# UNIT - III - AMPLIFIERS

## Amplifier :

⇒ It is a Circuit which increases the amplitude of the given input Signal without changing the frequency

⇒ It is used in radio, television & Communication Circuits.

⇒ The amplifying elements are BJT and FET

## Classification :

a) Based on transistor Configuration

CE amplifier
CC amplifier
CB amplifier

b) Based on active device

BJT amplifier
FET amplifier

c) Based on operating condition

Class A
Class B
Class AB
Class C

d) Based on number of stages

Single stage
Multi stage

e) Based on output

Voltage amplifier
power amplifier

f) Based on frequency response

Audio frequency

Intermediate frequency

Radio frequency

g) Based on Bandwidth

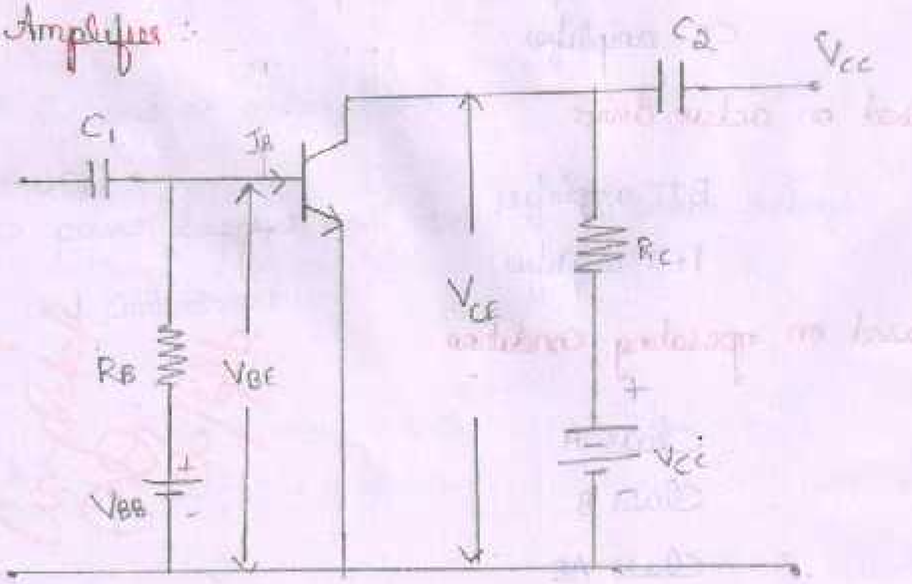
Narrow Band

Wide Band.

## Single stage Amplifier:

-> It has only one amplifying device.

## BJT - CE Amplifier:




-> The EB junction is forward biased by $V_{BB}$ and CB junction is reverse biased by $V_{CC}$ and hence the transistor remains in active region throughout the operation.

-> $C_1$, $C_2$ are the coupling capacitor to provide d c isolation at the input and output of the amplifier

→ I/p signal is given to BE circuit and the amplified output signal is taken from CE circuit.

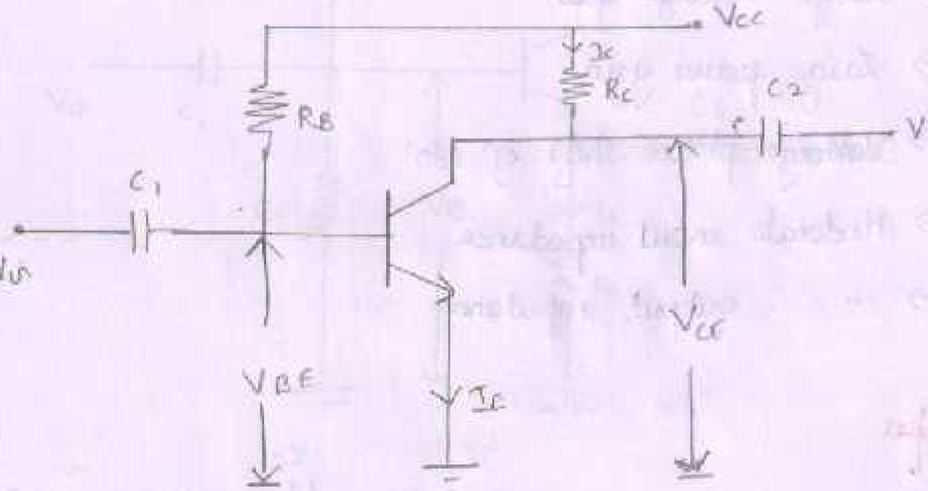
under d.c condition

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

$$I_C = \beta I_B$$

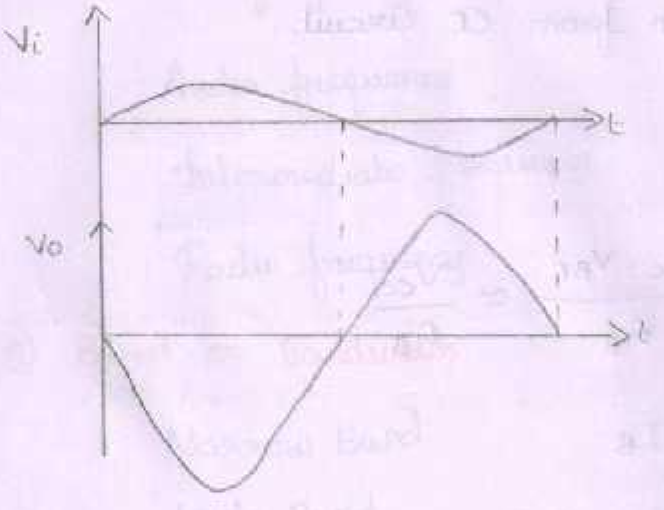
$$V_{CE} = V_{CC} - I_C R_C$$

CE Amplifier with a single power supply




→ when a.c is applied, during positive half cycle, the forward bias of the base emitter junction $V_{BE}$ is increased and hence $I_B$ will increase.

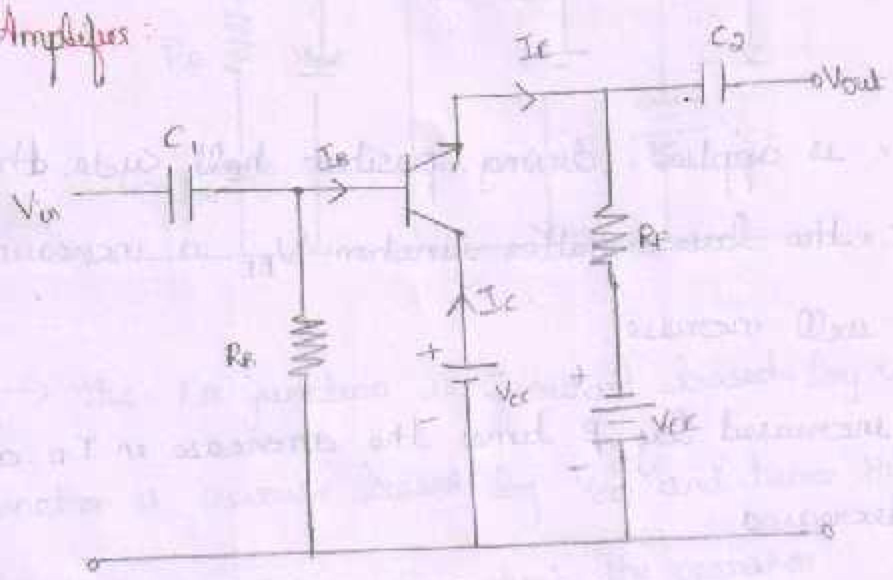
→ $I_C$ is increased by β times the increase in $I_B$ and $V_{CE}$ will get decreased.




Characteristics:

- → Large Current gain
- → Large Voltage gain
- → Large power gain
- → Voltage phase shift of 180°
- → Moderate input impedance
- → " output impedance

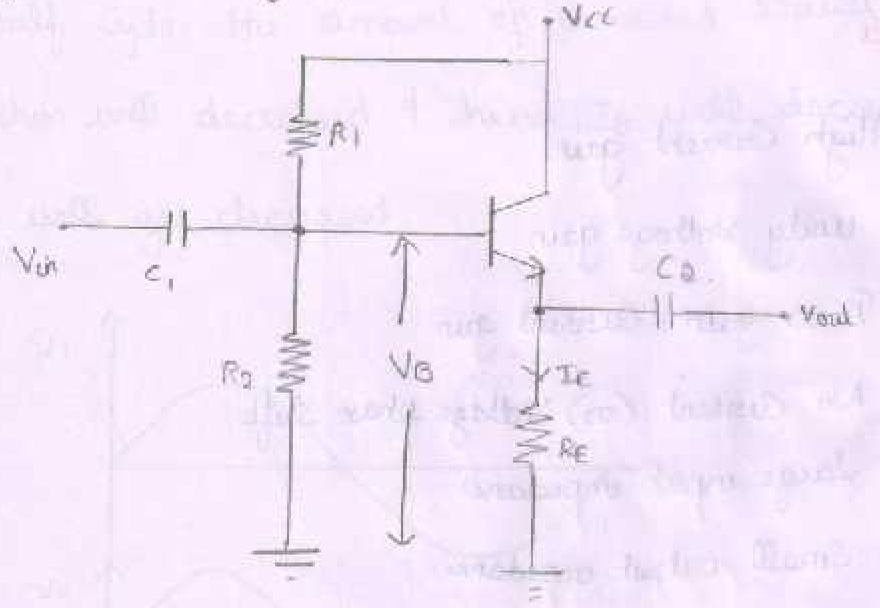
CC Amplifier:



→ The EB junction is forward biased by power supply $V_{EE}$ and CB is reverse biased by $V_{CC}$ therefore the transistor remains in the active region throughout the operation.

→ I/p signal is given to base-collector circuit and output signal is taken from emitter collector circuit.

CC Amplifier with single power supply



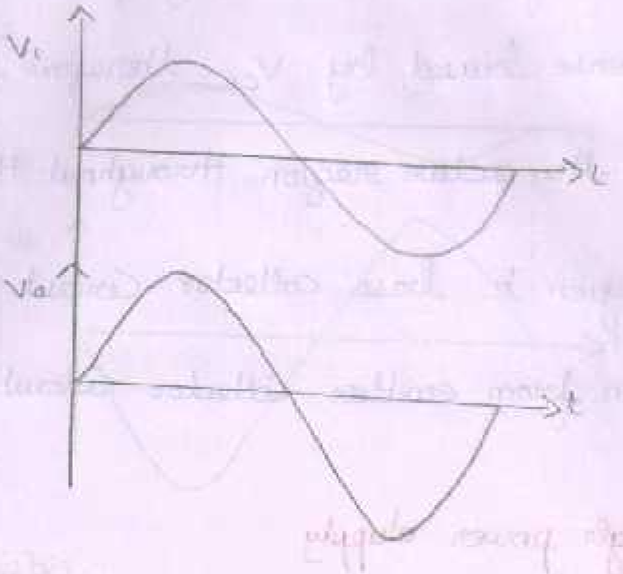

$V_o = I_E R_E$

$V_o = \beta I_B R_E$

→ When a.c signal is applied, during positive half cycle, $V_B$ increases and hence $I_B$ will increase.

$$I_E = I_C + I_B$$

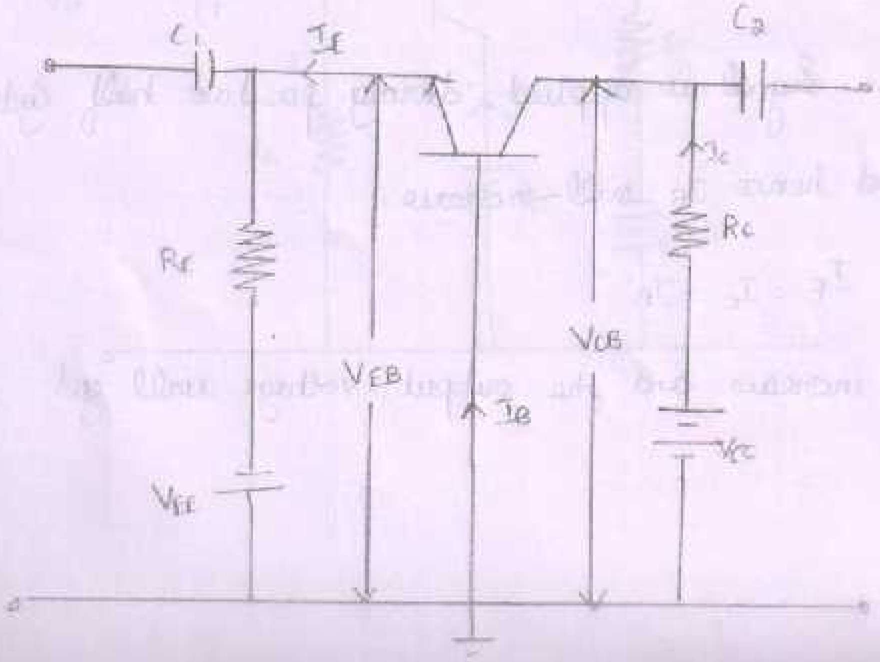
→ $I_E$ will increase and the output voltage will get increase.




## Characteristics :-

- High Current gain
- Unity Voltage gain
- Power gain = Current gain
- No Current (or) Voltage phase shift
- Large input impedance
- Small output impedance.

## CB Amplifier :-

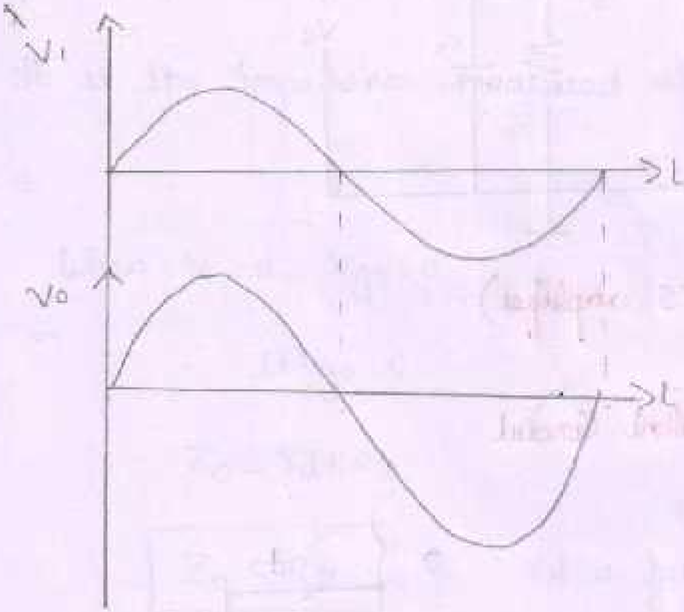


→ The EB junction is forward biased by $V_{EE}$ and CB junction is reverse biased by $V_{CC}$ and hence transistor remains in the active region throughout the operation

→ I/p signal is given to emitter base circuit and O/p signal is taken from collector base circuit

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

→ When a.c signal is applied at the input, during positive half cycle, the amount of forward biased base to BE junction will decreased & hence $I_B$ will decrease and also $I_C$ will get decreased.




Characteristics

→ Current gain less than unity

→ High Voltage gain

→ Power gain = Voltage gain

→ No phase shift for current (or) Voltage

→ Small input and large output impedance

FET Amplifiers :-

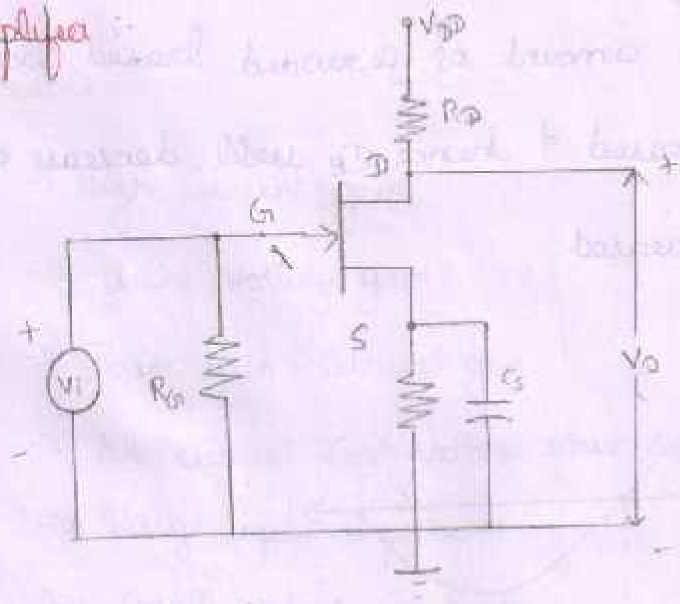
→ The Small Signal model of FET is used for analysing the FET amplifier configuration.

Common Source

Common drain (or) Source follower

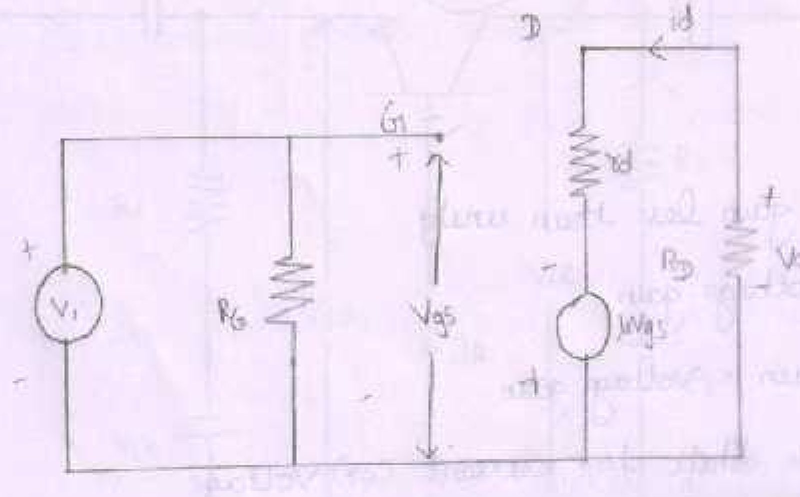
Common gate

Cs Amplifier :-




(CS amplifier)

Small Signal Equivalent Circuit :-



Voltage gain:

$$V_0 = \frac{-R_D}{R_D + r_d} \mu V_{gs}$$

$V_{gs} = V_i$ (input Voltage)

$$\text{Voltage gain } A_V = \frac{V_0}{V_i} = \frac{-\mu R_D}{R_D + r_d}$$

Input Impedance

$$Z_i = R_G$$

$$R_G = R_1 \parallel R_2$$

Output Impedance

→ It is the Impedance measured at the output terminal with $V_i = 0$.

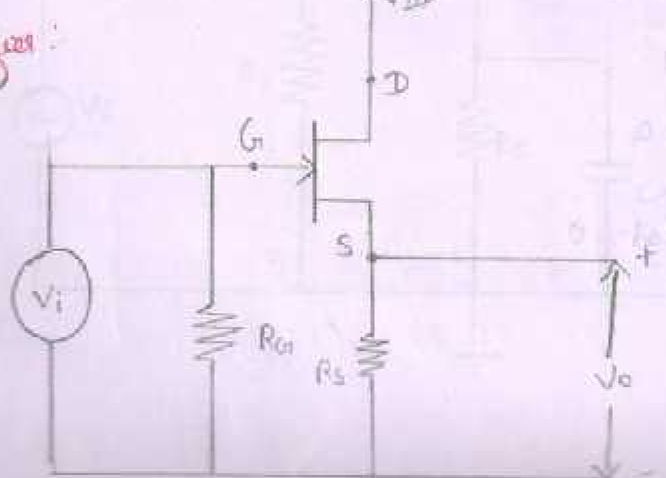
When $V_i = 0$, $V_{gs} = 0$

$\therefore \mu V_{gs} = 0$

$$Z_0 = r_d \parallel R_D$$

$$\boxed{Z_0 \simeq R_D} \quad \because r_d \text{ is far greater than } R_D$$

CD Amplifier:



Output Impedance, $Z_0 = \frac{r_d}{\mu+1} \parallel R_S$.

If $\mu >> 1$,

$$Z_0 \simeq \frac{r_d}{\mu} \parallel R_S$$

$$= \frac{1}{g_m} \parallel R_S$$

Frequency Response

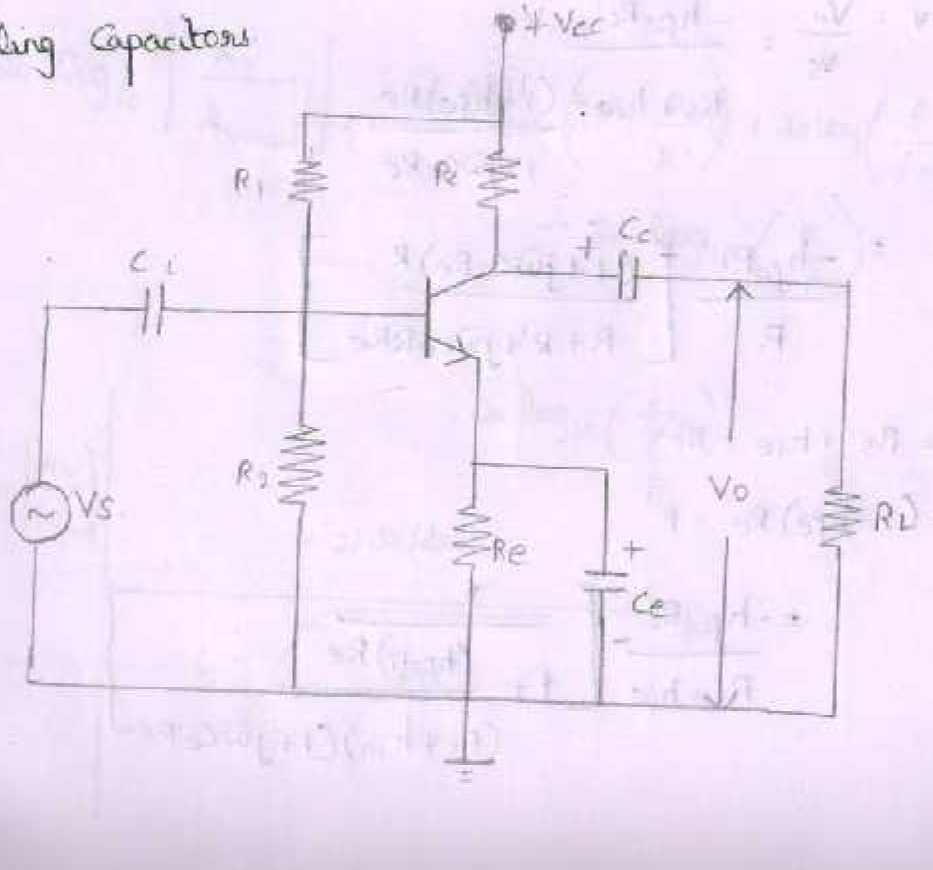
→ Defined as the measure of output parameter Variation with respect to Variation of input frequency.

→ The ratio of amplitude of the output sinusoidal to the amplitude of input sinusoidal is defined as amplifier gain.

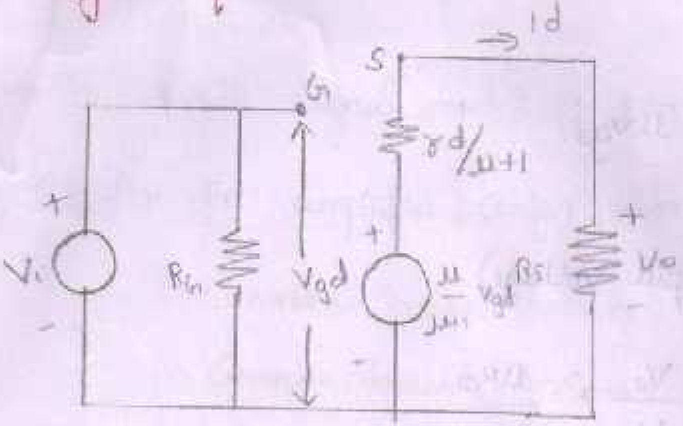
Low Frequency response of BJT Amplifiers.

→ It is determined by the emitter bypass Capacitor and the coupling Capacitors

→



## Small signal equivalent Circuit




Output Voltage $V_o = \frac{R_S}{R_S + \frac{r_d}{\mu+1}} \times \frac{\mu}{\mu+1} V_{gd}$

$$V_o = \frac{\mu R_S V_{gd}}{(\mu+1) R_S + r_d}$$

$$\boxed{V_{gd} = V_i}$$

Voltage gain

$$A_V = \frac{V_o}{V_i} = \frac{\mu R_S}{(\mu+1) R_S + r_d}$$

Input Impedance

$$Z_i = R_G$$

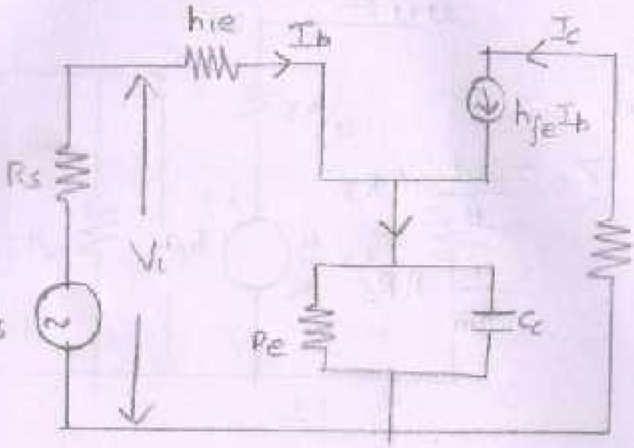
Output Impedance

→ $V_i = 0$

$V_{gd} = 0$

$\frac{\mu}{\mu+1} V_{gd} = 0$

Small signal hybrid equivalent circuit




$$V_o = -h_{fe} i_b R_c'$$

$$I_b = \frac{V_s}{R_s + R_i}$$

$$Z_e = \frac{R_e}{1 + j\omega C_e R_e}$$

$$V_o = \frac{-h_{fe} R_c' V_s}{R_s + h_{ie} + (1+h_{fe}) Z_e} = \frac{-h_{fe} R_c' V_s}{R_s + h_{ie} + \frac{(1+h_{fe}) R_e}{1 + j\omega C_e R_e}}$$

$$A_v = \frac{V_o}{V_s} = \frac{-h_{fe} R_c'}{R_s + h_{ie} + \frac{(1+h_{fe}) R_e}{1 + j\omega C_e R_e}}$$

$$= \frac{-h_{fe} R_c'}{R} \left[ \frac{(1 + j\omega C_e R_e) R}{R + R' + j\omega C_e R R_e} \right]$$

where $R_s + h_{ie} = R$

$(1+h_{fe}) R_e = R'$

$$= \frac{-h_{fe} R_c'}{R_s + h_{ie}} \left[ \frac{1}{1 + \frac{(h_{fe}+1) R_e}{(R_s + h_{ie})(1 + j\omega C_e R_e)}} \right]$$

$$A_v = \frac{-h_{fe} R_c}{R_s + h_{ie}} \left[ \frac{1 + j\omega C_e R_e}{1 + j\omega C_e R_e + \frac{(1+h_{fe}) R_e}{R_s + h_{ie}}} \right]$$

$$A_v = \frac{-h_{fe} R_c}{R\left(1 + \frac{R'}{R}\right)} \left[ \frac{1 + j\omega C_e R_e}{1 + \frac{j\omega C_e R_e R}{R + R'}} \right]$$

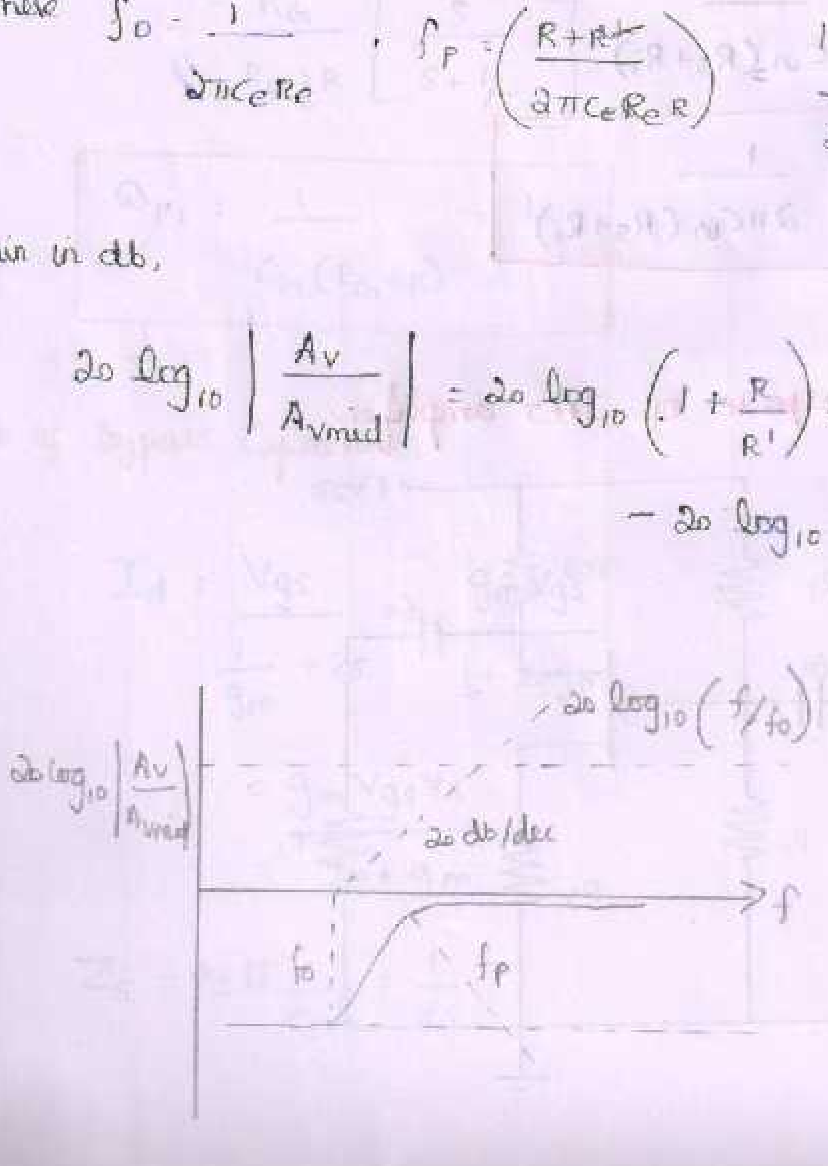
$$A_{vmid} = -\frac{h_{fe} R_c}{R}$$

$$A_v = \left[ \frac{A_{vmid}}{1 + R'/R} \right] \left[ \frac{1 + j(f/f_0)}{1 + j(f/f_P)} \right]$$

where $f_0 = \frac{1}{2\pi C_e R_e}$, $f_P = \left(\frac{R + R'}{2\pi C_e R_e R}\right) = \frac{1 + \left(\frac{R'}{R}\right)}{2\pi C_e R_e}$

Gain in db,

$$20 \log_{10} \left| \frac{A_v}{A_{vmid}} \right| = 20 \log_{10}\left(1 + \frac{R}{R'}\right) + 20\log\left(\frac{f}{f_0}\right) - 20 \log_{10}\left(\frac{f}{f_P}\right)$$



$\frac{R'}{R} \gg 1$ & $f_P \gg f_0$ at $f = f_P$

$$\left|\frac{A_v}{A_{vmid}}\right| = \frac{1}{1+\left(\frac{R'}{R'}\right)} \frac{f_P/f_0}{\sqrt{1+1}} = \frac{1}{\sqrt{2}}\left(\frac{f}{f_P}\right)$$

$$f_1 = f_P \approx \frac{(1+h_{fe})}{(R_s+h_{ie})2\pi C_e}$$

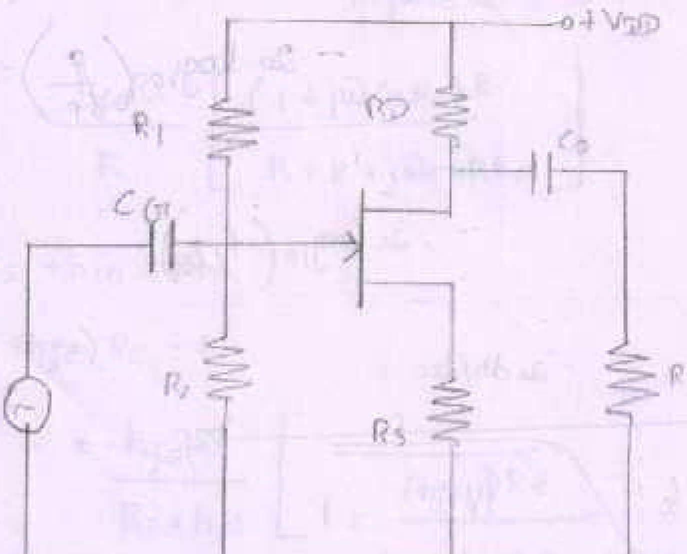
Effect of Coupling Capacitor:-

$$\frac{1}{\omega C_{in}} = R_i + R_s$$

$$\omega = \frac{1}{C_{in}(R_s+R_i)}$$

$$f_1 = \frac{1}{2\pi C_{in}(R_s+R_i)}$$

Low Frequency response of JFET amplifier:-



$$V_{gs} = \frac{V_s R_G}{R_G + R + \frac{1}{sC_G}}$$

$$= \frac{V_s R_G \cdot s}{(R_G + R)s + \frac{1}{C_G}}$$

$$V_{gs} = \frac{V_s R_G}{R_G + R}\left[\frac{s}{s + \frac{1}{C_G(R_G+R)}}\right]$$

$$\frac{V_{gs}}{V_s} = \frac{R_G}{R_G+R} \times \left[\frac{s}{s + \frac{1}{C_G(R_G+R)}}\right]$$

$$= \frac{R_G}{R_G+R}\left[\frac{s}{s + 1/\tau}\right]$$

$$\boxed{\omega_{P1} = \frac{1}{C_G(R_G+R)} = 1/\tau}$$

Effect of bypass Capacitor:

$$I_d = \frac{V_{gs}}{\frac{1}{g_m} + Z_s} = \frac{g_m V_{gs}}{1 + Z_s g_m}$$

$$= \frac{g_m V_{gs} Y_s}{Y_s + g_m}$$

$$Z_s = R_s \,\|\, \frac{1}{C_s s} = \frac{1}{Y_s}$$

$$I_d = \frac{g_m \left( \frac{1}{R_S} + sC_S \right) V_{gs}}{\frac{1}{R_S} + sC_S + g_m}$$

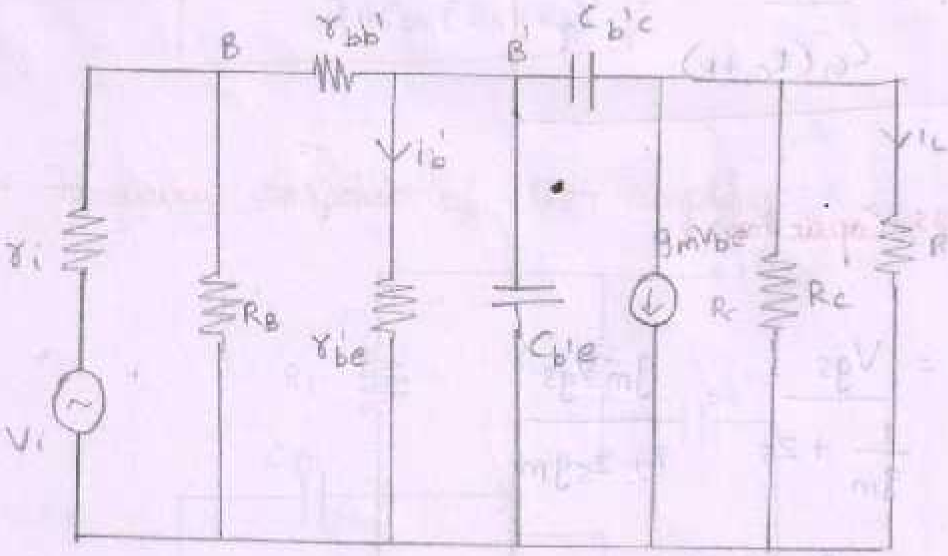
$$I_d = \frac{g_m V_{gs} \left( s + \frac{1}{R_S C_S} \right)}{s + \left( \frac{1}{R_S} + g_m \right) \frac{1}{C_S}}$$

$$\omega_{P2} = \frac{1}{C_S} \left( \frac{1}{R_S} + g_m \right)$$

$$\omega_2 = \frac{1}{R_S C_S}$$

## High frequency analysis

1) BJT amplifier:



Let $r_{b'e} = h_{ie}$

$g_m V_{b'e} = h_{fe} I_b$

$$g_m = \frac{h_{fe}}{h_{ie}}$$

$R_{b'e} = r_{b'e} \parallel (R_b + r_{b'b})$

$R_0 = R_c \parallel R_L$

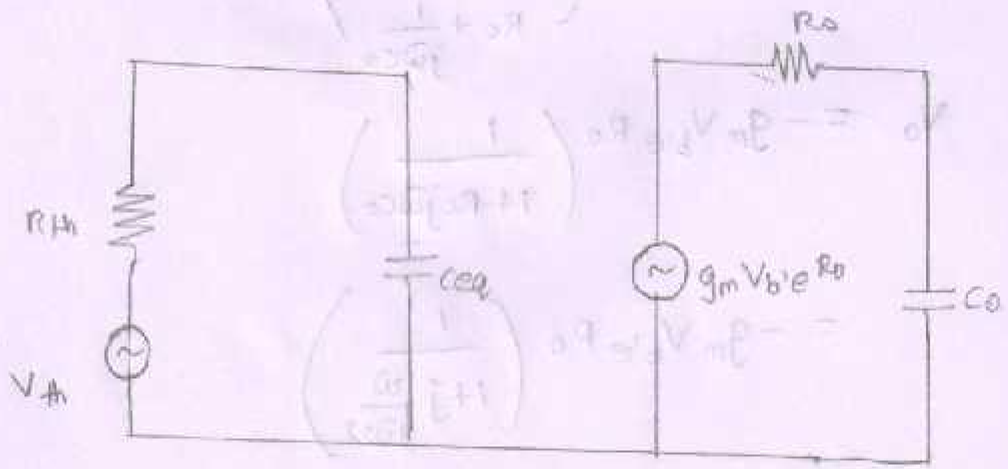
$C_{eq} = C_{b'e} + C_{b'c}(1 + A_v)$

$C_{eq} = C_{b'e} + C_{b'c}(1 + g_m R_L)$

$$C_0 = \frac{C_{b'c}(1+A)}{A}$$

$$= \frac{C_{b'c}(1 + g_m R_L)}{g_m R_L}$$

$$C_0 = C_{b'c}\left(1 + \frac{1}{g_m R_L}\right).$$



$$V_{th} = \frac{R_{b'e} V_s}{r_i + R_{b'e}}$$

$$V_{b'e} = \left( \frac{\frac{1}{j\omega C_{eq}}}{R_{th} + \frac{1}{j\omega C_{eq}}} \right) \left( \frac{R_{b'e} \cdot V_s}{r_i + R_{b'e}} \right)$$

$$V_{b'e} = \left( \frac{1}{R_{th} j\omega C_{eq} + 1} \right) \left( \frac{R_{b'e}}{r_i + R_{b'e}} \right) V_s$$

$$= \frac{1}{1 + j\left(\frac{\omega}{\omega_{21}}\right)} \left( \frac{R_{b'e}}{r_i + R_{b'e}} \right) V_s$$

$$W_{21} = \frac{1}{R_{th} C_{eq}}$$

By Considering o/p Circuit,

$$V_o = -g_m V_{b'e} R_o \left( \frac{\frac{1}{j\omega C_o}}{R_o + \frac{1}{j\omega C_o}} \right)$$

$$V_o = -g_m V_{b'e} R_o \left( \frac{1}{1 + R_o j\omega C_o} \right)$$

$$= -g_m V_{b'e} R_o \left( \frac{1}{1 + j \frac{\omega}{\omega_{22}}} \right)$$

$$W_{22} = \frac{1}{R_o C_o}$$

$$A_v = \frac{V_o}{V_s} = \frac{V_{b'e}}{V_s} \cdot \frac{V_o}{V_{b'e}}$$

$$A_v = -\frac{1}{1+j\frac{\omega}{\omega_{21}}} \left(\frac{R_{b'e}}{r_i + R_{b'e}}\right) g_m \cdot R_o \left(\frac{1}{1+j\left(\frac{\omega}{\omega_{22}}\right)}\right)$$

$$A_v = A_{V01} \, V_{V02} \left(\frac{1}{1+j\frac{\omega}{\omega_{21}}}\right) \left(\frac{1}{1+j\left(\frac{\omega}{\omega_{22}}\right)}\right)$$

$$A_v = A_{V0} \left(\frac{1}{1+j\frac{\omega}{\omega_{21}}}\right) \left(\frac{1}{1+j\left(\frac{\omega}{\omega_{22}}\right)}\right)$$

Unit - III Completed