}{2\pi\sqrt{L\times 7.957\times 10^{-9}}}$$

$$\therefore \quad L = \mathbf{3.183\ \mu H}$$

$$R = R_p \parallel r_d$$

$$\therefore \quad \frac{1}{R_p} = \frac{1}{R} - \frac{1}{r_d} = \frac{1}{2\,K} - \frac{1}{10\,K}$$

$$\therefore \quad R_p = 2.5\ k\Omega$$

$$Q_0 = \frac{R_p}{\omega_0 L}$$

$$= \frac{2.5\ k\Omega}{2\times\pi\times 1\times 10^6 \times 3.183\times 10^{-6}} = 125$$

$$R_s = \frac{\omega_0 L}{Q_0} = \frac{2\times\pi\times 1\times 10^6 \times 3.183\times 10^{-6}}{125}$$

$$= 0.16\ \Omega$$

2. single tuned transistor amplifier is used to amplify modulated RF carrier of 600 kHz and bandwidth of 15 kHz. The circuit has a total output resistance. Rt =20 kΩ and output capacitance C_o = 50 pF. Calculate values of inductance and capacitance of the tuned circuit.

Ans:

Given: f_r = 600 kHz, BW = 15 kHz

R_t = 20 kΩ

C_{eq} = (50 pF + c)

$$C_{eff} = \frac{f_r}{BW} = \frac{600\ kHz}{15\ kHz} = 40$$

1. We know that,

$$Q_{eff} = \omega_r C_{eq} R_t$$

$$\therefore \quad C_{eq} = \frac{Q_{eff}}{\omega_r R_t} = \frac{40}{2\pi\times 600\times 10^3 \times 20\times 10^3}$$

$$= 530.5\ pF$$

$$C_{eq} = (50\ pF + C)$$

$$\therefore \quad C = 530.5\ pF - 50\ pF = 480.5\ pF$$

2. We know that,

$$f_r = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

$$\therefore \quad L = \frac{1}{(2\pi f_r)^2 C_{eq}}$$

$$= \frac{1}{(2\pi \times 600 \times 10^3)^2 \times 530.5 \times 10^{-12}}$$

$$= \mathbf{1326.6\ \mu H}$$

If class C tuned amplifier has R_L = 6 k Ω and required tank circuit Q =80. Calculate the values of L and C of the tank circuit. Assume V_{cc} = 20 V, resonant frequency = 5 MHz and worst case power dissipation = 20 mW.

Ans:

We know that,

$$P_{D\,max} = \frac{(V_{pp\,max})^2}{40\,r_c} = \frac{(2\,V_{CC})^2}{40\,r_c}$$

$$\therefore \quad r_c = \frac{(2\,V_{CC})^2}{40 \times P_{D\,max}} = \frac{(2\times 20)^2}{40\times 20\,mW}$$

$$= 2\ k\Omega$$

We know that,

$$r_c = R_p \parallel R_L$$

$$\therefore \quad \frac{1}{R_p} = \frac{1}{r_c} - \frac{1}{R_L} = \frac{1}{2\,K} - \frac{1}{6\,K}$$

$$= 3.33 \times 10^{-4}$$

$$\therefore \quad R_p = 3\ k\Omega$$

We know that

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$\therefore \quad C = \frac{1}{(2\pi)^2 L f_r^2}$$

$$= \frac{1}{(2\pi)^2 \times 1.19 \times 10^{-6} \times \left(5 \times 10^6\right)^2}$$

$$= 851 \text{ pF}$$

UNIT - V

2 - Mark

1. Mention the three networks that are connected around the basic amplifier to implement feedback concept.

Ans.:

Sampling network, feedback network and mixer network.

2. What is loop gain or return ratio ?

Ans.:

A path of a signal from input terminals through basic amplifier, through the feedback network and back to the input terminals forms a loop. The gain of this loop is the product -AB. This gain is known as loop gain or return ratio.

3. What is the condition required for satisfactory operation of a negative feedback amplifier?

Ans. :

The condition for the negative feedback is that the part of the output signal which is feedback to the input of the amplifier and the input signal should be out of phase.

4. Give the Barkhausen' s criterion for oscillators.

Ans.:

The Barkhausen criterion states that:

1. The total phase shift around a loop, as the signal proceeds from input through amplifier, feedback network back to input again, completing a loop, is precisely 0°or 360°, or of course an integral multiple of 2π radians.

5. Differentiate oscillator with amplifier.

Sr. No.	Amplifier	Oscillator
1.	It uses negative feedback.	It uses positive feedback.
2.	Input is required.	Input is not required.
3.	It produces amplified output.	It produces constant frequency consta amplitude output.
4.	Phase shift depends on the configuration.	Total phase shift has to be 360 aroun loop.
5.	Amplifier has required bandwidth depending upon the applications.	Bandwidth is ideally zero as operation is at single frequency.
6.	Used generally in audio and video circuits.	Used in signal generators, heterodyn receivers, clocks etc.

6. What are the advantages of crystal oscillators?

Ans.:

The features of crystal oscillator are,

1. It produces extremely stable outputs. Due to replacement of transistors or elements like inductors and capacitors in conventional oscillators, the frequency may get changed. In crystal oscillators such a change is not possible.

2. The temperature has no effect on the frequency.

3. It has very much reduced phase noise.

4. The crystal frequency depends on its physical dimensions hence proper frequency rating can be achieved by cutting crystal to proper dimensions.
5. Aging rates of crystals are 2×10^{-8} per year, for a quartz crystal. This is negligibly small.
6. In a quartz crystal, the frequency drift with time is, typically less than 1 part in 10^6 i.e.
7. 0.0001 % per day. This is also very very small.

In all, the frequency stability of crystal oscillators is very very good.

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6. An amplifier has a mid frequency gain of 100 and a bandwidth of 200 kHz.

1. What will be the new bandwidth and gain, if 5 % negative feedback is introduced?
2. What should be the amount of feedback, if the bandwidth is to be restricted to 1 MHz?

Ans:

Given : A = 100 BW = 200 kHz and $\beta = 0.05$

1. $A_{vf} = \frac{A_v}{1+\beta A_v} = \frac{100}{1+0.05\times100} = \mathbf{16.67}$

$BW_f = BW\times(1+\beta A_v)$

$= 200\times10^3\times(1+0.05\times100) = \mathbf{1.2\ MHz}$

2. Given $BW_f = 1$ MHz

$1\times10^6 = BW\,(1+\beta A_v)$

$= 200\times10^3\times(1+\beta\times100)$

$\beta = \mathbf{0.04}$

7. Design a RC phase shift oscillator to generate 5 kHz sine wave with 20 V peak to peak amplitude. Draw the designed circuit. Assume h_{fe} = 150.

Ans.:

For RC phase shift oscillator,

$h_{fe} = 4k + 23 + \frac{29}{k}$ ... given $h_{fe} = 150$

$\therefore \quad 150 = 4k + 23 + \frac{29}{k}$

i.e. $4k^2 - 127\,k + 29 = 0$

$\therefore \quad k = 31.52,\ 0.23,$ Select $k = 0.23$

$\therefore \quad f = \frac{1}{2\pi R C\sqrt{6+4k}}$ ... given $f = 5$ kHz

$\therefore$ Choose $C = 1000$ pF

$\therefore \quad 5\times10^{3} = \frac{1}{2\pi R \times 1000\times10^{-12}\times\sqrt{6+4\times0.23}}$

$\therefore \quad R = 12.1\ k\Omega \approx 12\ k\Omega$

$\therefore \quad k = \frac{R_C}{R}$ i.e. $R_C = kR = 2.7\ k\Omega$

- Neglecting effect of biasing resistances assuming them to be large and selecting transistor with $h_{ie} = 2\ k\Omega$,

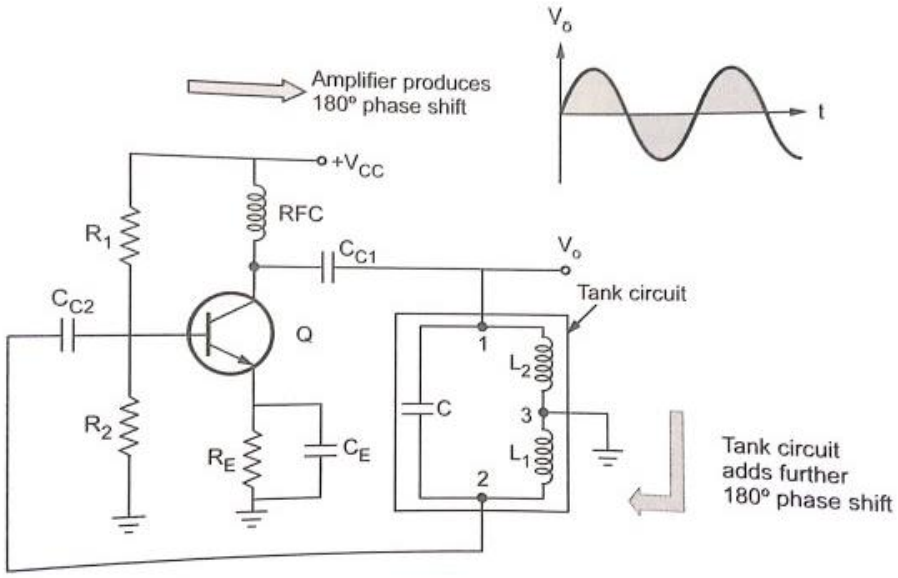
  $R'_i = h_{ie} = 2\ k\Omega$,

  $\therefore$ Last resistance in phase shift network

  $R_3 = R - R'_i = 12 - 2 = 10\ k\Omega$

- Using the **back to back** connected Zener diodes of 9.3 V (V_z) each at the output of emitter follower and using this at the output of the oscillator, the output amplitude can be controlled to 10 V i.e. 20 V peak to peak. The Zener diode 9.3 V and forward biased diode of 0.7 V gives total 10 V.

- The designed circuit is as shown in the following figure.



3. Hartley Oscillator

Ans:

- It uses two inductive reactances and one capacitive reactance in its feedback network. Depending on the active device used in amplifier stage, the two types of Hartley oscillators are,

i) BJT Hartley oscillator ii) FET Hartley oscillator.

Transistorised Hartley Oscillator

- The Fig. 10.9.1 shows the practical circuit of Hartley oscillator using BJT as an active device. The resistances R1, R2 and RE are the biasing resistors.
- The RFC is radio frequency choke whose reactance value is very high at high frequency and can be treated as open circuit. While for d.c. operation, it is shorted hence does not cause problems for d.c. operation.
- Due to RFC, the isolation between a.c. and d.c. operation is achieved. The Cc, and Cc2 are the coupling capacitors while CE is the emitter bypass capacitor. The CE amplifier provides phase shift of 180.
- In the feedback circuit, as the centre of L, and L2 is grounded, it provides additional phase shift of 180. This satisfies Barkhausen condition. In this

oscillator, X1 = ωL_1, $X_2 = \omega L_2$, $X_3 = -\frac{1}{\omega C}$

- For LC oscillator, $X_1 + X_2 + X_3 = 0$

$$\therefore \quad \omega L_1 + \omega L_2 - \frac{1}{\omega C} = 0$$

$$\text{i.e.} \quad \omega(L_1 + L_2) = \frac{1}{\omega C}$$

$$\therefore \ \omega = \frac{1}{\sqrt{(L_1 + L_2)C}} \quad \text{i.e.} \quad \boxed{f = \frac{1}{2\pi\sqrt{(L_1 + L_2)C}}}$$

- The inductance $L_1 + L_2$ is equivalent inductance denoted as Leg. To satisfy IAβI = 1, the hfe of the BJT used must be L_1 / L_2

$$\boxed{h_{fe} = \frac{L_1}{L_2}}$$

- Practically L_1 and L_2 are wound on a single core and there exists a mutual inductance M between them.

In this case, $\boxed{L_{eq} = L_1 + L_2 + 2M}$

$$\boxed{f = \frac{1}{2\pi\sqrt{L_{eq}\,C}}} \quad \text{and} \quad \boxed{h_{fe} = \frac{L_1 + M}{L_2 + M}}$$

- If capacitor C is kept variable, frequency can be varied over wide range.

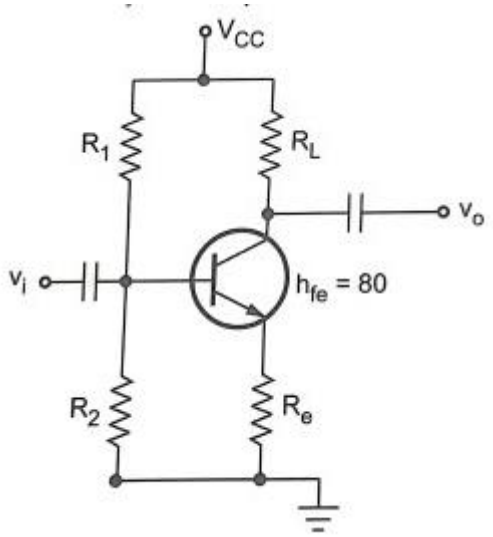
4. A current series feedback amplifier is shown in the figure given below.

It has the following parameters:

R1 = 20 KΩ, R_2 = 20KΩ, hie = 2 kΩ, R_L = 1 kΩ,

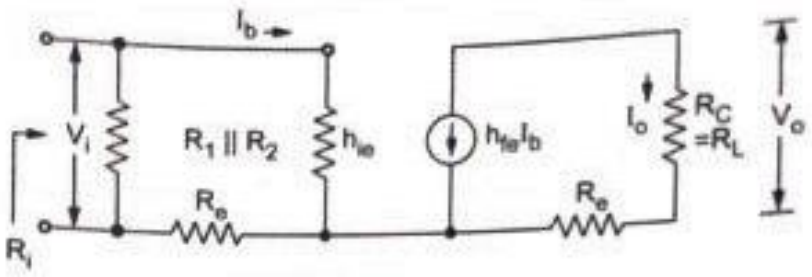
R_e = 100 kΩ, h_{fe} = 80; h_{re} = 0; h_{oe} = 0.

Calculate G_M. β. R_{if} and A_{uf}



Ans:

The Following figure shows the equivalent circuit for the given current series feedback amplifier.



The open loop transfer gain is given by

$$G_M = \frac{I_o}{V_i} = \frac{-h_{fe} I_b}{V_i} \qquad \because I_o = -h_{fe} I_b$$

$$= \frac{-h_{fe} I_b}{V_i} = \frac{-h_{fe} I_b}{I_b(h_{ie} + R_e)} = \frac{-h_{fe}}{h_{ie} + R_e}$$

$$= \frac{-80}{2000 + 100} = -0.038$$

$$\beta = \frac{V_f}{I_o} = \frac{I_e R_e}{I_o} = \frac{-I_o R_e}{I_o} = -R_e \qquad \because I_e = -I_o$$

$$= -100$$

$$D = 1 + \beta G_M = 1 + (-100)(-0.038) = 4.81$$

$$G_{MF} = \frac{-0.038}{4.81} = -7.9\times10^{-3}$$

$$A_{vf} = G_{MF}\times R_L = -7.9\times10^{-3}\times1000 = -7.9$$

$$R_i = h_{ie} + R_e = 2000 + 100 = 2100\ \Omega$$

$$R_i' = R_1 \| R_2 \| R_i = 1.735\ k\Omega$$

$$R_{if} = R_i D = 2100\times4.81 = 10.1\ k\Omega$$