Electrical Engineering

Electronic II , 3^{rd} class

1- Frequency Response

2- Feedback

3- Operational Amplifier

4- Oscillator

5- Active Filter

6- Power Amplifier

7- Integrated circuit Design

8- Integrated circuit Fabrication

Chapter One :- Frequency Response characterstics.

Frequency Response: is a measure of any system output with varying in the frequency of the applied signal.

Decibels: The term decibel has its origin in fact that power and audio levels are related on a logarithmic basis.

$$\log_b a = x \Rightarrow \boxed{b^x = a}$$

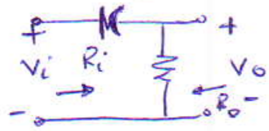
$$\text{bel} \Rightarrow \boxed{G = \log_{10} \frac{P_o}{P_i}}$$ Alexander Graham bel

$$1 \text{ bel} = 10 \text{ decibel} = 10 \text{ dB}$$

$$\therefore \boxed{G_{dB} = 10 \log_{10} \frac{P_o}{P_i}} \text{ dB}$$

$$\boxed{G_{dBm} = 10 \log_{10} \frac{P_o}{1 mW}} \text{ dBm}$$ at 600Ω {characteristic impedance of Audio Transmission line}

$$G_{dB} = 10 \log_{10} \frac{P_o}{P_i} = 10 \log_{10} \frac{V_o^2/R_i}{V_i^2/R_i} = 10 \log_{10} \left(\frac{V_o}{V_i}\right)^2$$



$$\Rightarrow \boxed{G_{dB} = 20 \log_{10} \left|\frac{V_o}{V_i}\right|} \text{ dB}$$

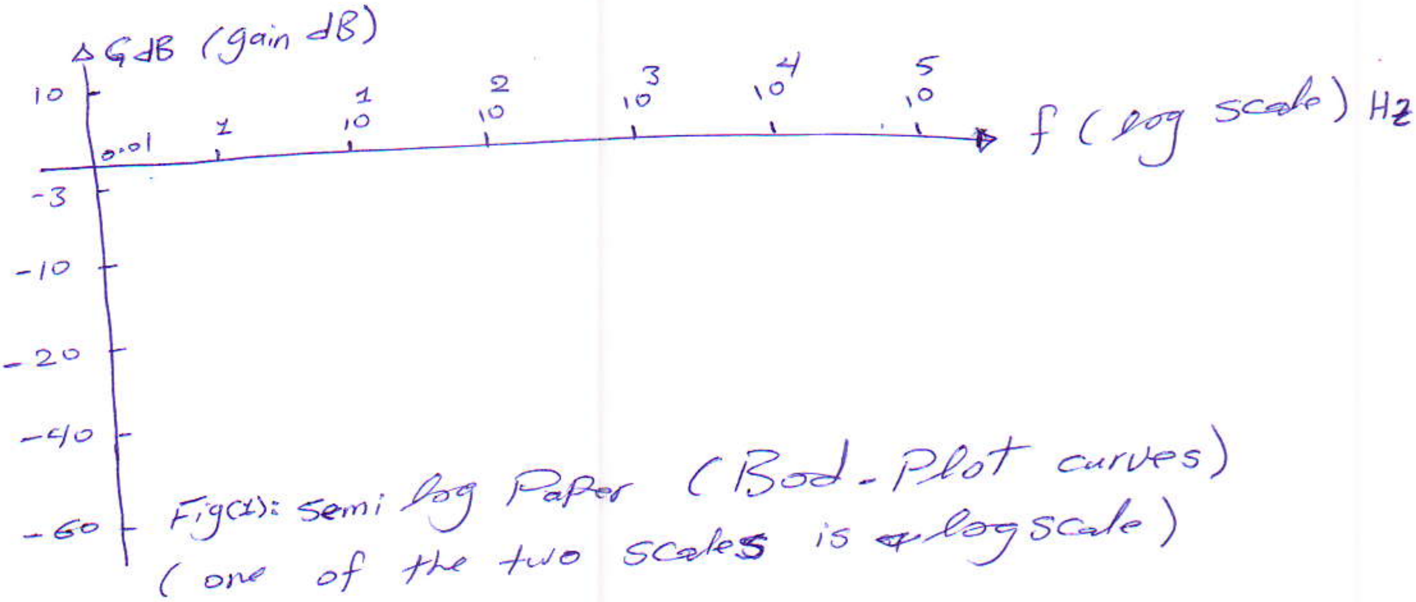
and

$$\boxed{G_{dB} = 20 \log_{10} \left|\frac{I_o}{I_i}\right|} \text{ dB}$$

$\log_{10} 1 = 0$; $10^{-1} = \frac{1}{10} = 0.1 \Rightarrow \log_{10} 0.1 = -1$

$\log_{10} 10 = 1$; $10^{-2} = \frac{1}{100} = 0.01 \Rightarrow \log_{10} 0.01 = -2$

$\log_{10} 100 = 2$; $10^{-3} = \frac{1}{1000} = 0.001 \Rightarrow \log_{10} 10^{-3} = -3$



Fig(1): semi log Paper (Bod-Plot curves)
(one of the two scales is a log scale)

For a cascade stages:- voltage gain overall is given:

$$A_{vor} = A_{v1} \cdot A_{v2} \cdot A_{v3} \cdots$$

Applying logarithmic relationship (decibel gain) GdB

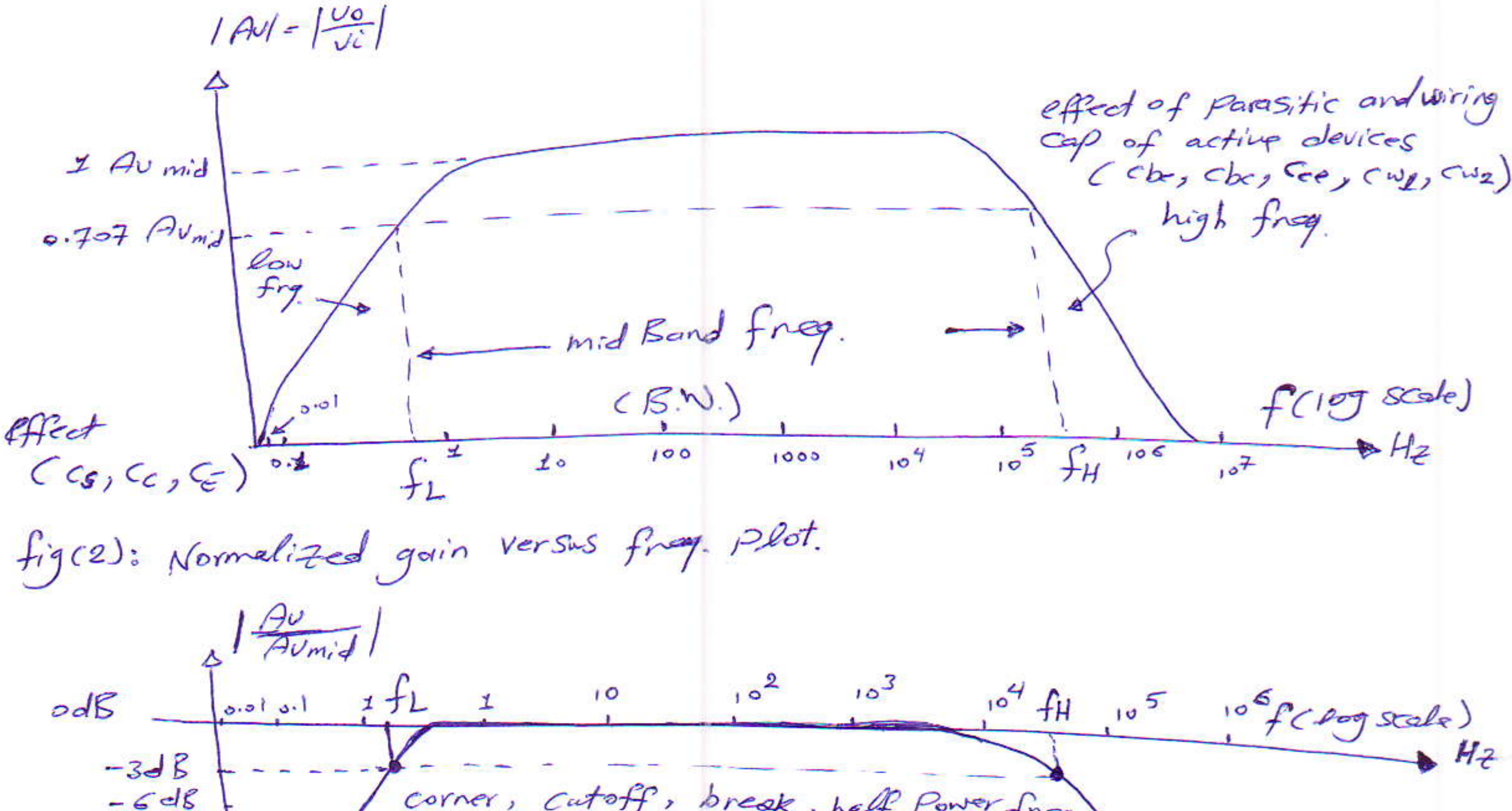
$$G_{dB} = 20 \log_{10} A_{vor} = 20 \log_{10} A_{v1} + 20 \log_{10} A_{v2} + \cdots$$

$\boxed{G_v = G_{v1} + G_{v2} + G_{v3} + \cdots}$ dB voltage gain of system

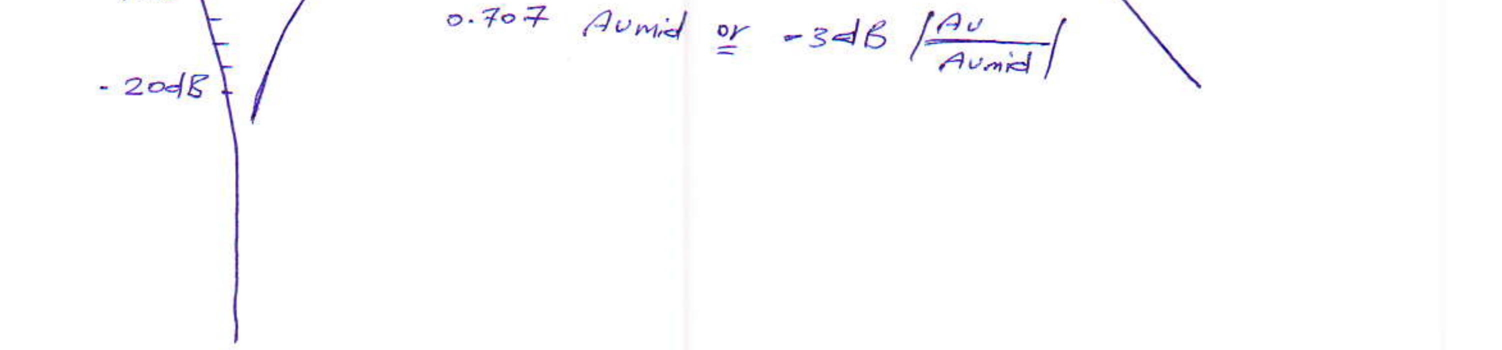
$\boxed{G_i = G_{i1} + G_{i2} + G_{i3} + \cdots}$ dB current gain of system.

* At a low frequency of the input signal, the reactance of the coupling and by pass capacitors (C_C, C_E) increase also the impedance to the passage signal increase causing the gain to be reduced.

* while at high freq. component of the input signal, the connection wires capacitances (c_{w_1} and c_{w_2}) and miller effect Cap. (C_{be}, C_{bc}, C_{ce}), the last Cap. can be called Parasitic Cap. All these Cap. will effect on the gain to reduce.



fig(2): Normalized gain versus freq. plot.



fig(3): Decibel plot of the normalized gain versus freq. plot.

from the Bode plot, the gain decrease at both low and high freq. regions with a midband region where the gain is relatively constant; the two corner frequencies (f_L, f_H) define the midband region, the Band width $\boxed{(BW = f_H - f_L)}$ and extend from f_L to f_H.

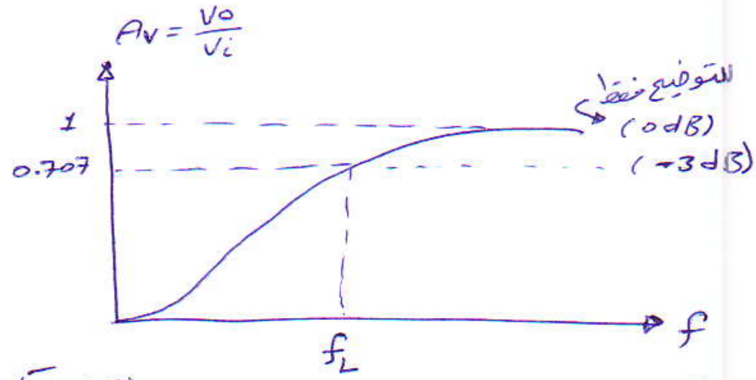
0.707 was chosen as corner, cutoff, break or half Power frequencies to fix the freq. ~~boundaries~~ boundaries of relatively high gain of the midband value and at this ~~~~ level the output Power is half of the midband Power output, that is, at this frequencies:

$$P_{o\,mid} = \left|\frac{V_o^2}{R_o}\right| = \left|\frac{(A_{v\,mid}\, V_i)^2}{R_o}\right|$$

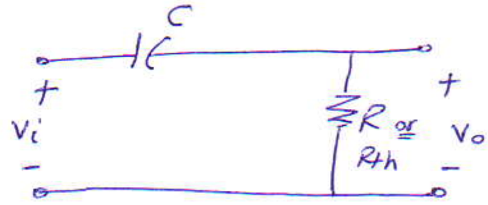
$$\Rightarrow P_{o\,HPF} = \frac{|0.707\, A_{v\,mid}\, V_i|^2}{R_o} = \boxed{\frac{0.5\ |A_{v\,mid}\, V_i|^2}{R_o}}$$

half Power freq.

* Low frequency analysis _ Bode Plot :



Fig(5): Low freq. response for the Rc circuit.



Fig(4): high Pass Rc network

$$X_c = \frac{1}{2\pi f C} \quad \because Av = \frac{V_o}{V_i}$$

At high frequencies $V_o \simeq V_i$; $X_c = \frac{1}{2\pi f C} \simeq 0\,\Omega$ (S.C)

At low frequencies $V_o = 0$; $X_c = \frac{1}{2\pi (0) C} = \infty$ (O.C)

* As the freq. increases, the capacitive reactance decreases and more i/p voltage appear across the o/p terminals.

$$V_o = \frac{R_{th}\, V_i}{R_{th} + X_c} \Rightarrow \frac{V_o}{V_i} = Av = \frac{R_{th}}{R_{th} + X_c}$$

and the gain magnitude is :

$$|Av| = \frac{R_{th}}{\sqrt{R_{th}^2 + X_c^2}} = \frac{\cancel{R_{th}}}{\sqrt{2}\,\cancel{R_{th}}} = \frac{1}{\sqrt{2}} = 0.707 \Big|_{X_c = R_{th}\ \text{(special case)}}$$

at the frequency where $X_C = R_{th}$, the output will be 70.7% of the input for the network

$$X_C = \frac{1}{2\pi f_L C} = R_{th} \quad \therefore \quad \boxed{f_L = \frac{1}{2\pi R_{th} C}}$$

In terms of logs :

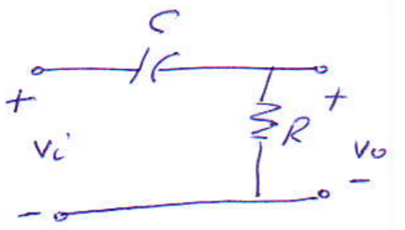
$$G_V = 20\log_{10} A_V \Rightarrow A_V = \frac{V_o}{V_i} = 0.707 \Rightarrow G_V = 20\log_{10}\frac{1}{\sqrt{2}} = -3\,dB$$

while at $A_V = 1$ or $V_i = V_o$ (max value) $\Rightarrow G_V = 20\log_{10} 1 = 0\,dB$

that means there is a 3dB drop in gain when $\boxed{f = f_L}$

In the single transistor amplifier, the cap C_S, C_C, C_E will effect on the gain at low freq. response

$$A_V = \frac{V_o}{V_i} = \frac{R_{th}}{R_{th} + \frac{1}{J\omega C}} = \frac{1}{1 - J\left(\frac{1}{\omega C R_{th}}\right)} \quad \text{--- (1)}$$



$$R_{th} = X_C = \frac{1}{J\omega C} = \frac{1}{J 2\pi f_L C}$$ (special case)

$$f_L = \frac{1}{J 2\pi R_{th} C}$$ (From above) and subs in equation (1)

and we get:

$$\boxed{A_V = \frac{1}{1 - J\frac{f_L}{f}}}$$

In the magnitude and Phase form:

$$\boxed{A_v = \frac{V_o}{V_i} = \frac{1}{\sqrt{1+(f_L/f)^2}} \angle \tan^{-1}\left(\frac{f_L}{f}\right)}$$

If $f = f_L \Rightarrow |A_v| = \frac{1}{\sqrt{2}} = 0.707 = -3dB$ (cutoff)

If $f \gg f_L \Rightarrow |A_v| = 1 = 0\,dB$ (midband)

If $f \ll f_L$ Ignore

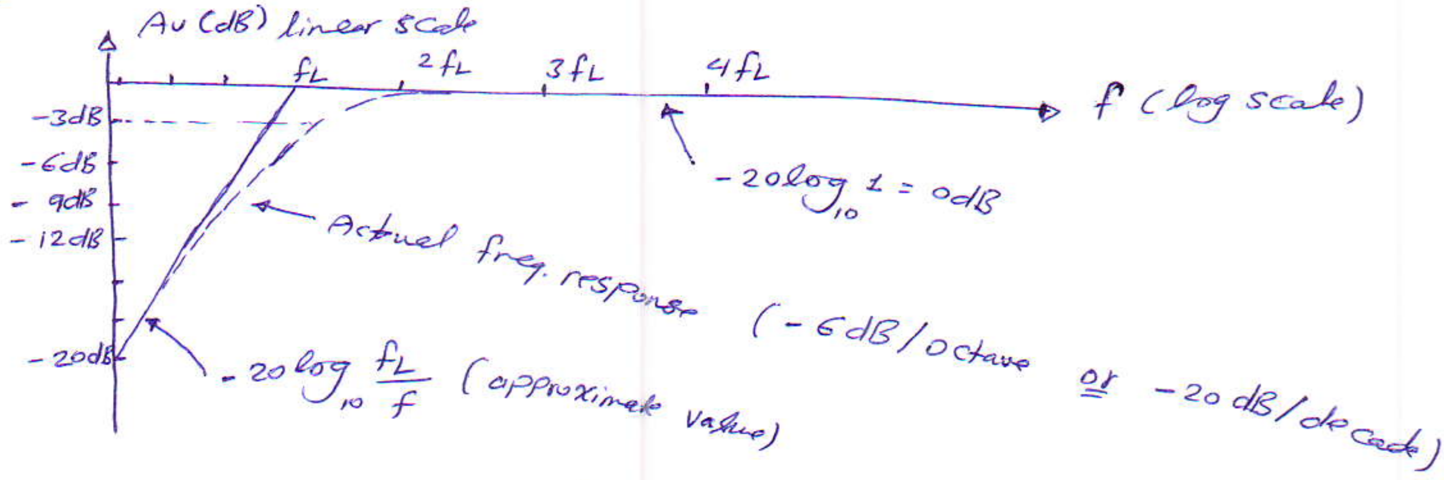
$$\boxed{A_{v_{dB}} = 20 \log_{10} \frac{1}{\sqrt{1+(f_L/f)^2}}}$$

$$\Rightarrow A_{v\,dB} = 20 \log_{10} \left[1+\left(\frac{f_L}{f}\right)^2\right]^{-\frac{1}{2}}$$

$\therefore A_{v_{dB}} = \boxed{-10 \log_{10} \left[1+\left(\frac{f_L}{f}\right)^2\right]}$ actual equation for gain value

or for the frequencies $f \ll f_L$ or $\left(\frac{f_L}{f}\right)^2 \gg 1$ the equation above Can be approximated by

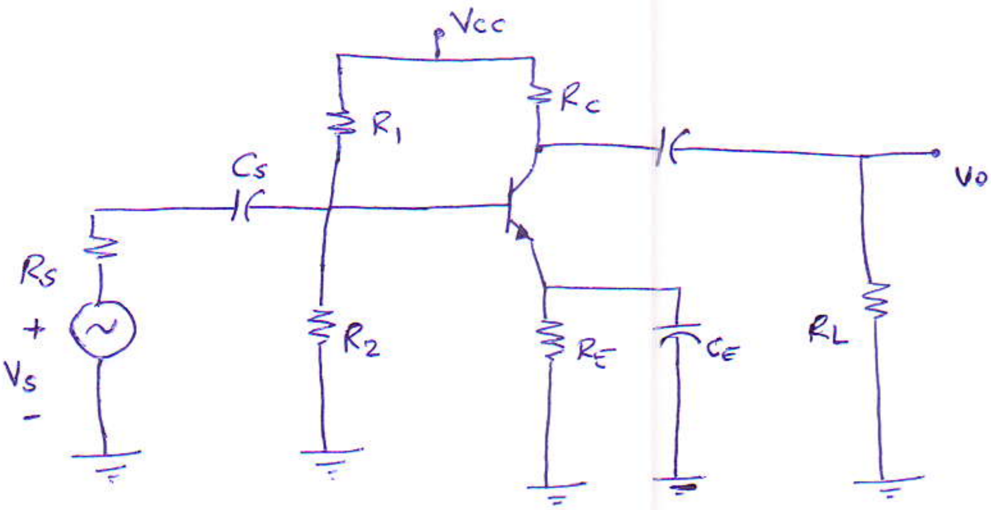
$\boxed{A_{v\,dB} = -20 \log_{10} \frac{f_L}{f}}$ Approximate gain value



Fig(6): Bode Plot for low freq. region.

* Low Frequency Response - BJT Amplifiers:

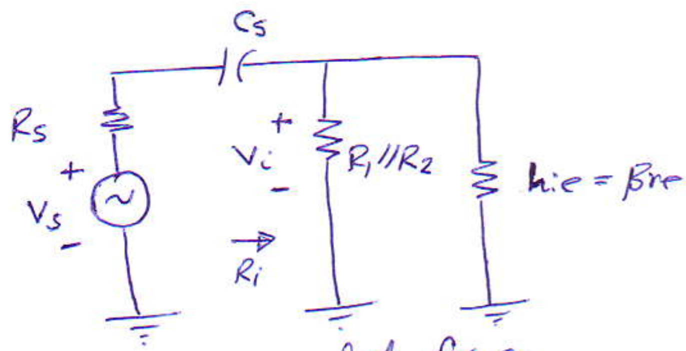
The analysis of this section will employ the loaded voltage divider BJT bias configuration, but the result can be applied to any BJT.



Fig(7): BJT amplifier Network

$$f_L = \frac{1}{2\pi R_{th} C}$$

① Effect of C_s:

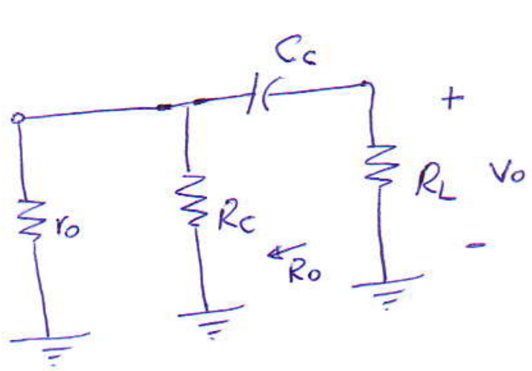


localized ac equivalent for Cs

$$\boxed{f_{L_S} = \frac{1}{2\pi (R_s + R_i) C_s}}$$

$$\boxed{R_i = R_1 \parallel R_2 \parallel \beta r_e}$$

② Effect of C_c:



localized ac equivalent for Cc

$$\boxed{f_{L_C} = \frac{1}{2\pi (R_o + R_L) C_c}}$$

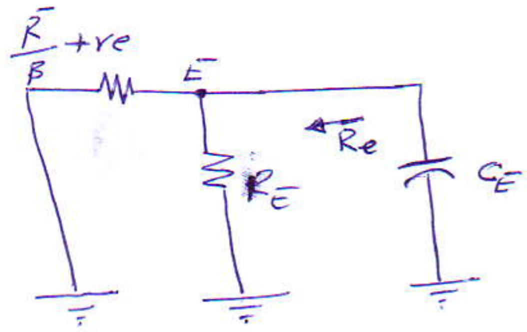
$$\boxed{R_o = R_c \parallel r_o}$$

(3) Effect of C_E:

$$\boxed{f_{L_E} = \frac{1}{2\pi R_e C_E}}$$

$$\boxed{R_e = R_E \,//\, \frac{\bar{R_s}}{\beta} + r_e}$$

where $\bar{R_s} = R_s // R_1 // R_2$



Ex: (a) Determine the lower cutoff freq. for the network of fig (7) using the following parameters:

$C_s = 10\,\mu F$, $C_E = 20\,\mu F$, $C_c = 1\,\mu F$

$R_s = 1\,k\Omega$, $R_1 = 40\,k\Omega$, $R_2 = 10\,k\Omega$, $R_E = 2\,k\Omega$, $R_c = 4\,k\Omega$

$R_L = 2.2\,k\Omega$, $\beta = 100$, $r_o = \infty$, $V_{cc} = 20V$

(b) Sketch the freq. response using a bode plot

Solution:

(a) To determine re for dc conditions, we first apply the test equation:

$\beta R_E = (100)(2k) = 200k \gg 10R_2 = 100k\Omega$

$\therefore$ approximate analysis can be applied.

Since

$$V_B = \frac{R_2 V_{cc}}{R_2 + R_1} = \frac{10k\,(20)}{10k + 40k} = 4V$$

$$I_E = \frac{V_E}{R_E} = \frac{V_B - V_{BE}}{R_E} = \frac{4 - 0.7}{2k} = 1.65mA$$

$$r_e = \frac{26mV}{I_E} = \frac{26mV}{1.65mA} \simeq 15.76\,\Omega$$

$\beta r_e = (100)(15.76) = 1576 = 1.576\,k\Omega$

midband gain

$$A_v = \frac{v_o}{v_i} \cong \frac{-R_C \,//\, R_L}{r_e} = \frac{(4k)\,//\,(2.2k)}{15.76} \simeq -90$$

The input impedance $Z_i = R_i = R_1 \,//\, R_2 \,//\, \beta r_e = 40k \,//\, 10k \,//\, 1.576k = 1.32\,k\Omega$

$$\text{overall gain} = \frac{V_o}{V_s} = \frac{v_o}{v_i} \cdot \frac{v_i}{V_s} = (-90)\left(\frac{R_i}{R_i + R_s}\right) = (-90)(0.569)$$

$$= -51.21$$

$$f_{L_S} = \frac{1}{2\pi (R_S + R_i) C_S} = \frac{1}{(6.28)(1k + 1.32k)(10\mu)} \cong 6.86\,Hz$$

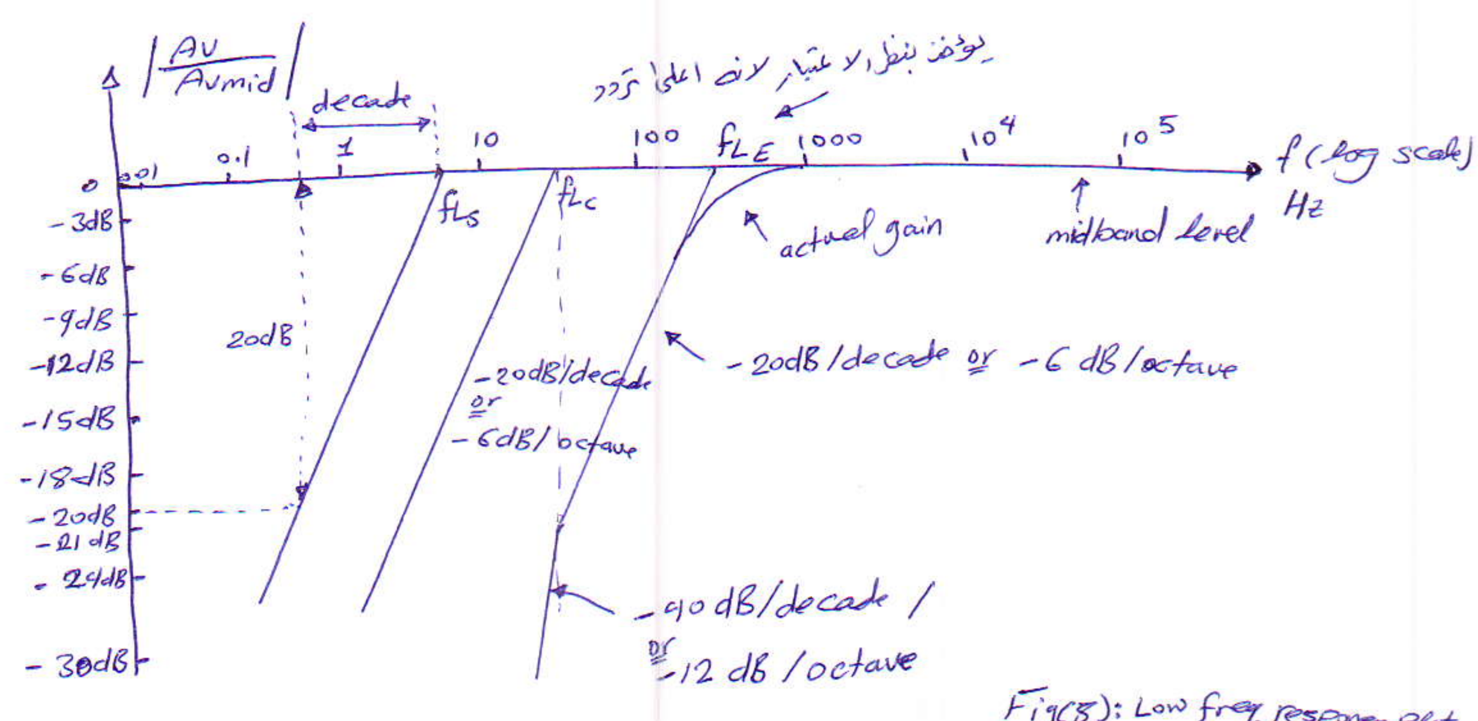
$$f_{L_C} = \frac{1}{2\pi (R_C + R_L) C_C} = \frac{1}{(6.28)(4k + 2.2k)(1\mu)} = 25.68\,Hz$$

$R_s' = R_S \,//\, R_1 \,//\, R_2 = 1k \,//\, 40k \,//\, 10k \cong 0.889\,k\Omega$

$$R_e = R_E \,//\left(\frac{R_s'}{\beta} + r_e\right) = 2k \,//\left(\frac{0.889K}{100} + 15.76\right) \simeq 24.35\,\Omega$$

$$\therefore f_{L_E} = \frac{1}{2\pi R_e C_E} = \frac{1}{(6.28)(24.35)(20\mu)} = 327\,Hz$$

(b)



Fig(8): Low freq. response plot.

* Low Frequency Response - FET Amplifier:

The analysis of the amplifier in the low freq. region will be quite similar to that of the BJT amplifier as follow:

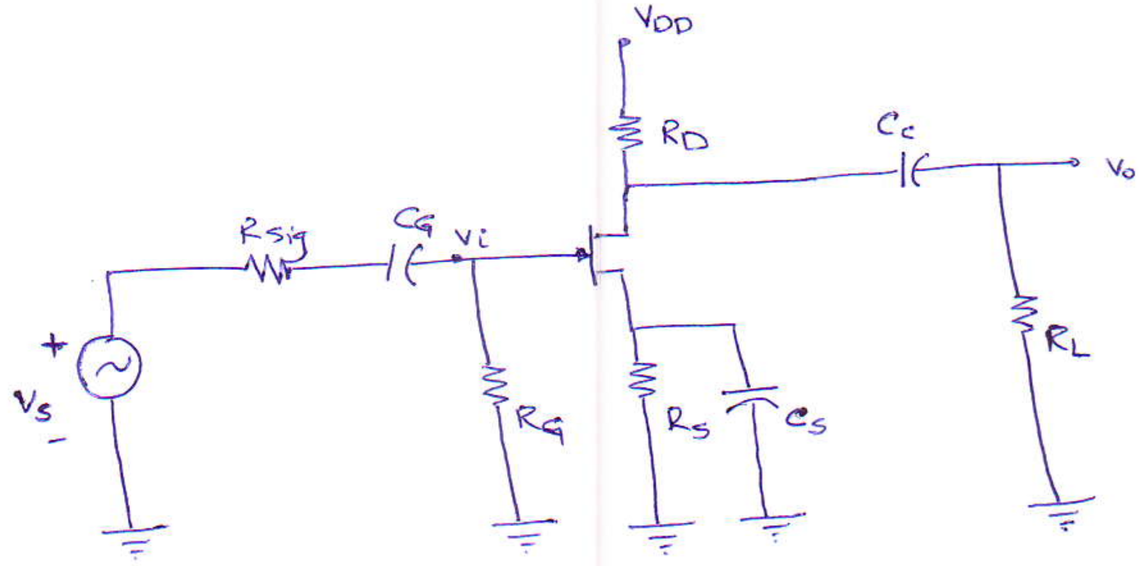
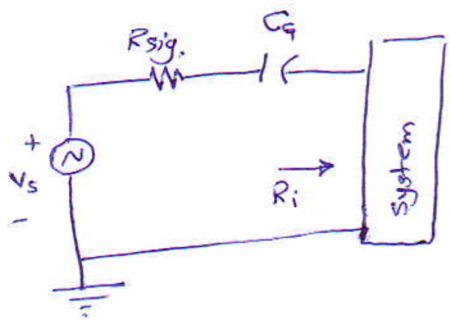


Fig (9): FET amplifier Network.

$$F_L = \frac{1}{2\pi R_{th} C}$$

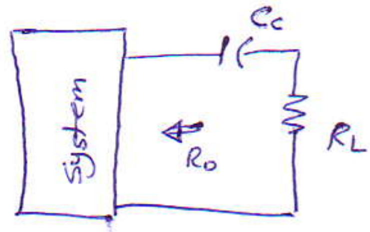
① Effect of C_G:



$$\boxed{f_{L_G} = \frac{1}{2\pi (R_{sig} + R_i) C_G}}$$

$$\boxed{R_i = R_G}$$

② Effect of C_c:

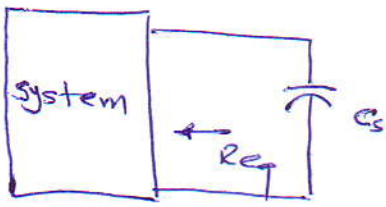


$$\boxed{f_{L_c} = \frac{1}{2\pi (R_o + R_L) C_c}}$$

$$\boxed{R_o = R_D // r_d}$$

③ Effect of C_s:

$$\boxed{f_{L_s} = \frac{1}{2\pi R_{eq} C_s}}$$



$$\boxed{R_{eq} = \frac{R_S}{1 + R_S(1+g_m r_d)/(r_d + R_D /\!/ R_L)}}$$

which for $r_d \simeq \infty\,\Omega$ becomes

$$\boxed{R_{eq} = R_S /\!/ \frac{1}{g_m}}$$

Ex:-

ⓐ Determine the lower cutoff freq. for the network of fig(9) using the following Parameter

$C_G = 0.01\,\mu F$, $C_C = 0.5\,\mu F$, $C_S = 2\,\mu F$

$R_{sig} = 10\,k\Omega$, $R_G = 1\,M\Omega$, $R_D = 4.7\,k\Omega$, $R_S = 1\,k\Omega$, $R_L = 2.2\,k\Omega$

$I_{DSS} = 8\,mA$, $V_P = -4\,V$ $r_d = \infty\,\Omega$, $V_{DD} = 20\,V$

ⓑ Sketch the freq. response using a Bode Plot.

Solution:-

ⓐ To find g_m value must be return to DC analysis

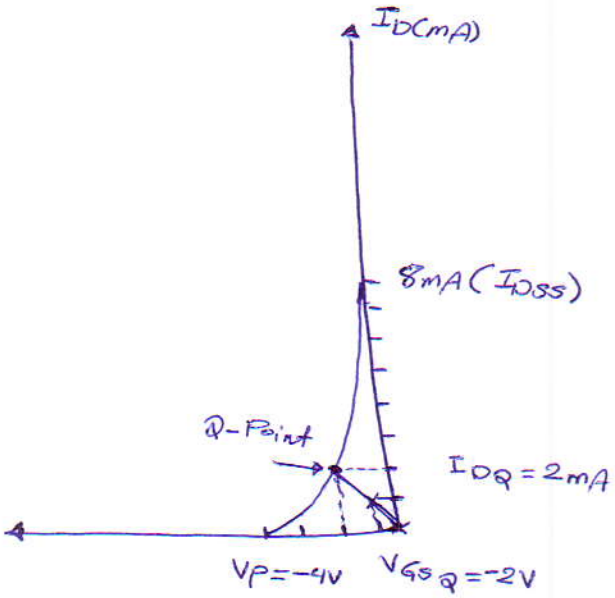
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

to be continue.

$$V_{GS} = V_G - V_S$$
$$= \cancel{V_i}^{\,0} - V_S$$
$$= -V_S \Rightarrow V_G = -I_D R_S$$

for $I_D = 0 \Rightarrow V_{GS} = 0V$

$I_D = 1mA \Rightarrow V_{GS} = -1V$



$$g_{mo} = \frac{2I_{DSS}}{|V_P|} = \frac{2(8m)}{4} = 4mS$$

$$g_m = g_{m_o}\left(1 - \frac{V_{GSQ}}{V_P}\right) = 4mS\left(1 - \frac{-2}{-4}\right) = 2mS$$

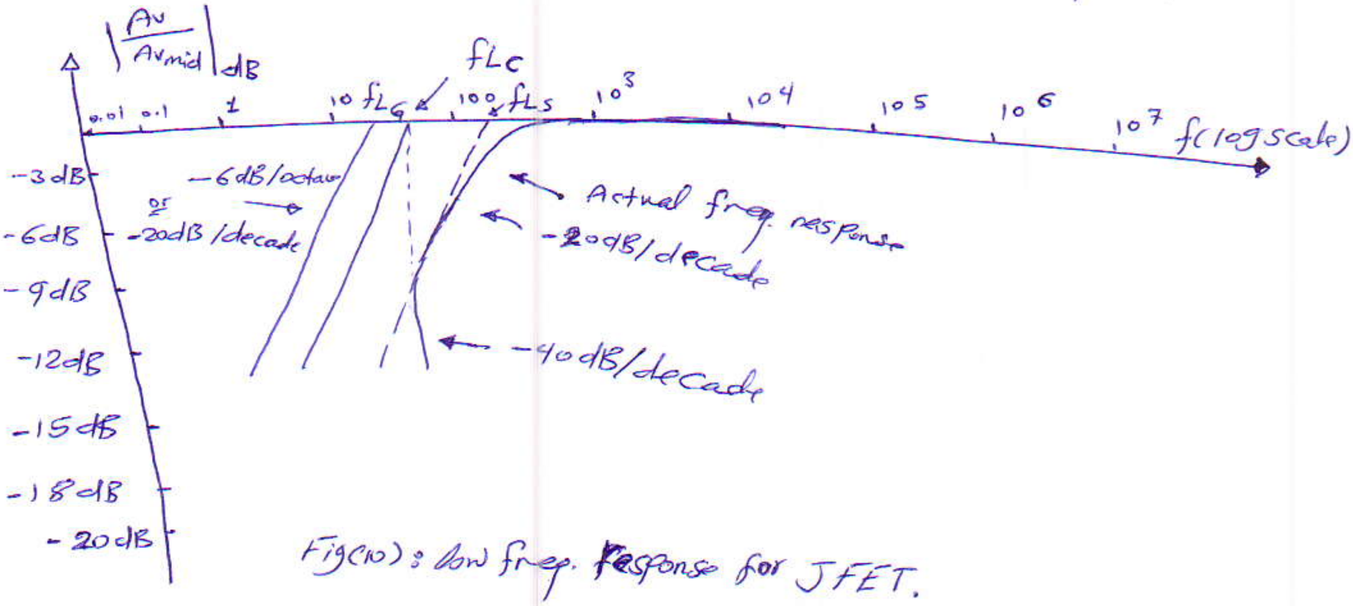
$$f_{L_G} = \frac{1}{2\pi (R_{sig} + R_i) C_G} = \frac{1}{(6.28)(10K + 1M)(0.01\mu)} \simeq 15.8Hz$$

$$f_{L_C} = \frac{1}{2\pi (R_o + R_L) C_C} = \frac{1}{(6.28)(4.7K + 2.2K)(0.5\mu)} \simeq 46.13Hz$$

$$R_{eq} = R_S \,//\, \frac{1}{g_m} = 1K \,//\, \frac{1}{2m} = 333.33\Omega$$

$$f_{L_S} = \frac{1}{2\pi R_{eq} C_S} = \frac{1}{(6.28)(333.33)(2\mu)} = 238.73Hz$$ (التردد الاعلى هو الذي يعتبر) بالنسبة لل low freq.

(b)



Fig(10): low freq. response for JFET.

* Miller Effect Capacitance:

At the high freq. of the i/p signal two factors will define the -3dB Point, the network capacitance (Parasitic of the P-N Junction and introduce wiring capacitance) to be considered as descrete components between the external loads of the transistor or system.

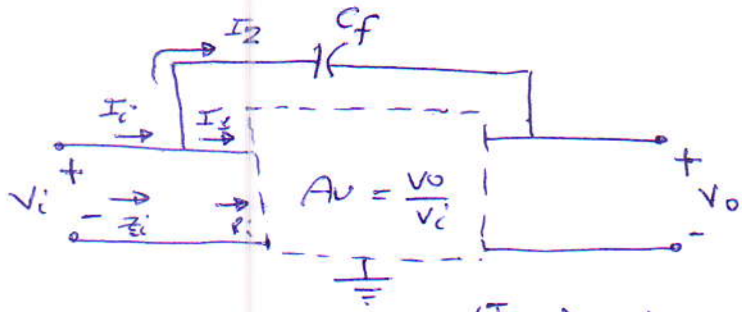


Fig (10): Network employed for the Miller input capacitance

$$\boxed{C_{Mi} = (1+|A_v|)\, C_f}$$

C_f: feedback capacitance

and can be represented by the network in fig (11)

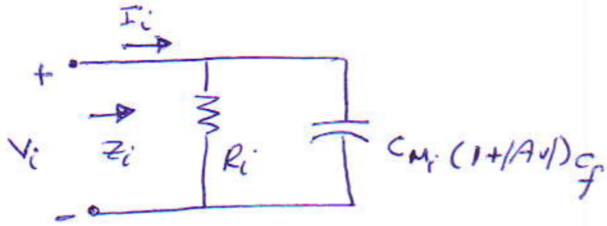
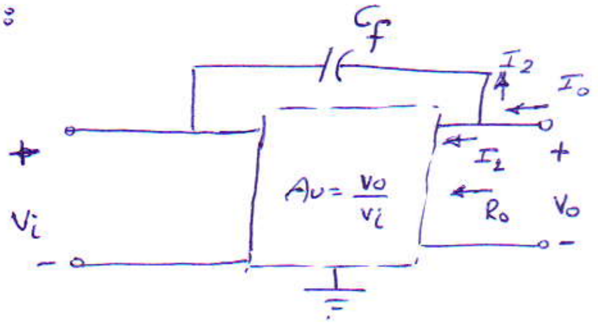


Fig (12)

For any inverting amplifier, the input cap. will be increased by a Miller effect cap sensitive to the gain of the amplifier and Parasitic (electrode) capacitance between the i/p and o/p terminals of the active device.

The resistance R_o is usually sufficiently large and can be represented the Miller o/p capacitance as follow:



Fig(13): Network employed for the Miller output capacitance

$$\boxed{C_{M_o} = (1 + |\frac{1}{A_v}|)C_f}$$

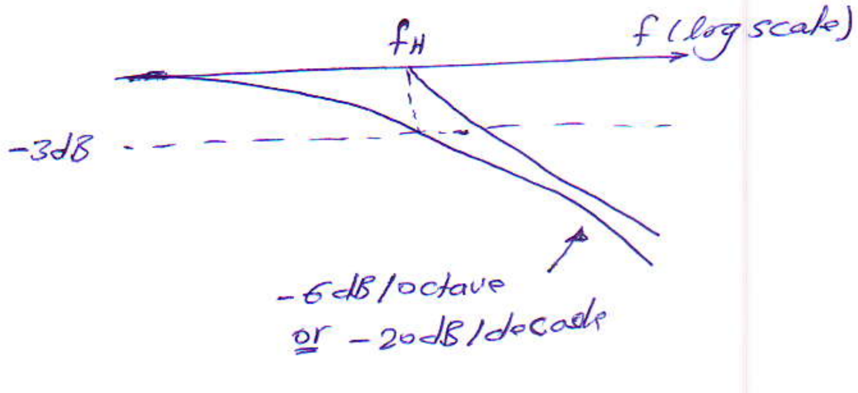
for $A_v \gg 1$

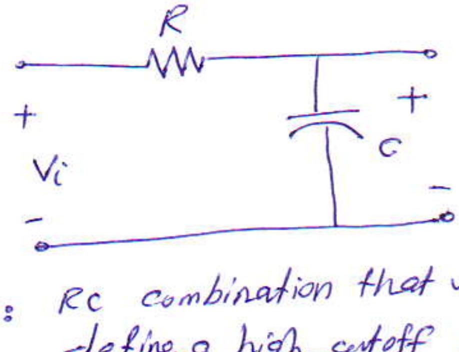
$$\Rightarrow \boxed{C_{M_o} = C_f}$$

* High frequency Response - BJT Amplifier:

At the high freq. end, there are two factors that define -3dB cutoff Point, the network cap (Parasitic cap and introduce wiring cap), and the freq. dependent of h_{fe} (β).

In the high freq. region, the RC network concern has the configuration appearing in fig (14):





Fig(14): RC combination that will define a high-cutoff freq.

* when the i/p signal freq. increase, the reactance X_C decrease in magnitude, resulting in a short effect across the o/p and a decrease in gain.

where

$$V_o = V_i \frac{X_C}{X_C + R} \quad (\text{from fig(14)})$$

$$= V_i \frac{\frac{1}{JWC}}{\frac{1}{JWC} + R} = \frac{V_i \cancel{\frac{1}{JWC}}}{\frac{1 + JWCR}{\cancel{JWC}}} = V_i \frac{1}{1 + JWCR}$$

and at $R = \frac{1}{2\pi f_H C}$ (special case)

we get:

$$\boxed{A_V = \frac{V_o}{V_i} = \frac{1}{1 + J\frac{f}{f_H}}}$$

and the magnitude $\boxed{|A_V| = \frac{1}{\sqrt{1 + (\frac{f}{f_H})^2}}}$

$$\boxed{|A_V|_{dB} = -10 \log_{10} \left[1 + (\frac{f}{f_H})^2\right]}$$ Actual gain value

or

$$\boxed{|A_V|_{dB} \simeq -20 \log_{10} (\frac{f}{f_H})}$$ Approximation gain value

The various Parasitic capacitances (C_{be}, C_{bc}, C_{ce}) of the transistor in fig(15) are included with wiring cap. (C_{wi}, C_{wo}) introduced during construction, not the absence of the cap. C_s, C_E, and C_c which are all assumed to be in the short circuit state at these frequencies.

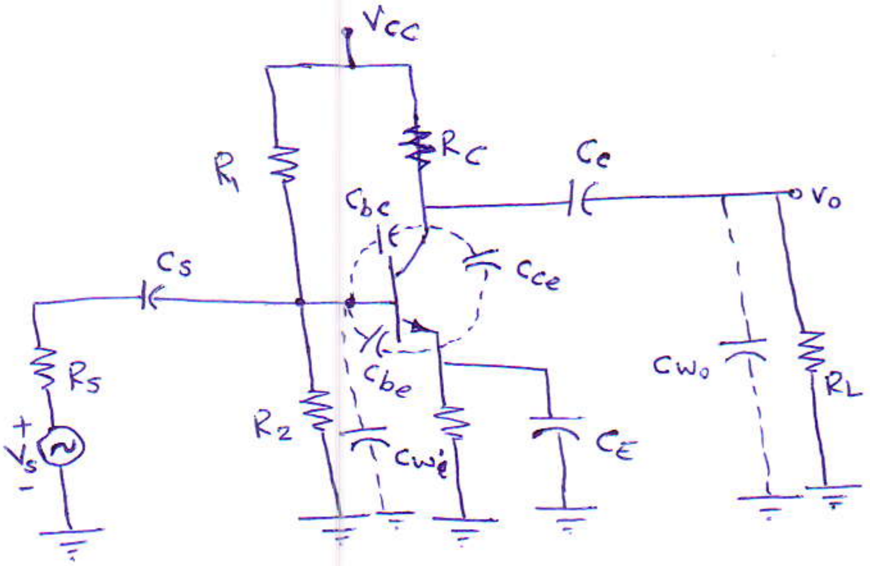
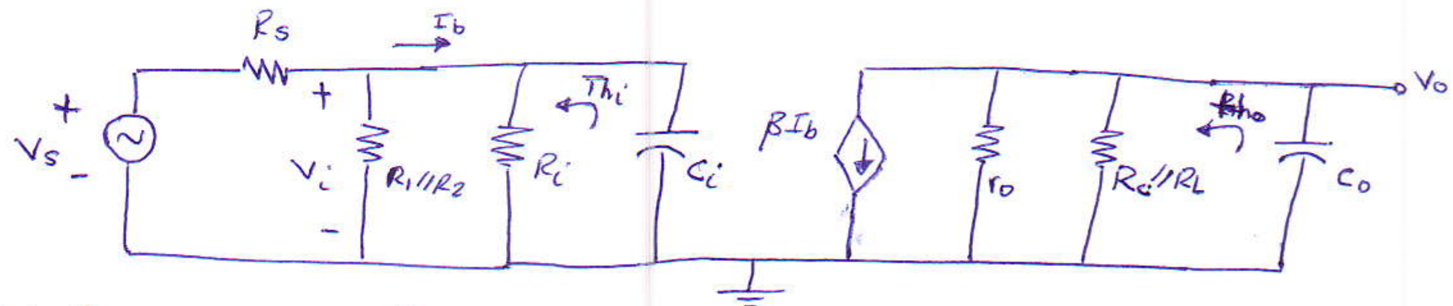


Fig (15): BJT network with capacitor that effect the high frequency Response



High-freq. ac equivalent for network above.

$$\boxed{C_i = C_{wi} + C_{be} + C_{Mi}}$$

$$\boxed{C_o = C_{wo} + C_{ce} + C_{Mo}}$$

$$\boxed{R_{thi} = R_s // R_1 // R_2 // R_i}$$

$$\boxed{R_{tho} = R_C // R_L // r_o}$$

to be continue

$$C_i = C_{w_i} + C_{be} + C_{M_i} = \boxed{C_{w_i} + C_{be} + (1 + |A_v|)\, C_{bc}}$$

At very high freq., the effect of C_i is to reduce the total impedance of the parallel combination of R_1, R_2, R_i and C_i. The result is a reduceed level of voltage across C_i, a reduction in I_b and a gain for the system.

$$\boxed{f_{H_o} = \frac{1}{2\pi R_{th_o} C_o}} \quad \text{and} \quad \boxed{f_{H_i} = \frac{1}{2\pi R_{th_i} C_i}}$$

$$C_o = C_{w_o} + C_{ce} + C_{M_o} = \boxed{C_{wo} + C_{ce} + \left(1 + \left|\frac{1}{A_v}\right|\right) C_{bc}}$$

for a large A_v: $\quad 1 \gg \frac{1}{A_v}$

we get:

$$\boxed{C_o \cong C_{wo} + C_{ce} + C_{bc}}$$

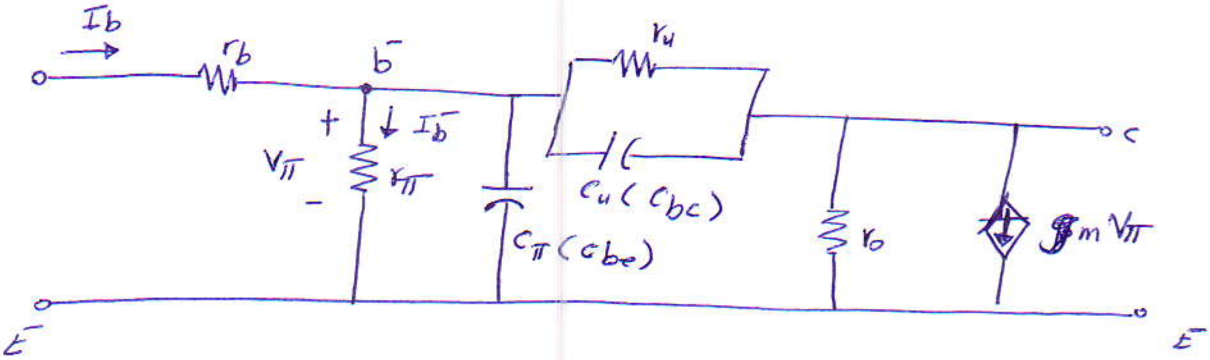
* (يوضع بنظر الإعتبار التردد الأقل من الترددات التي سوف تستخرج في السؤال حيث ان التردد الأقل هو الأكثر تأثيراً على الاستجابة).

* hfe or β Variation :

The variation of hfe (or β) with frequency will approach, with some degree of accuracy, the following relationship:

$$\boxed{h_{fe} = \frac{h_{fe\,mid}}{1 + J\left(\frac{f}{f_\beta}\right)}}$$

The fig(16) below will appear the variation Parameters which are appearing in the high freq. effect on the hfe or β



Fig(16): High freq. transistor small-signal ac equivalent circuit.

$$g_m v_\pi = g_m (I_{b'} r_\pi) = \frac{1}{r_e} (I_{b'} \beta r_e) = \boxed{\beta I_{b'}}$$

r_b: includes the base contact, base bulk and base spreading resistance levels

C_π is larger than C_u

r_π : is simply βr_e as introduced for the common emitter re model.

r_u: is a very large resistance and provides a feedback Path from the o/p to i/p cct in the equivalent model. (usually quite large $\gg \beta r_o$).

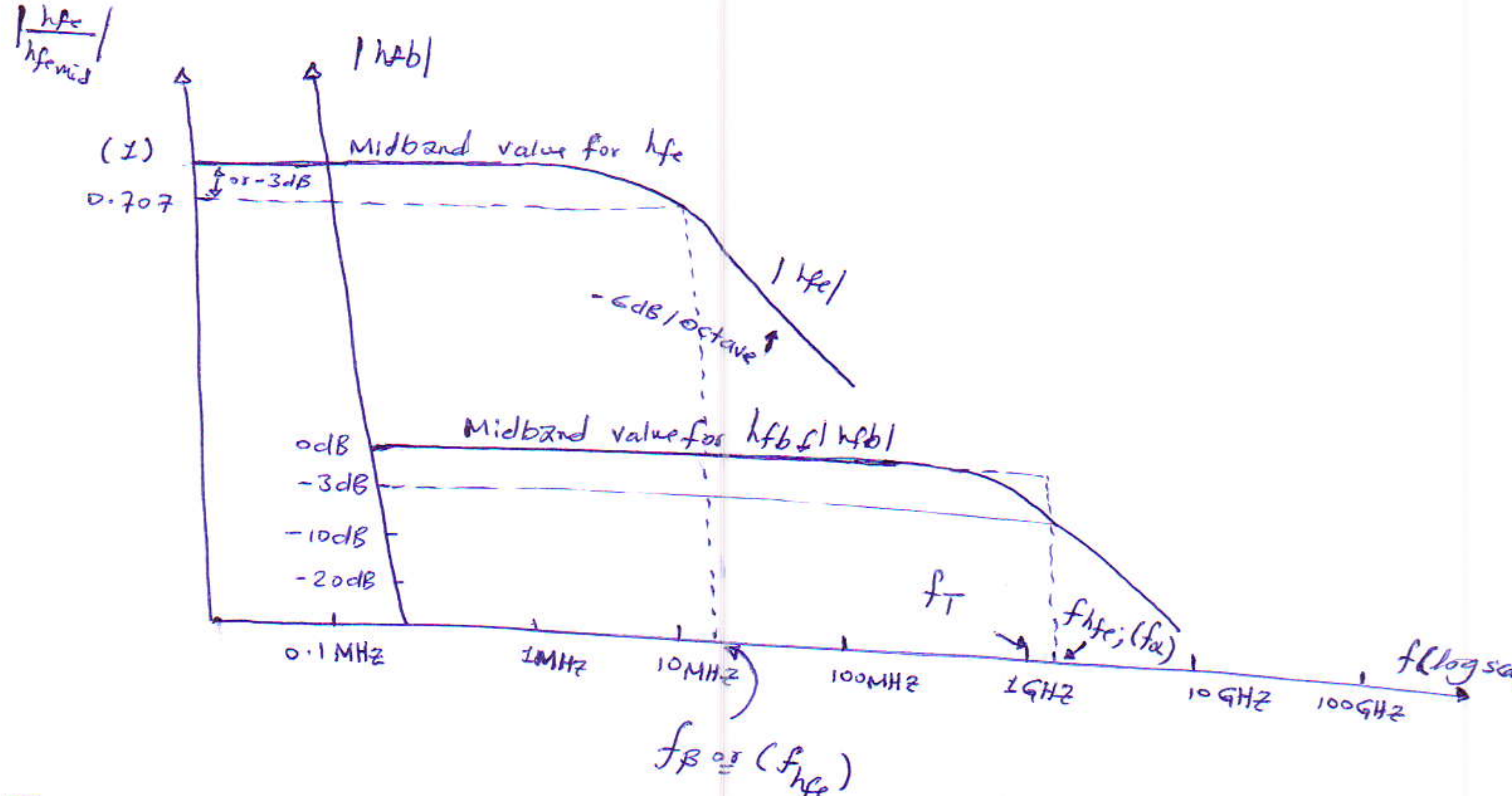
$r_\pi = \beta r_e = \boxed{h_{fe\,mid}\, r_e}$

f_β (sometimes appearing as h_{fe}) $= \boxed{\dfrac{1}{2\pi r_\pi (C_\pi + C_\mu)}}$

$\boxed{f_\beta = \dfrac{1}{h_{fe\,mid}} \dfrac{1}{2\pi r_e (C_\pi + C_\mu)}}$ and $\boxed{f_\beta \cong \dfrac{1}{2\pi \beta_{mid} r_e (C_\pi + C_\mu)}}$

* When we are comparing the h_{fe} values in the high freq. response with the h_{fb} (for common base configuration) or called (α). Note the small change in h_{fb} for the chosen freq. range and the CB configuration displays improved high-freq. chara. over the **CE** conf. and also the absence of the **Miller** effect cap. due to the noninverting characteristics of the CB config. as shown in fig(17):

(قيمة الكسب في CB موجبة لذلك فان قيم المتسعات لتأثير ميلر تصبح كبيرة جداً وهذا غير منطقي
لذلك تهمل تلك القيم ولا تظهر تأثير ميلر في حالة CB)



Fig(17): h_{fe} and h_{fb} versus frequency in the high-frequency region

The following equation Permits a direct conversion for determining f_β if f_α and α are specified

$$\boxed{f_\beta = f_\alpha (1-\alpha)}$$

عادة قيم الـ(α) وهي قيمة تكبير التيار عند استخدام CB تكون (0.99) وبالتالي تقريبا $\boxed{f_\beta = 0.01 f_\alpha}$

ويمكن ملاحظة هنا الامر من الشكل (17) في الصفحة السابقة

~.~.~.~.~.

A quantity called the gain-bandwidth Product is defined for the transistor by the condition

$$\left| \frac{h_{fe(mid)}}{1 + j\left(\frac{f}{f_\beta}\right)} \right| = 1$$

where $|h_{fe}|_{dB} = 20 \log_{10} \left| \frac{h_{fe(mid)}}{1 + j\left(\frac{f}{f_\beta}\right)} \right| = 20 \log_{10} 1 = 0\,dB$

$$\boxed{f_T \simeq h_{fe\,mid}\, f_\beta}$$

(gain-bandwidth Product)

f_β is approximate a bandwidth (BW) when we ignore a lower cutoff freq.

وهو قيمة عرض الحزمة تقريباً في حالة جعل الترانستور يعمل في حالة CB وكذلك يعني آخر تردد يعمل فيه الترانستور عندما يكون الكسب (واحد) 0dB $|h_{fe}| = 1$

or $\boxed{f_T = \beta_{mid}\, f_\beta}$ and $\boxed{f_\beta = \frac{f_T}{\beta_{mid}}}$

$$\Rightarrow f_T = \cancel{\beta_{mid}} \frac{1}{2\pi\, \cancel{\beta_{mid}}\, r_e (C_\pi + C_\mu)}$$

$$\therefore \boxed{f_T = \frac{1}{2\pi\, r_e (C_\pi + C_\mu)}}$$

Ex: For the common emitter - voltage divider with the Parameter as follow:

$R_s = 1k\Omega$, $R_1 = 40k\Omega$, $R_2 = 10k\Omega$, $R_E = 2k\Omega$, $R_C = 4k\Omega$, $R_L = 2.2k\Omega$

$C_s = 10\mu F$, $C_c = 1\mu F$, $C_E = 20\mu F$, $\beta = 100$, $r_o = \infty$, $V_{cc} = 20V$

with the adition of

$C_\pi\ (C_{be}) = 36PF$, $C_\mu\ (C_{bc}) = 4PF$, $C_{ce} = 1PF$, $C_{wi} = 6PF$ and $C_{wo} = 8PF$.

(a) Determine f_{Hi} and f_{Ho}

(b) Find f_β and f_T

(c) sketch the freq. response for the low and high freq. regions.

~.~.~.~.~.~.

Solution: (a)

$R_i = 1.32k\Omega$, $Av_{mid} = -90$ and $R_{thi} = R_s // R_1 // R_2 // R_i$

$= 1k // 40k // 10k // 1.32k \simeq 0.531k\Omega$

and $C_i = C_{wi} + C_{be} + (1 - A_v)\, C_{be}$

$= 6P + 36P + (1-(-90))\, 4p = 406PF$

$$f_{Hi} = \frac{1}{2\pi R_{thi}\, C_i} = \frac{1}{2\pi\,(0.531K)(406P)} = 738.24\,KHz$$

to be continue

(a)

$$R_{th_o} = R_C // R_L = 4k // 2.2k = 1.419\,k\Omega$$

$$C_o = C_{W_o} + C_{ce} + C_{M_o} = 8P + 1P + \left(1 - \frac{1}{-90}\right) 4P = 13.04\,PF$$

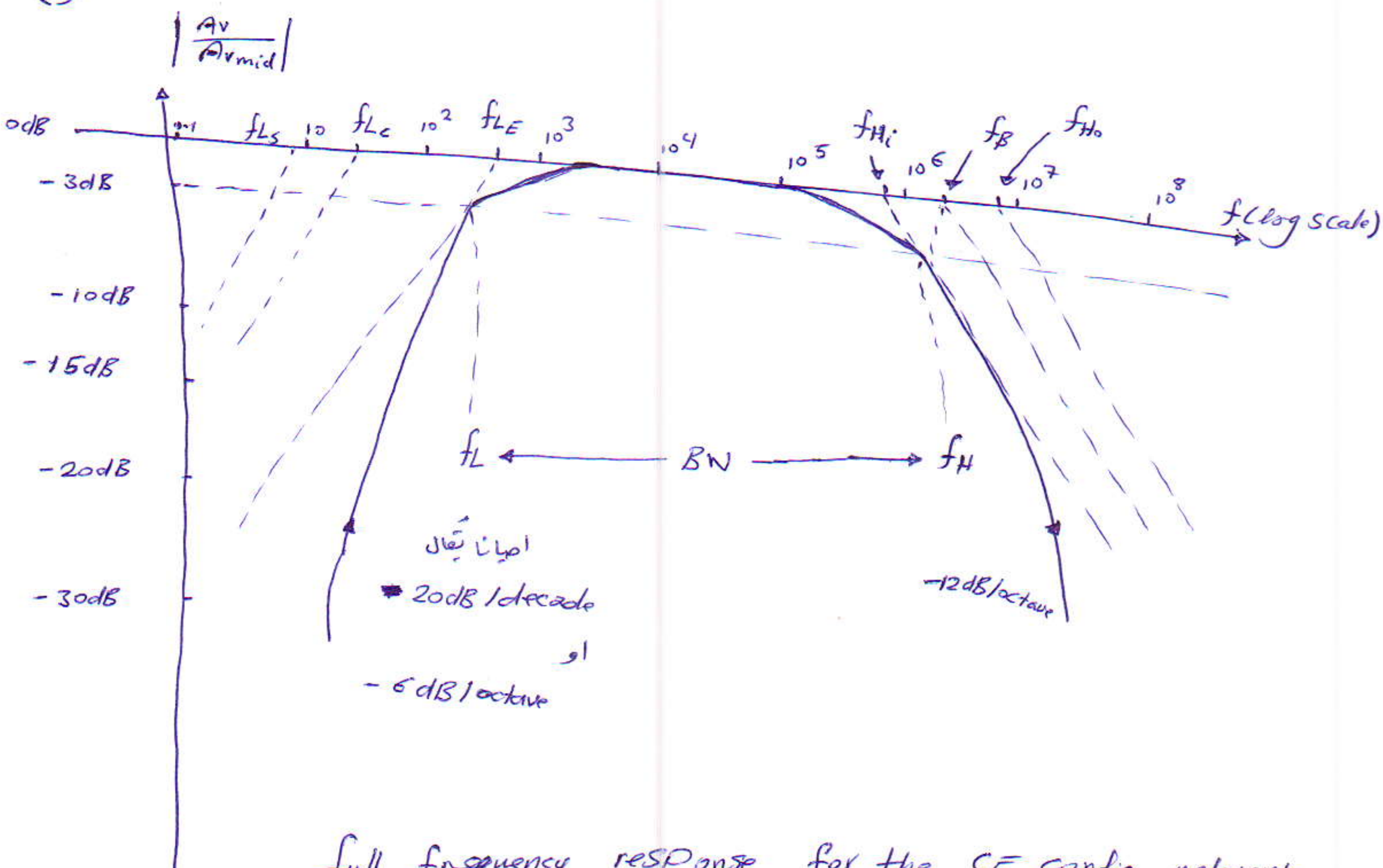
$$f_{H_o} = \frac{1}{2\pi R_{th_o} C_o} = \frac{1}{2\pi (1.419k)(13.04P)} = 8.6\,MHz$$

(b)

$$f_\beta = \frac{1}{2\pi \beta_{mid} r_e (C_{be} + C_{bc})} = \frac{1}{2\pi (100)(15.76\Omega)(36P + 4P)} = 2.52\,MHz$$

$$f_T = \beta_{mid} f_\beta = (100)(2.52M) = 252\,MHz$$

(c)



full frequency response for the CE config. network.

* High-Frequency Response - FET Amplifiers:

The analysis of the high-freq. response of the FET amplifier will proceed in a very similar manner to that encountered for the BJT amplifier as shown in fig (18).

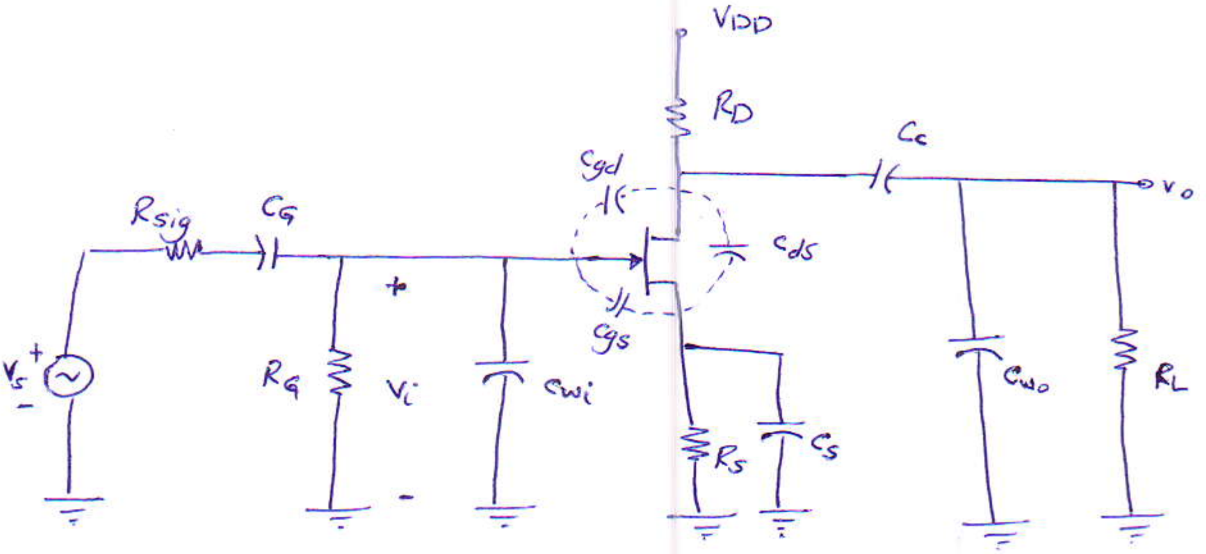


Fig (18): Capacitive elements that affect the high-freq. response of a JFET amplifier.

$$\boxed{f_{Hi} = \frac{1}{2\pi R_{thi} C_i}} \qquad \boxed{R_{thi} = R_{sig} // R_G}$$

$$\boxed{C_i = C_{wi} + C_{gs} + C_{Mi}} \qquad \boxed{C_{Mi} = (1 + |A_v|)\, C_{gd}}$$

and for output circuit

$$\boxed{f_{Ho} = \frac{1}{2\pi R_{tho} C_o}} \qquad \boxed{R_{tho} = R_D // R_L // r_d}$$

$$\boxed{C_o = C_{wo} + C_{ds} + C_{Mo}} \qquad \boxed{C_{Mo} = \left(1 + \left|\frac{1}{A_v}\right|\right) C_{gd}}$$

Ex: Determine the high cutoff frequency with the following Parameter:

$C_G = 0.01\,\mu F$, $C_C = 0.5\,\mu F$, $C_S = 2\,\mu F$, $R_{sig} = 10\,k\Omega$, $R_G = 1\,M\Omega$

$R_D = 4.7\,k\Omega$, $R_S = 1\,k\Omega$, $R_L = 2.2\,k\Omega$, $I_{DSS} = 8\,mA$, $V_P = -4$, $r_d = \infty\,\Omega$

$V_{DD} = 20V$, $C_{gd} = 2PF$, $C_{gs} = 4PF$, $C_{ds} = 0.5PF$, $C_{wi} = 5PF$, $C_{wo} = 6PF$

Solution:

$R_{thi} = R_{sig} // R_G = 10K // 1M = 9.9\,k\Omega$

$\boxed{A_v = -3}$ From Previous example

$C_i = C_{wi} + C_{gs} + (1 + |A_v|) C_{gd} = 5P + 4P + (1 + |-3|) 2P = 17PF$

$$f_{Hi} = \frac{1}{2\pi R_{thi} C_i} = \frac{1}{2\pi (9.9K)(17P)} = 945.67\,KHz$$

$R_{tho} = R_D // R_L$

$= 4.7K // 2.2k \cong 1.5\,k\Omega$

$C_o = C_{wo} + C_{ds} + C_{Mo} = 6P + 0.5P + (1 + |\frac{1}{-3}|) 2P = 9.17PF$

$$f_{Ho} = \frac{1}{2\pi (1.5k)(9.17P)} = 11.57\,MHz$$

* Multistage Frequency Effect:

when amplifier stages are cascaded to form a multistage amplifier, the dominant frequency response is determined by the responses of the individual stages. There are two cases to consider:

1. Each stage has a different lower cirtikal freq. and a different upper cutoff frequency.

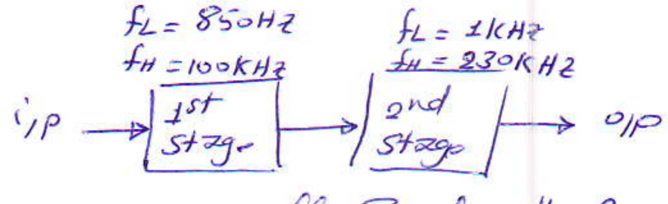
2. Each stage has the same lower cutoff freq. and the same upper cutoff frequency.

~.~.

* Different cutoff frequency: (Nonidentical Stages)

when the lower cutoff freq of each amplifier stage is different, the dominant f_L is equal to the highest freq. of stage. when the upper cutoff freq. of each amplifier is different, the dominant f_H is equal to the lowest freq. of stage.

Ex:



Determine the overall Bandwidth?

Solution:

f_L (dominant) $= 1KHz$

f_H (dominant) $= 100KHz$ and $BW = f_H - f_L$

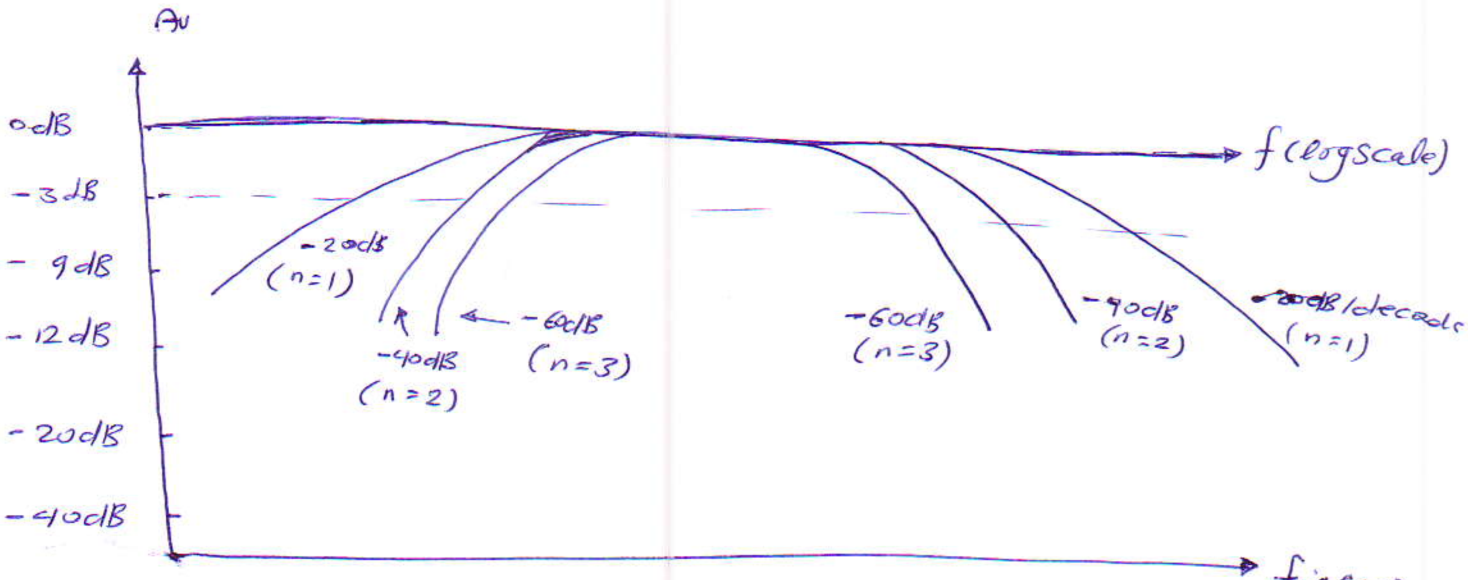
$= 100K - 1K = 99KHz$

* Equal cutoff frequencies and Gain: (identical stages)

$f_{L_1} = f_{L_2} = f_{L_n}$; $f_{H_1} = f_{H_2} = f_{H_n}$, $A_{v_1} = A_{v_2} = A_{v_n}$

$$\boxed{A_{v(\text{total or overall})} = A_{v_T} = (A_m)^n}$$ n: number of stages

* For two identical stages cascade, the drop-off rate in the high and low frequency regions has increased to −12dB/octave or −40 dB/decade. And for three stages increased to −18dB/octave or −60 dB/decade as shown in fig below:



fig(19)

Effect of an increased number of stages on the cutoff frequencies and the Bandwidth.

$$\frac{Av_{low}}{Av_{mid}}(\text{overall}) = \left(\frac{Av_{low}}{Av_{mid}}\right)^n = \frac{1}{\left(1 - j\frac{f_L}{f}\right)^n}$$

and the result equal to:

$$\boxed{f_L^- = \frac{f_L}{\sqrt{2^{1/n} - 1}}}$$

In a similar manner, it can be shown that for the high freq. region

$$\boxed{f_H^- = \left(\sqrt{(2^{1/n} - 1)}\right) f_H}$$

(يقل ال BW كلما زادت عدد ال stage ولكن ال gain يزداد وال BW لا يمكن ان يصبح صفر مطلقاً")

n	$\sqrt{2^{1/n} - 1}$
2	0.64
3	0.51
4	0.43
5	0.39

Ex: $Av_{(overall)} = 4900$ for a multistage amplifier, find the number of stages, if the stage are identical and Av for each stage is equal 70.

Solution:

$$Av_{(overall)} = (A_v)^n$$

$$(4900) = (70)^n \Rightarrow \sqrt[n]{4900} = 70$$

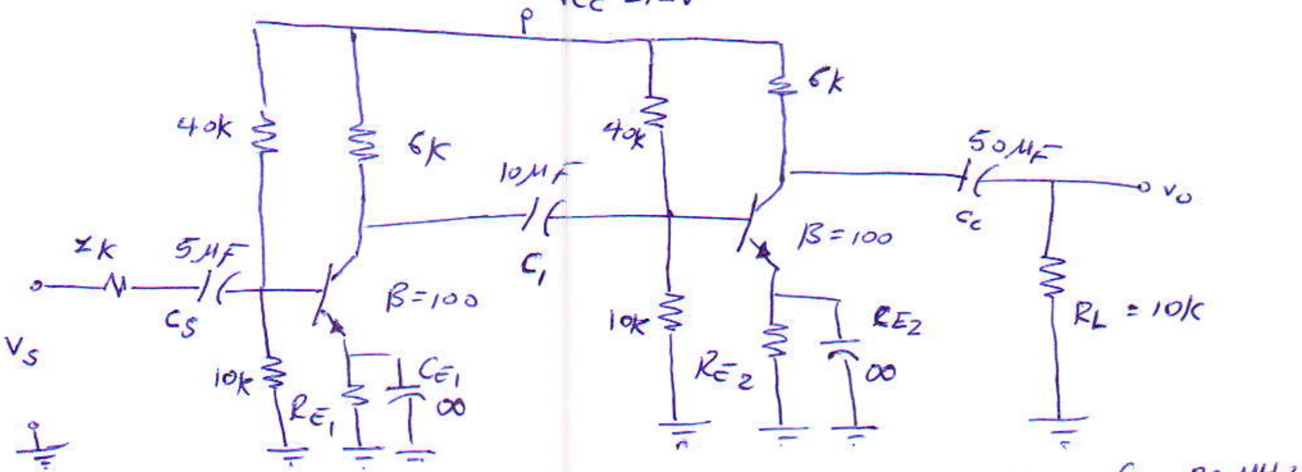
$$\Rightarrow n = \frac{\ln 4900}{\ln 70} \quad \therefore \boxed{n = 2}$$

∴ identical stage

لان النتيجة Integer

Ex: For the circuit shown Calculate:

1. R_{E_1} and R_{E_2} to obtain the emitter current 0.5mA for each transistor
2. The Band width
3. The gain at 1 Hz, 1 kHz, 10kHz, 1 MHz
4. How can you make the f_H (dominant) is equal to 100kHz

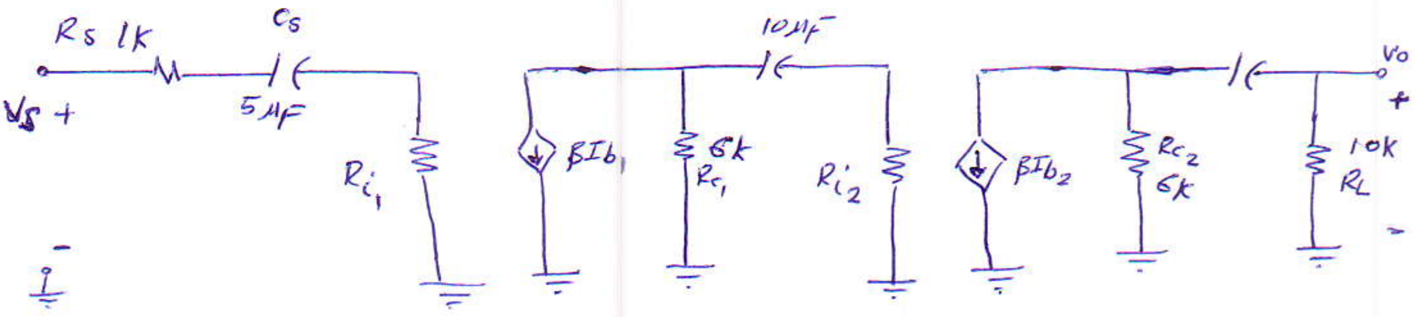


$C_{bc} = 4PF$; $f_T = 200MHz$

Solution:

* Frequency Response at low freq: take the effect C_s, C_c and C_1 and ignore the effect of the (C_{E_1} and C_{E_2})

عشان تكبير على المستوى (∞)
فا نهائي D.C تكون (O.C)
في ال (A.C) تكون (S.C)



$\boxed{Ri_1 = R_1 // R_2 // \beta re}$

$\boxed{Ri_2 = R_1 // R_2 // \beta re}$

to be continue

① For approximation Solution

$$V_B = \frac{12 * 10k}{10k + 40k} = \boxed{2.4V} \quad \text{and} \quad V_E = V_B - V_{BE} = 2.4 - 0.7 = \boxed{1.7V}$$

$$R_{E_1} = R_{E_2} = \frac{V_E}{I_E} = \frac{1.7V}{0.5mA} = \boxed{3.4k\Omega}$$

② $B.w = F_H - F_L$

$$h_{ie_1} = h_{ie_2} = \beta r_e = 100 * \frac{26mV}{0.5mA} = \boxed{5.2k\Omega} \quad \boxed{r_e = 52\Omega}$$

* Take the effect of C_s:

$$f_{L_S} = \frac{1}{2\pi R_{th_S} C_S} \quad ; \quad R_{th_S} = R_i + R_S = R_S + (R_1 // R_2 // \beta r_e)$$

$$= 1k + (10k // 40k // 5.2k) = \boxed{4.15k}$$

$$= \frac{1}{2\pi (4.15k)(5\mu F)} = \boxed{7.67Hz} \quad (\text{dominant freq.})$$

* Take the effect of C_1:

$$f_{L_{C_1}} = \frac{1}{2\pi R_{th_1} C_1} \quad ; \quad R_{th_1} = R_{C_1} + (R_{1_2} // R_{2_2} // h_{ie_2})$$

$$= 6k + (10k // 40k // 5.2k) = \boxed{9.15k\Omega}$$

$$f_{L_{C_1}} = \frac{1}{2\pi R_{th_1} C_1} = \frac{1}{2\pi (9.15k)(10\mu F)} = \boxed{1.7Hz}$$

* Take the effect of C_c:

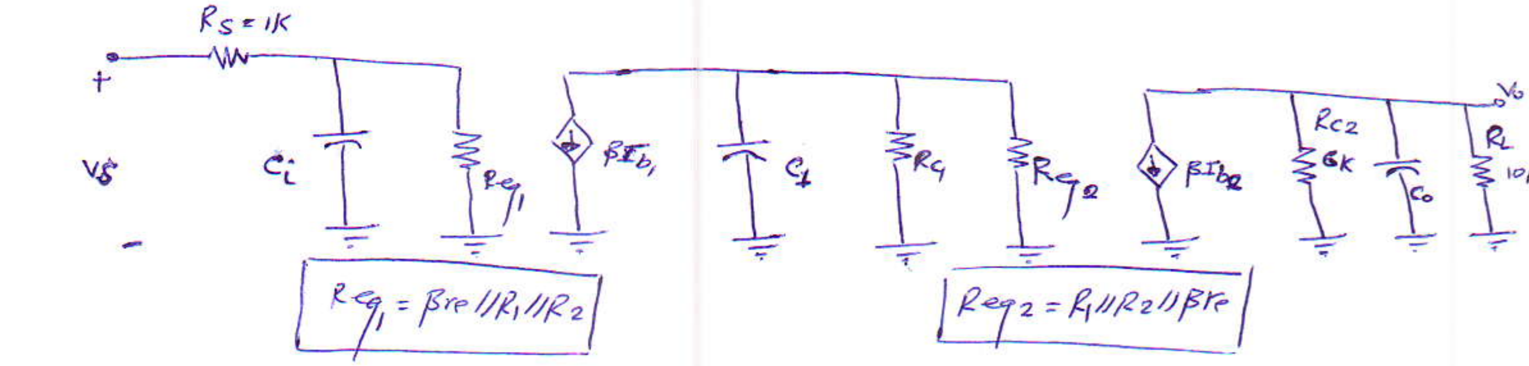
$$f_{L_{C_c}} = \frac{1}{2\pi R_{th_c} C_c} \quad ; \quad R_{th_c} = R_{C_2} + R_L = 6k + 10k = \boxed{16K}$$

$$= \frac{1}{2\pi (16K)(50\mu F)} = \boxed{0.199Hz}$$

(~~[illegible]~~)

to be continue.

* Frequency Response at high frequency (Parasitic Capacitances):



$C_i = C_{wi} + C_{be_1} + C_{bc_1}(1 + |A_{v_1}|)$

$C_x = C_{wx} + C_{ce_x} + C_{bc_1}\left(1 + \left|\frac{1}{A_{v_1}}\right|\right) + C_{be_2} + C_{bc_2}(1 + |A_{v2}|)$

$C_o = C_{wo} + C_{ce_2} + C_{bc_2}\left(1 + \left|\frac{1}{A_{v_2}}\right|\right)$

* Take the effect of C_i:

$f_{Hi} = \frac{1}{2\pi R_{thi} C_i}$; $R_{thi} = R_S // R_{eq_1} = 1k // (40//10)k // 5.2K$

$= \boxed{0.76k\,\Omega}$

* عندما لا يعطي قيمة (cw) في السؤال فاننا نهمل تأثيرها
وكذلك قيمة Cce

$C_i = \cancel{C_{wi}}^{\,0} + C_{be_1} + C_{Mi}$

$C_{Mi} = C_{bc_1}(1 + |A_{v_1}|)$ $\qquad C_{bc} = 4PF$

$= 4P(1 + |A_{v_1}|)$

$A_{v_1} = \frac{-R_L'}{r_e}$; $R_L' = \beta r_{e_2} // R_1 // R_2 // R_{C_1} = (5.2k) // 10k // 40k // 6k$

$= \frac{-2.066}{52} \cong \boxed{-40}$

to be continue

$\Rightarrow C_{Mi} = 4P(1+|-40|) = 164PF$

$$f_T = \frac{1}{2\pi r_e (C_{be_1} + C_{bc_1})} \Rightarrow 200MHz = \frac{1}{2\pi(52)(4PF + C_{be_1})}$$

$\Rightarrow (4PF + C_{be_1}) \cong 15PF \quad \therefore C_{be_1} = \boxed{11PF} = C_{be_2}$

$$\therefore f_{Hi} = \frac{1}{2\pi[(11P)+(164P)](0.76k)} = \boxed{1.197\,MHz}$$

* Take the effect of C_1:

$$f_{HC_1} = \frac{1}{2\pi R_{th_1} C_1} \; ; \quad R_{th_1} = R_{C_1} // R_1 // R_2 // \beta r_e$$

$$= 6k // 10k // 40k // 5.2k = \boxed{2.066\,k\Omega}$$

$$C_1 = \cancel{C_{w_1}}^{0} + \cancel{C_{ce_1}}^{0} + \underbrace{C_{bc_1}\left(1+\left|\frac{1}{A_{v_1}}\right|\right)}_{C_{Mo}} + C_{be_2} + \underbrace{C_{bc_2}(1+|A_{v2}|)}_{C_{Mi}}$$

$$A_{v2} = \frac{-R_L'}{r_e} = \frac{-6k//10k}{52} \cong \boxed{-72}$$

$$\Rightarrow C_1 = 11P + 4P\left(1+\left|\frac{1}{-40}\right|\right) + 4P(1+|-72|) \cong \boxed{307PF}$$

$$\therefore f_{HC_1} = \frac{1}{2\pi(307P)(2.066K)} = \boxed{0.251\,MHz} \text{ (dominant freq.)}$$

* Take the effect of C_o:

$$f_{Ho} = \frac{1}{2\pi R_{tho} C_o} \; ; \quad R_{tho} = R_{C_2} // R_L = \boxed{3.75\,k\Omega}$$

$$C_o = \cancel{C_{wo}}^{0} + \cancel{C_{ce_2}}^{0} + C_{bc_2}\left(1+\left|\frac{1}{A_{v2}}\right|\right)$$

to be continue.

$$C_o = 4P\left(1 + \left|\frac{1}{-72}\right|\right) = \boxed{4.05PF}$$

$$\Rightarrow f_{H_o} = \frac{1}{2\pi(4.05P)(3.75K)} = \boxed{10.484\,MHZ}$$

$$\therefore BW = f_H^- - f_L^- = 0.251M - 7.67 \simeq \boxed{0.251\,MHZ}$$

(3)

$$A_{vT}\,(\text{midband}) = A_{v1} * A_{v2} = (-40)(-72) = \boxed{2880}$$

* at 1 HZ (low freq.)

$$\frac{A_v}{A_{vmid}} = \frac{1}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}} \Rightarrow A_v = \frac{2880}{\sqrt{1 + \left(\frac{7.67}{1}\right)^2}} \simeq \boxed{372}$$

* at 1 KHz and 10KHz the gain is equal to gain midband

* at 1 MHZ (high freq.)

$$\frac{A_v}{A_{vmid}} = \frac{1}{\sqrt{1 + \left(\frac{f}{f_H}\right)^2}} \Rightarrow A_v = \frac{2880}{\sqrt{1 + \left(\frac{1M}{0.251M}\right)^2}} \simeq \boxed{701}$$

(4) $$f_{HC_1} = \frac{1}{2\pi C_1 R_{th_1}} \quad ; \quad \boxed{R_{th_1} = 2.066K\Omega}$$

$$100KHZ = \frac{1}{2\pi(2.066k)(307P + \bar{C})} \Rightarrow 307P + \bar{C} \simeq 770P$$

$$\therefore \boxed{\bar{C} = 463PF}$$

وهي قيمة السعة التي يجب ان تضاف
داخلياً اثناء التصنيع لتجعل f_H
يكون قيمته 100KHZ

H.W: For the common emitter amplifier circuit with the following Parameter:

$C_{bc} = 2PF$; $C_{be} = 100PF$; $C_{ce} = 5PF$ and $R_1 = 40k\Omega$, $R_2 = 10k\Omega$, $R_S = 400\Omega$, $R_C = 3k\Omega$, $R_L = 6k\Omega$, $R_E = 0.5k\Omega$, $C_S = 1\mu F$, $C_C = 1.8\mu F$ and $C_E = 10\mu F$, $\beta = 100$, $V_{CC} = 12V$

Assume the wiring capacitors at i/p is 4PF and at o/p is 6PF

1- A_{Vmid} and f_L

2- f_H and Bandwidth

3- Sketch the frequency Response using Bode Plot

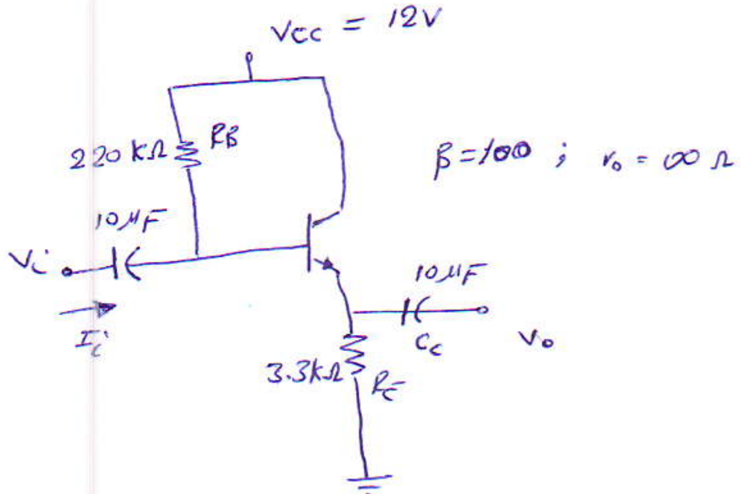
4- Calculate the voltage gain at 20Hz, 10KHz and 5MHz

5- Calculate the frequency at which the gain drops to 60% of its maximum value

6- If we add another capacitor $\bar{C}$ Parallel with C_S, is the BW will effect? Explain (Assume $\bar{C} = 1\mu F$)

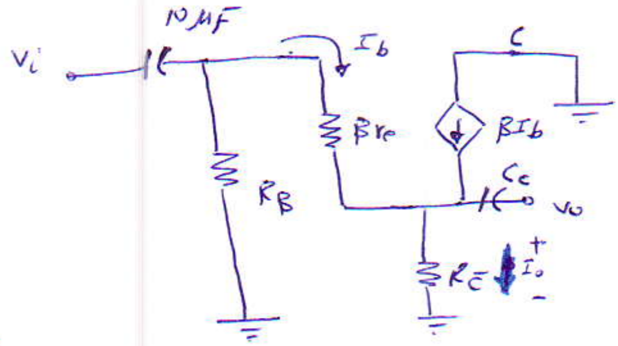
Ex: For the emitter follower Network below Determine

1. The gain at midband frequency.
2. Lower cutoff frequencies.



Solution :-

At first, we obtain the ac equivalent circuit at low frequency



1.

$V_o = I_o R_E$

$= (1+\beta) I_b R_E$

$I_b = \dfrac{v_i}{Z_b} = \dfrac{v_i}{\beta r_e + (1+\beta) R_E}$

$\therefore \dfrac{v_o}{v_i} = A_v = \dfrac{(1+\beta)R_E}{\beta r_e + (1+\beta)R_E} \simeq \dfrac{\cancel{\beta} R_E}{\cancel{\beta}(r_e + R_E)} = \boxed{\dfrac{R_E}{r_e + R_E}}$

to find r_e :

$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0 \Rightarrow V_{CC} - I_B R_B - V_{BE} - (I_B + \beta I_B) R_E = 0$

$\Rightarrow I_B = \dfrac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_E} = \dfrac{12 - 0.7}{220k + (1+100)\, 3.3k} = \boxed{20.42\, \mu A}$

to be continue.

$$I_E = (1+\beta) I_B = (1+100)\, 20.42\mu = \boxed{2.062 mA}$$

$$\therefore r_e = \frac{26mV}{20.062mA} = 12.61\,\Omega$$

$$\Rightarrow A_v = \frac{3.3k}{3.3k + 12.61} = \boxed{0.996 \simeq 1}$$

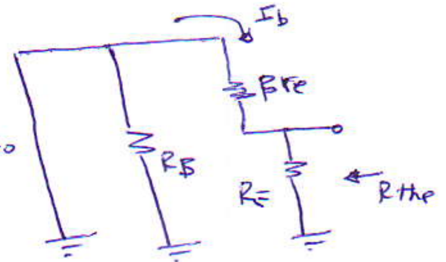
(2)

$$f_{Ls} = \frac{1}{2\pi R_{ths} C_s} \quad ; \quad R_{ths} = R_B // Z_b$$
$$= \boxed{R_B // [\beta r_e + (1+\beta) R_E]}$$

$$f_{Lc} = \frac{1}{2\pi R_{the} C_c} \quad ; \quad \boxed{R_{the} = R_E // r_e}$$

ومن ثم نعوض بالقيم ونجد قيمة f_{Ls} و f_{Lc} ولكن للتوضيح الآن نفصل كيف تم احتساب R_{the}

حيث نجعل فولتية الإدخال تساوي صفر (short cct) $V_i=0$ يعني أن قيمة R_B تم الغائها

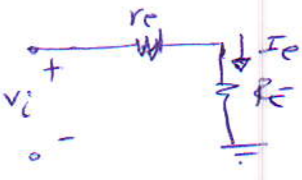


$$I_e = (1+\beta) I_b \quad ; \quad I_b = \frac{v_i}{Z_b}$$

$$\Rightarrow \left[I_b = \frac{v_i}{h_{ie} + (1+\beta) R_E} \right] \quad * (1+\beta) \text{ كلا الطرفين}$$

$$\underbrace{(1+\beta) I_b}_{I_e} = \frac{v_i (1+\beta)}{\beta r_e + (1+\beta) R_E} \Rightarrow I_e = \frac{v_i}{\frac{\beta r_e}{1+\beta} + R_E} = \frac{v_i}{r_e + R_E}$$

يعني ذلك أن قيمة التيار I_e هي عبارة عن فولتية v_i على مقاومتين على التوالي $(r_e + R_E)$ ولكن بجعل قيمة $V_i=0$ (short cct) تصبح قيمة المقاومة المكافئة هي $\boxed{R_E // r_e}$

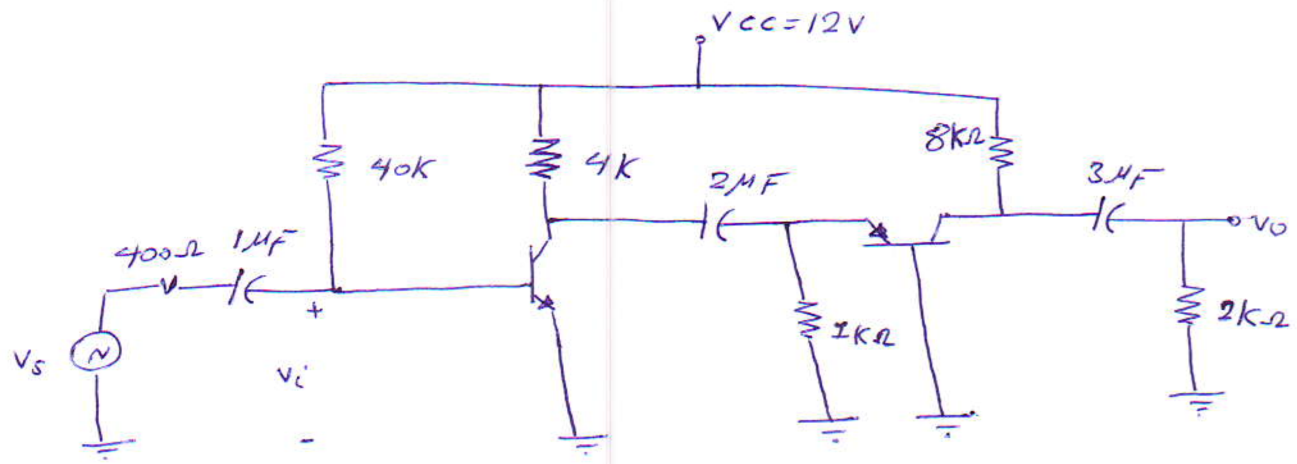


H.w: For the Cascode amplifier shown in figure below:

1- Calculate midband voltage gain, f_L and f_H : Assuming that f_H is due to the stray Capacitance of the C.E Stage

2- Sketch the Bode Plot response

3- what is the advantage of this Connection



$C_{be} = 200PF$

$C_{bc} = C_{ce} = 5PF$

$h_{ie} = 2k\Omega$

$h_{fe} = 100$

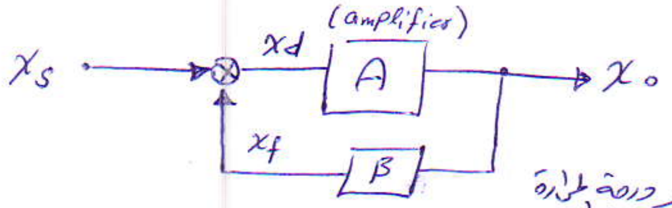
Feedback Amplifier:

is one in which a fraction of the amplifier output is fed back to the inputs to control the output and consist of two parts an amplifier and a F.B connection.

x_s: external signal

x_o: output signal

x_f: F.B signal



يتأثر الكسب للمكبر بتغيير درجة الحرارة
وتغيير فولتية القدرة المجهزة وتقادم عمر المكونات
وتغيير معالم الترانستور عند استبداله لذلك
نلجأ الى التغذية العكسية للحصول على استقرارية
افضل

A_f: close loop gain (gain with F.B)

x_d: Difference Signal $\Rightarrow x_d = x_s \mp x_f$

A: gain of the basic amplifier (open loop gain)

β: F.B ratio , $\beta = \frac{x_f}{x_o}$

1- If x_f is inphase with x_s: +ve F.B , $x_d = x_s + x_f$ and this is Principle oscillators.

2- If x_f is out of Phase with x_s: -ve F.B , then $x_d = x_s - x_f$

Effect of -ve F.B:

① Reduce the gain ; ② Extend the BW

③ Increase gain stability against impedances Parameters variations.

④ Reduce Noise and Nonlinear distortion

⑤ control the I/P and O/P impedances

to be continue.

For the F.B. amplifier

$$A = \frac{x_o}{x_i} \quad ; \quad x_i = x_d \;, \Rightarrow x_i = x_s - x_f$$

$$\therefore x_o = A x_i \quad \therefore x_o = A(x_s - x_f) \text{ ---- } ①$$

$x_f = \beta x_o$ --- ② subs. ① in ② and we get:

$$x_o = A(x_s - \beta x_o) = A x_s - A\beta x_o \Rightarrow \boxed{\frac{x_o}{x_s} = \frac{A}{1 + A\beta} = A_f}$$

the equation above show that the gain with F.B. reduces by the factor $\boxed{(1+A\beta)}$

Effect of Negative F.B. on amplifier:

① Reduction in frequency distortion:

when $\beta A \gg 1 \Rightarrow$ gain with feedback is $A_f \simeq \frac{1}{\beta}$ (Purely Resistive)

β: هي عبارة عن قيم مقاومات ولا تعتمد قيمتها على تردد الإدخال لذلك لا تتأثر بالتردد الداخل
بينما في المكبر الاعتيادي من غير F.B فان الكسب (A) يتأثر بالتردد الداخل بصوره
مباشرة وبالتالي فان -ve F.B يقلل من التشوية بسبب زيادة التردد او نقصانه

② Reduction in Noise and Nonlinear Distortion :

* Nonlinear Distortion :

this distortion is due to the non-linear relation between i/p voltage and current in transistor

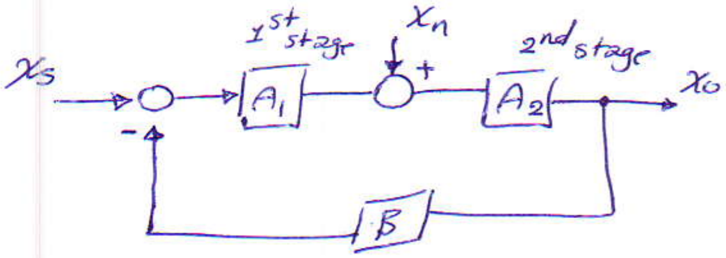
Assuming distortion without F.B. is "D", with F.B. it will be

$$\boxed{D_f = \frac{D}{1+A\beta}}$$

حيث يقل التشويه اللاخطي إذ أنه
يُقسم على $(1+A\beta)$

* Noise :

-ve F.B reduces the internal noise, consider the system shown in fig. below, where x_n is an internal noise (generated by A_1)



without F.B.

$$x_o = (x_s A_1 + x_n) A_2$$

$$= x_s A_1 A_2 + x_n A_2$$

with F.B

$$x_o = \frac{A_1 A_2}{1+A\beta} x_s + \frac{A_2}{1+A\beta} x_n$$

نلاحظ أن قيمة الضوضاء (noise)
قد قسمت على $(1+A\beta)$ لذلك
قلت بنسبة كبيرة
أكبر من الكسب الأصلي للمكبر

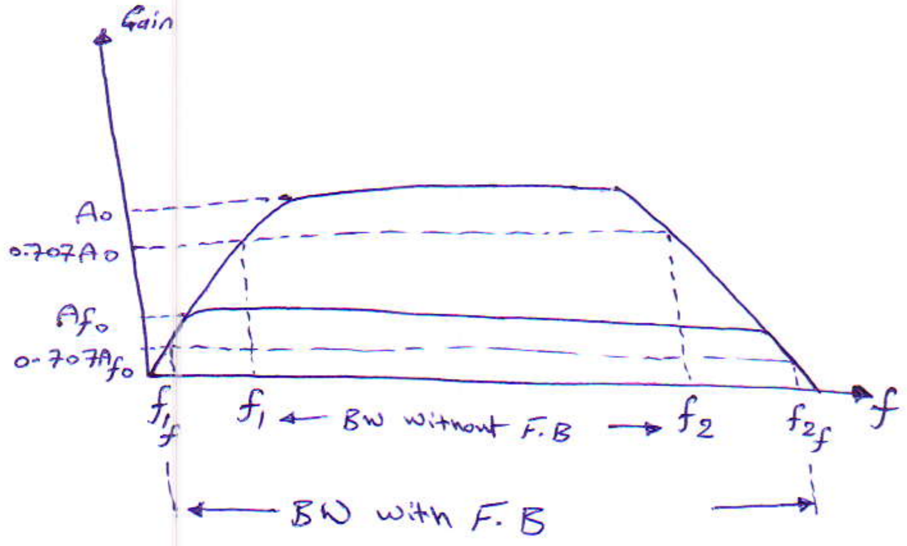
$\therefore$ -ve F.B reduce the effect of internal noise.

3 Effect of -ve feedback on Gain and Bandwidth:

The overall gain with -ve F.B

$$A_f = \frac{A}{1+A\beta} \simeq \frac{A}{A\beta} \simeq \frac{1}{\beta} \quad \text{for } A\beta >> 1$$

عملياً يتأثر كسب المكبر بالمتسعات المربوطة على التوالي في الترانسستور في حالة الترددات الواطئة اما في الترددات العالية فان الكسب يتأثر بالمتسعات الداخلية (Parasitic). اما في حالة ربط التغذية العكسية فان الكسب تقريباً يساوي $\frac{1}{\beta}$ لذلك فان قيمة β لا تتأثر بالمتسعات مطلقاً لانها قيمة مقاومات عادةً لذلك لا يقل الكسب مباشرةً عند تغيير قيمة الـ A ولكن يعتبر تغيير كبير لقيمة الـ A لذلك يزداد الـ BW وكما موضح في المرسم ادناه



The -ve F.B. extends the B.W of the amplifier were it reduces f_L and increases f_H resulting increasing the B.W of the amp.

حيث بالإمكان اثبات هذه الحقيقة رياضياً

$$A_{f_L} = \frac{A_m}{1 - j\frac{f_L}{f}} \quad \text{--- (1)}$$

when the -ve F.B is applied the gain will be reduced to:

$$A_f = \frac{A}{1+A\beta} \quad \text{--- (2)}$$

substituting (1) in (2) and we get: ينتج

$$\Rightarrow (A_{Lf})_F = \frac{\frac{A_m}{1-\frac{f_L}{f}}}{1+\left(\frac{A\beta}{1-j\frac{f_L}{f}}\right)} = \frac{A_m}{1-j\frac{f_L}{f}+A\beta} = \frac{A_m}{\frac{f(1+A\beta)-jf_L}{f}}$$

تقسيم البسط والمقام على $(1+A\beta)$

$$\Rightarrow (A_{Lf})_F = \frac{\boxed{\frac{A_m}{1+A\beta}}}{1-j\frac{f_L}{f\,\boxed{(1+A\beta)}}} = \frac{A_{mF}}{1-j\frac{(f_L)_F}{f}}$$

← F.B gain

← F.B f_L

$$\therefore \boxed{(f_L)_F = \frac{f_L}{1+A\beta}}$$ and in the same way we can show that

$$\boxed{(f_H)_F = f_H(1+A\beta)}$$ وبالتالي تقلّ قيمة f_L وتزداد قيمة f_H لذلك ازدادت الـ BW

④ Gain stability with FeedBack:

$$A_f = \frac{A}{1+A\beta}$$

$$\Rightarrow \left|\frac{dA_f}{A_f}\right| = \frac{1}{|1+A\beta|}\left|\frac{dA}{A}\right|$$

where $A\beta \gg 1$

$$\Rightarrow \left|\frac{dA_f}{A_f}\right| \simeq \left|\frac{1}{A\beta}\right|\left|\frac{dA_f}{A}\right|$$

في حالة ربط النظام بالتغذية العكسية فانه تغيير بالكسب لا يؤثر مباشرةً على الكسب الكلي ~~بصورة~~ كبيرة لذلك تزداد استقرارية الكسب وبالتالي فانه اي تغيير بسيط في درجة الحرارة او قيمة المكونات فانه لا يؤثر على استقرارية الكسب

حيث ان قيمة تغيير كسب التغذية العكسية تم تقليلها بمعامل $\left|\frac{1}{A\beta}\right|$ بينما الكسب من دون التغذية العكسية يتغير مباشرةً $\left|\frac{dA}{A}\right|$

Ex: If an amplifier gain of -1000 and F.B of $\beta = -0.1$ has a gain change of 20% due to temperature, calculate the change in gain of the F.B amplifier.

Solution:

$$\left|\frac{dA_f}{A_f}\right| \simeq \left|\frac{1}{A\beta}\right| \left|\frac{dA}{A}\right| = \left|\frac{1}{(-0.1)(1000)}\right| * \left|\frac{20}{100}\right| = 0.2\ \%$$

نلاحظ ان نسبة الاستقرارية للكسب في حالة F.B أحسن مئة مرة من الكسب الاصلي عند عدم ربط ال F.B

(5) Effect of -ve F.B. on the I/P and O/P impedances:

This effect depends on the F.B. signal is sampled and added to the input, i.e depend on the "topology"

For series input connection, the I/P impedance increase and for shunt connection the input impedance decrease, the same effect is for the output impedance. as shown in table below:

Parameter	Voltage series	Voltage shunt	Current series	Current shunt
I/P impedance	Increase	decrease	increase	decrease
O/P impedance	decrease	decrease	increase	increase

Effect of -ve F.B. on I/P and O/P impedance

دراسة الخصائص الهندسية

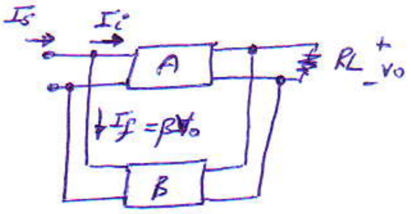
* F.B Connection Types (Topologies):

1. Voltage series F.B.
2. Voltage shunt F.B.
3. Current series F.B.
4. current shunt F.B

إعتماداً على ربط الإخراج نام فولتية او تيار
الإخراج يسوق دائرة التغذية العكسية
لجعل الإدخال يبسط سيطرة دقيقة على
قيمة الإخراج

~ . ~ . ~ . ~ .

① Voltage shunt:

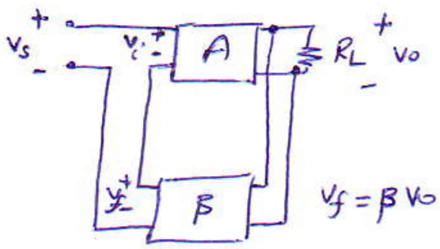


(transresistance amplifier)

يستخدم في ال digital ameter

مقاومة إدخال وإخراج قليلة

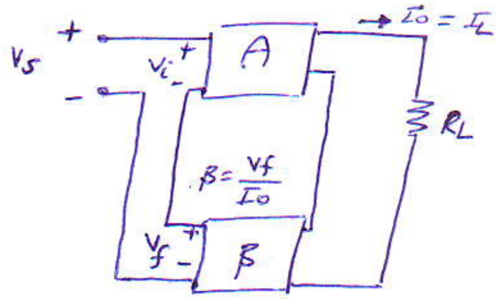
② Voltage series:



(voltage amplifier)

with Z_i is increased and o/p (Z_o) is decreased

③ Current series:



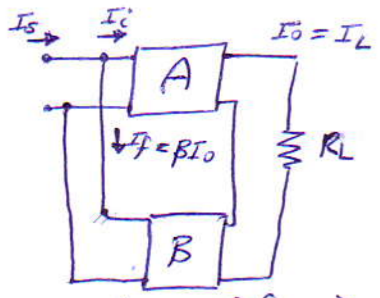
(transconductance amplifier)

I/p and o/p impedances are increased

يصلح لصناعة ال Digital voltmeter والذي

تكون مقاومة اخراجه ب MΩ

④ current shunt:



(current amplifier)

with Z_i is decreased and Z_o is increased

Procedures summary of analysis F.B. amplifier

Topology / characteristics	Voltage series	Voltage Shunt	Current Series	current shunt
1- To find i/p loop	set $V_o = 0$	$V_o=0$	$I_o = 0$	$I_o = 0$
2- To find o/p loop	set $I_i = 0$	$V_i = 0$	$I_i = 0$	$V_i = 0$
3- Signal Source	Thevinen	Norton	Thevinen	Norton
4- $\beta = \frac{x_f}{x_o}$	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
5- $A = \frac{x_o}{x_i}$	$A_V = \frac{V_o}{V_i}$	$R_M = \frac{V_o}{I_i}$	$G_M = \frac{I_o}{V_i}$	$A_i = \frac{I_o}{I_i}$
6- $D = 1 + A\beta$	$1+\beta A_V$	$1+\beta R_M$	$1+\beta G_M$	$1+\beta A_i$
7- A_f	$\frac{A_V}{D}$	$\frac{R_M}{D}$	$\frac{G_M}{D}$	$\frac{A_i}{D}$
8- R_{if}	$R_i \cdot D$	$\frac{R_i}{D}$	$R_i \cdot D$	$\frac{R_i}{D}$
9- R_{of}	$\frac{R_o}{D}$	$\frac{R_o}{D}$	$R_o \cdot D$	$R_o D$

Method Analysis of F.B. amplifier:

a- To find the I/P circuit:

ناخذ تأثير الإدخال بجعل الإخراج يساوي صفر، الإخراج اما تيار او فولتية

1- Set the output voltage ($V_o = 0$) short o/p (for voltage sampling).

2- Set the output current ($I_o = 0$) open o/p (for current sampling)

b- To find the o/p circuit:

ناخذ تأثير الإخراج بجعل الإدخال صفر، الإدخال اما توازي او توالي

1- Set $V_i = 0$ for shunt comparison (short circuit to i/p).

2- Set $I_i = 0$ for series comparison (open circuit to i/p).

To complete the analysis: follow the steps below:

1- Identify the F.B. Topology

2- Draw the basic amplifier circuit without F.B.

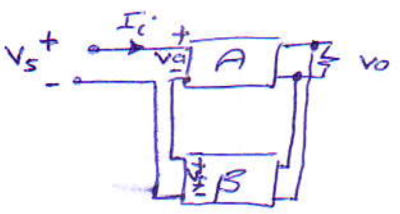
3- Replace each active device by proper model.

~ . ~ . ~ . ~ .

Ex: Prove that $Z_{if} = Z_i(1+\beta A)$ for the voltage series F.B connection?

Solution:

$V_s = V_a + V_f$



$V_f = \beta V_o$ and $V_o = A V_a$

$\Rightarrow V_s = V_a + \beta V_o = V_a + A\beta V_a$

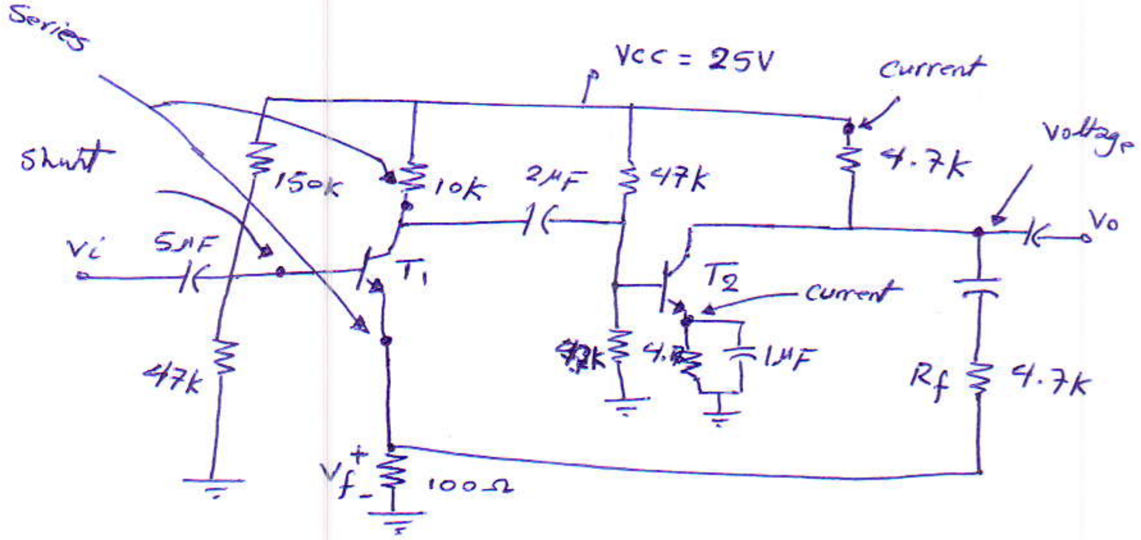
$\therefore V_s = V_a(1+A\beta) \quad \because V_s = Z_{if} \cdot I_i$

$\Rightarrow \dfrac{V_s}{I_i} = \dfrac{V_a}{I_i}(1+A\beta) \quad \therefore \boxed{Z_{if} = Z_i(1+A\beta)}$

Z_{if} (i/p impedance with F.B)

Z_i (i/p impedance without F.B)

Ex: For the F.B amplifier shown below T_1 and T_2 are Identical transistors with: $h_{fe} = 50$, $h_{ie} = 1.1 K\Omega$; calculate the overall gain, the i/p and o/p impedance (Z_i and Z_o) before and after F.B?

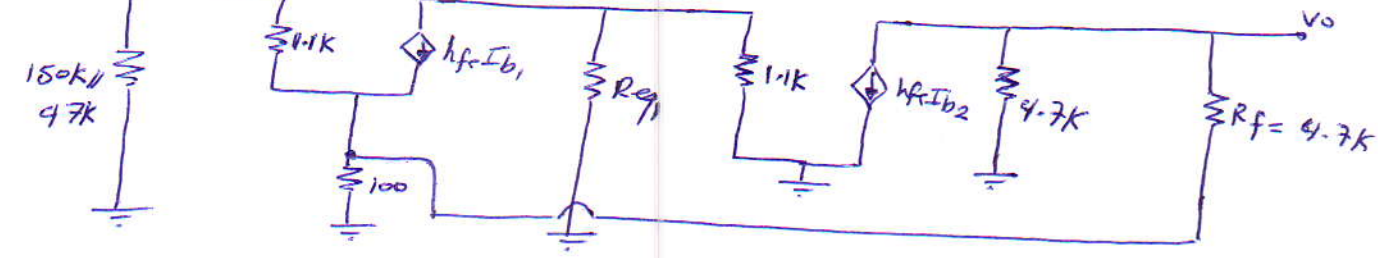


Solution:

Step ①

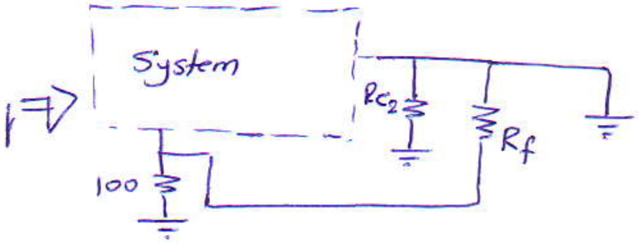
① Topology type is Voltage-series

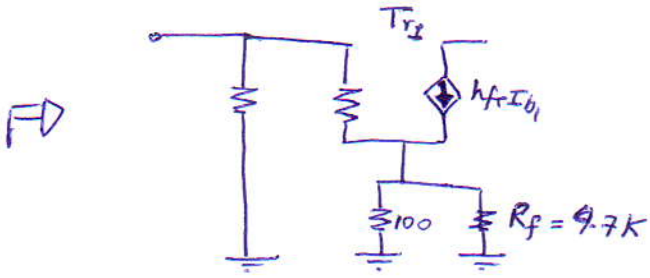
Step ② to find the input cct set $V_o = 0$ because (o/p is voltage)



$$\boxed{R_{eq_1} = R_{C_1} // R_{B_1} // R_{B_2}}$$

to be continue

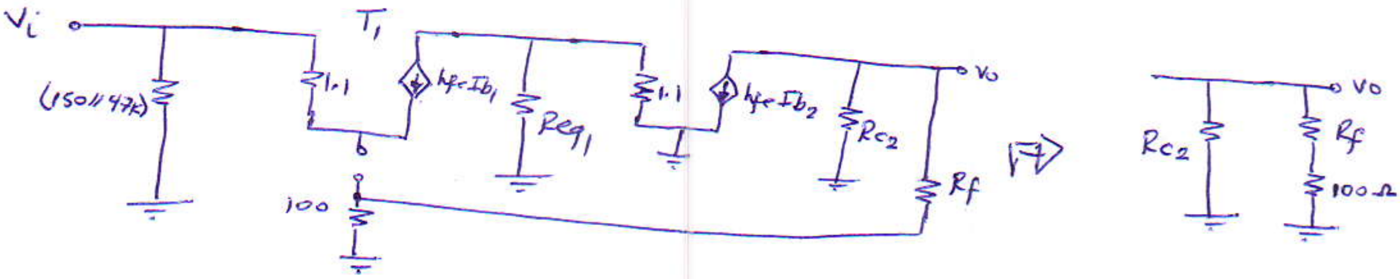




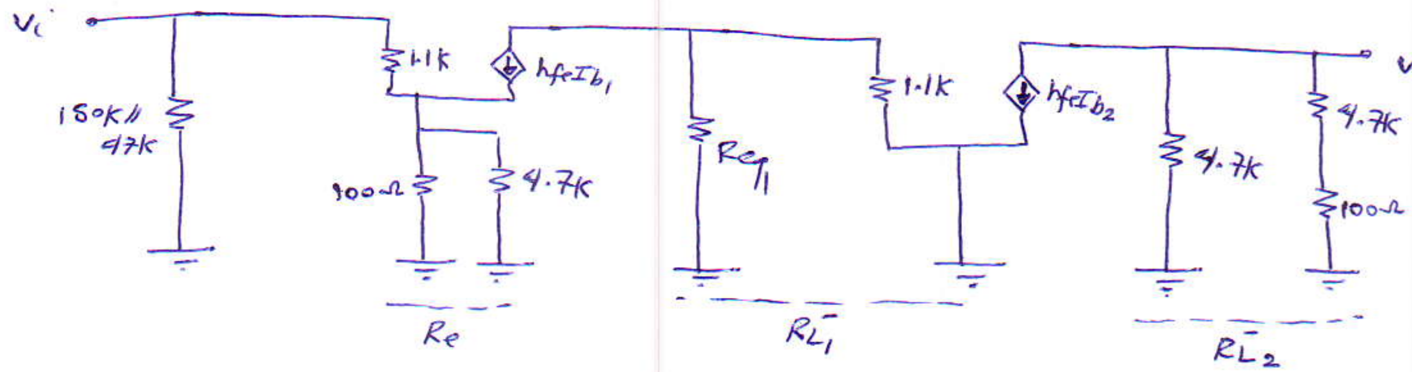
$\boxed{R_{e_1} = R_f // 100}$

step ③ to find the output circuit:

set ($I_i = 0$ because input series)



Step ④ Basic amplifier cet without F.B



$R_{L_1}^- = R_{c_1} // R_{B_1} // R_{B_2} // h_{ie_2} = 10K // 47K // 33K // 1.1K = \boxed{942\ \Omega}$

$R_{L_2}^- = (4.7K + 100) // 4.7K = \boxed{2.37K\Omega}$

$R_e = 100 // 4.7K = \boxed{98\ \Omega}$

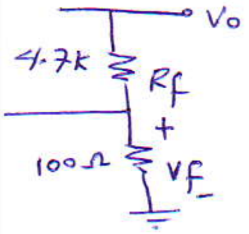
يتبع

$$A_{v_1} = \frac{-h_{fe} R_{L_1}'}{h_{ie_1} + (1+\beta) R_e} = \frac{-50 * 942}{1.1k + (1+50)\, 98} = \boxed{-7.72}$$

$$A_{v_2} = \frac{-h_{fe} R_{L_2}'}{h_{ie}} = \frac{-50 * 2.37k}{1.1k} = \boxed{-108}$$

$$\text{overall gain } (A_{v_T}) = A_{v_1} \cdot A_{v_2} = (-7.72)(-108) \simeq \boxed{834}$$

To find β value ?



$$V_f = \frac{V_o * 100}{100 + 4.7k}$$

$$\because \beta = \frac{V_f}{V_o} \quad \therefore \beta = \frac{100}{100 + 4.7} = \boxed{\frac{1}{48}}$$

$$\Rightarrow D = 1 + \beta A_{v_T} = 1 + \left(\frac{1}{48}\right)(834) = \boxed{18.4}$$

$$\Rightarrow A_{vf} = \frac{A_{vT}}{D} = \frac{834}{18.4} \simeq \boxed{45.4}$$

① نلاحظ انخفاض الكسب من 834 الى 45.4

② تذكر $A_f \simeq \frac{1}{\beta}$ اي تقريباً يساوي $\boxed{48}$

لانه $A_f = \frac{\cancel{A}}{1 + \cancel{A}\beta} \simeq \frac{1}{\beta}$

$$Z_{if} = Z_i (1 + A\beta) = Z_i (18.4)$$

$$Z_i = h_{ie_1} + (1+\beta) R_e$$

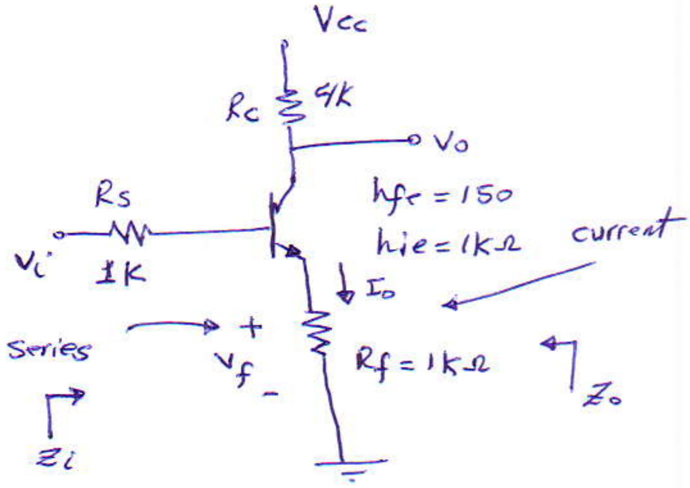
تزداد

$$= 1.1k + (1+50)\, 98 \simeq 6.1k\Omega \Rightarrow Z_{if} = 6.1k * 18.4 = \boxed{112.24k\Omega}$$

$$Z_{of} = \frac{Z_o}{D} = \frac{R_{C_2} /\!/ R_{L_2}'}{D} = \frac{4.7k /\!/ 4.8k}{18.4} = \boxed{129\Omega}$$ تقل

ملاحظة: يتم احتساب Z_i للترانزستور بعد مقاومة R_B لضمان حساب قيمة Z_i من غير ادخال قيم المقاومات المربوطة لاحقاً. اما في حالة ورد في السؤال فيتم الاخذ بنظر الاعتبار مكان تحديد Z_i

Ex: For the circuit shown; calculate A_{vf}, Z_{if} and Z_{of} ?



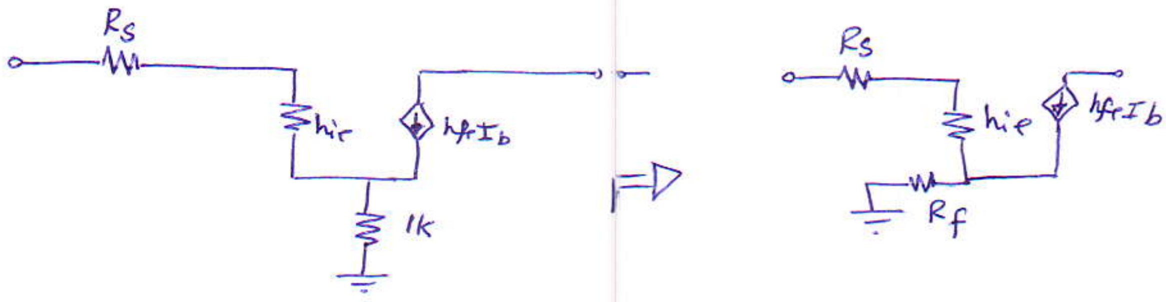
Solution:

Step ①:

Topology type is current - series

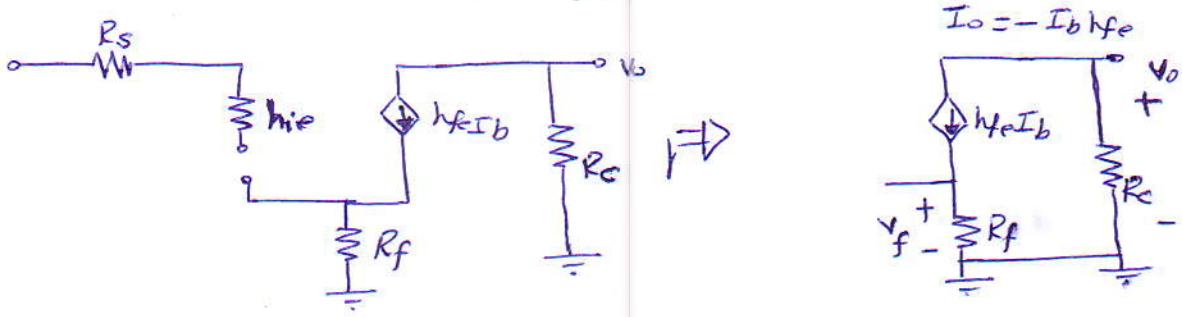
Step ②:

To find the input circuit $I_o = 0$

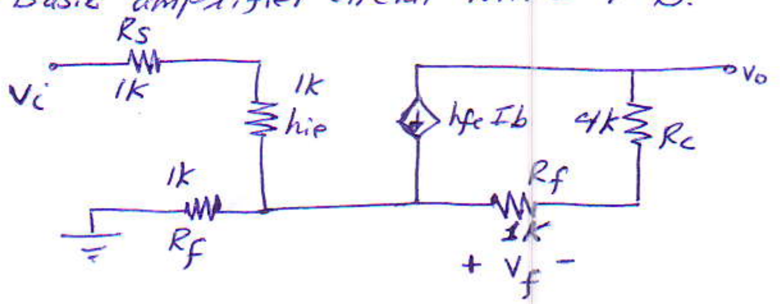


Step ③:

To find the output circuit $I_i = 0$



Step ④: Basic amplifier circuit without F.B.



to be continue.

$\beta = \frac{V_f}{I_o}$; $V_f = -I_o R_f \Rightarrow \beta = -R_f = \boxed{-1k\Omega}$

A_f (gain with feedback) $= \frac{I_o}{V_i} = \frac{A}{1+\beta A}$

$G_M = \frac{I_o}{V_i} = \frac{-h_{fe}\cancel{I_b}}{\cancel{I_b}(R_s + h_{ie} + R_f)} = \frac{-150}{(1k+1k+1k)} = \boxed{-50mA/V}$

$D = 1 + \beta G_M = 1 + (-1000)(-50*10^{-3}) = \boxed{51}$

A_f or $G_{Mf} = \frac{A}{1+A\beta} = \frac{G_m}{D} = \frac{-50\,mA/V}{51} \simeq \boxed{-1\,mA/V}$

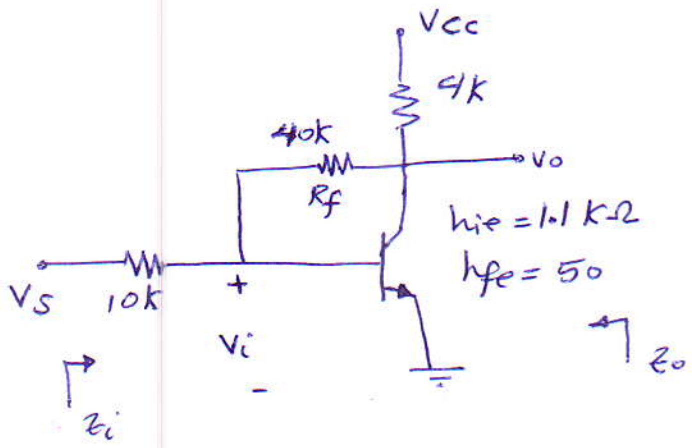
$A_{vf} = \frac{V_o}{V_i} = \frac{-I_o R_c}{V_i} = -1*10^{-3}*4k = \boxed{-4}$

G_{mf}

$Z_{if} = (R_s + R_f + h_{ie})D = (3k)(51) = \boxed{153K}$

$Z_{of} = R_c * D = 4k * 51 = \boxed{204k\Omega}$

Ex: For the circuit shown below; find A_{vf}, Z_{if} and Z_{of}?

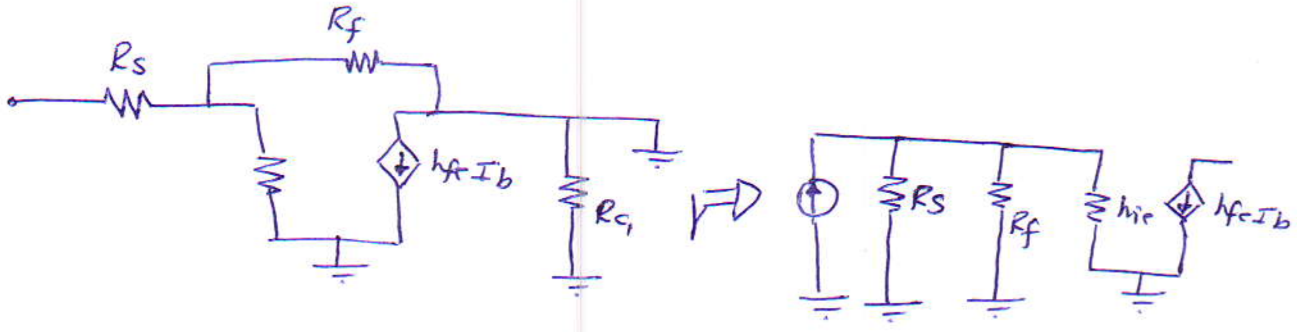


to be continue.

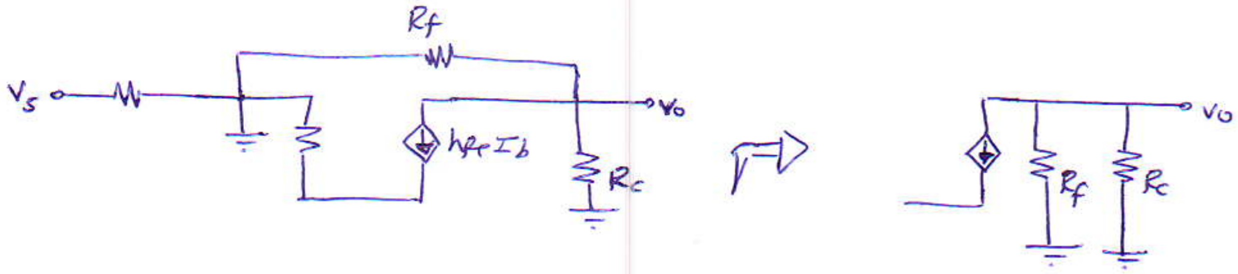
Solution:

Step①: Topology type is Voltage-shunt

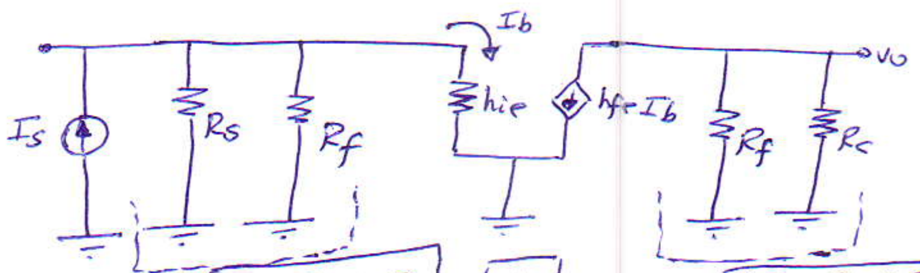
Step②: To find input circuit ($V_o = 0$)



Step③: To find output circuit ($V_i = 0$)



Step④: Basic amplifier circuit without F.B.



$\boxed{\bar{R} = R_S \parallel R_f} = \boxed{8K}$ $\boxed{\bar{R_L} = R_f \parallel R_C} \simeq \boxed{3.64K}$

$$R_M = \frac{V_o}{I_s} = \frac{-I_o \bar{R_L}}{I_s} = \frac{-I_b h_{fe} \bar{R_L}}{I_s} = \frac{-h_{fe}\bar{R_L}}{\cancel{I_s}} * \cancel{I_s} * \frac{(R_S \parallel R_f)}{(R_S \parallel R_f) + h_{ie}}$$

$$\Rightarrow R_M = \frac{-50 * 3.64K * 8K}{8K + 1.1K} = \boxed{-160 K\Omega}$$

to be continue

$$\beta = \frac{I_f}{V_o} = \frac{1}{\cancel{V_o}} \cdot \frac{\cancel{V_i} - \cancel{V_o}}{R_f} = \frac{-1}{R_f} = -\frac{1}{40} = \boxed{-0.025\,mA/V}$$

تهمل لأنها صغيرة

$$D = 1 + \beta R_M = 1 + (-0.025 \times 10^{-3})(-160 \times 10^{3}) = \boxed{5}$$

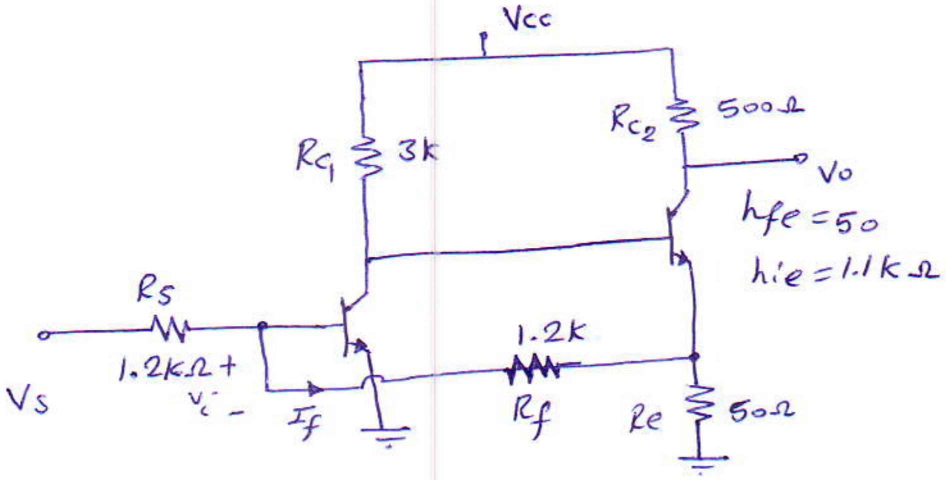
$$R_{Mf} = \frac{R_M}{D} = \frac{-160k}{5} = \boxed{-32k} = A_f$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{I_s R_s} = \frac{R_{Mf}}{R_s} = \frac{-32k}{10k} = \boxed{-3.2}$$

$$Z_{if} = Z_i / D = \frac{R_s \,//\, R_f \,//\, h_{ie}}{5} = \frac{968}{5} \simeq \boxed{193\,\Omega}$$

$$Z_{of} = \frac{Z_o}{D} = \frac{R_c \,//\, R_f}{5} = \frac{3.64k}{5} = \boxed{728\,\Omega}$$

Ex: For the circuit shown; Determine A_{vf}, Z_{if} and Z_{of}



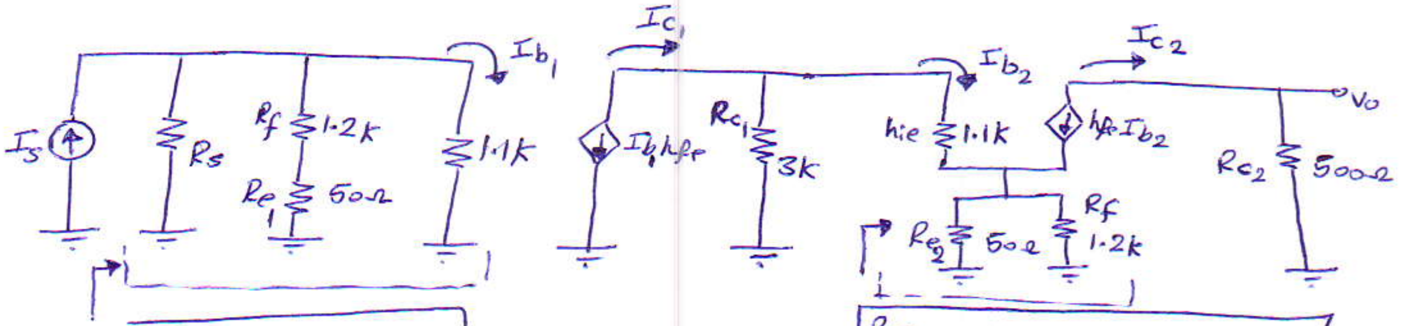
Solution:

step ①: F.B type is current-shunt

step ② and ③ will be appear in step ④

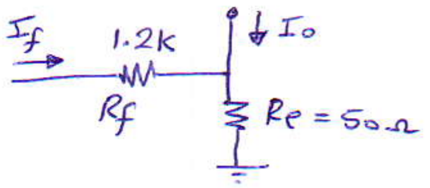
يتبع

step ④: Basic amplifier circuit without F.B.



R_i $\boxed{R = R_s // (R_f + R_e)}$ $= \boxed{612\,\Omega}$

$\boxed{R_{eq_1} = h_{ie} + (1+\beta)(R_{e_2} // R_f)}$ $= \boxed{3.55k}$



$$\beta = \frac{I_f}{I_o}$$

$$I_f = I_o * \frac{R_e}{R_e + R_f} \Rightarrow \beta = \frac{I_f}{I_o} = \frac{R_e}{R_e + R_f}$$

$$\therefore \beta = \frac{50}{50 + 1.2k} = \boxed{0.04}$$

$$A_{I_T} = \frac{I_{c_2}}{I_s} = \frac{I_{c_2}}{I_{b_2}} \cdot \frac{I_{b_2}}{I_{c_1}} \cdot \frac{I_{c_1}}{I_{b_1}} \cdot \frac{I_{b_1}}{I_s}$$

$$I_{c_2} = -h_{fe} I_{b_2} \Rightarrow \frac{I_{c_2}}{I_{b_2}} = \boxed{-50}$$

$$I_{c_1} = -I_{b_1} h_{fe} \Rightarrow \frac{I_{c_1}}{I_{b_1}} = \boxed{-50}$$

$$I_{b_2} = +I_{c_1} * \frac{3k}{3k + 3.55k} \Rightarrow \frac{I_{b_2}}{I_{c_1}} = \boxed{+0.458}$$

$$I_{b_1} = I_s * \frac{612}{612 + 1.1k} \Rightarrow \frac{I_{b_1}}{I_s} = \boxed{0.357}$$

تابع

$$A_{I_T} = (-50)(-50)(0.458)(0.357) = \boxed{408}$$

$$D = 1 + \beta A_{I_T} = 1 + (0.04)(408) = \boxed{17.32}$$

$$A_{vf} = \frac{V_o}{V_S} = \frac{-I_{c2} R_{c2}}{I_S R_S} = A_{If} * \frac{R_{c2}}{R_S}$$

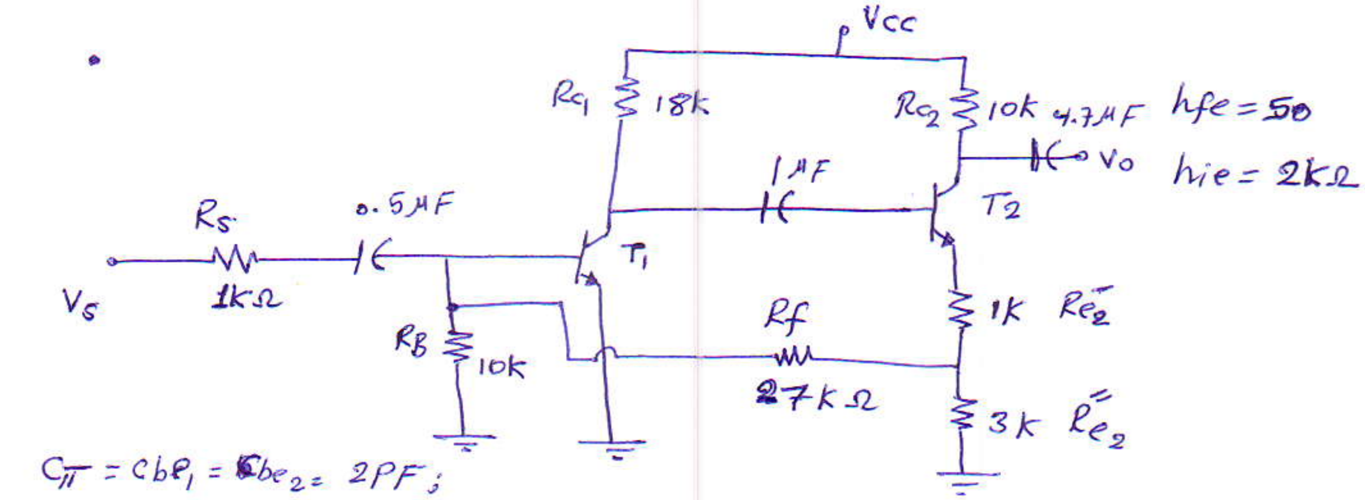
$$A_{If} = \frac{408}{17.32} \cong \boxed{23.6} \Rightarrow A_{vf} = 23.6 * \frac{500}{1.2k} = \boxed{9.83}$$

$$R_i = R' // R_{ie} = 612 // 1.1k = \boxed{394\,\Omega} \Rightarrow Z_{if} = \frac{394}{17.32} \cong \boxed{23\,\Omega}$$

$$Z_{of} = R_{c_2} * D = 500 * 17.32 = \boxed{8.6\,k\Omega}$$

H.W1: Prove that $Z_{if} = Z_i(1+A\beta)$ and $Z_{of} = Z_o(1+A\beta)$ for the current-series connection?

H.W2: For the cct shown below; Determine A_{vf}, Z_{if} and Z_{of}? After that calculate the upper cutoff freq. and the lower after and before F.B?

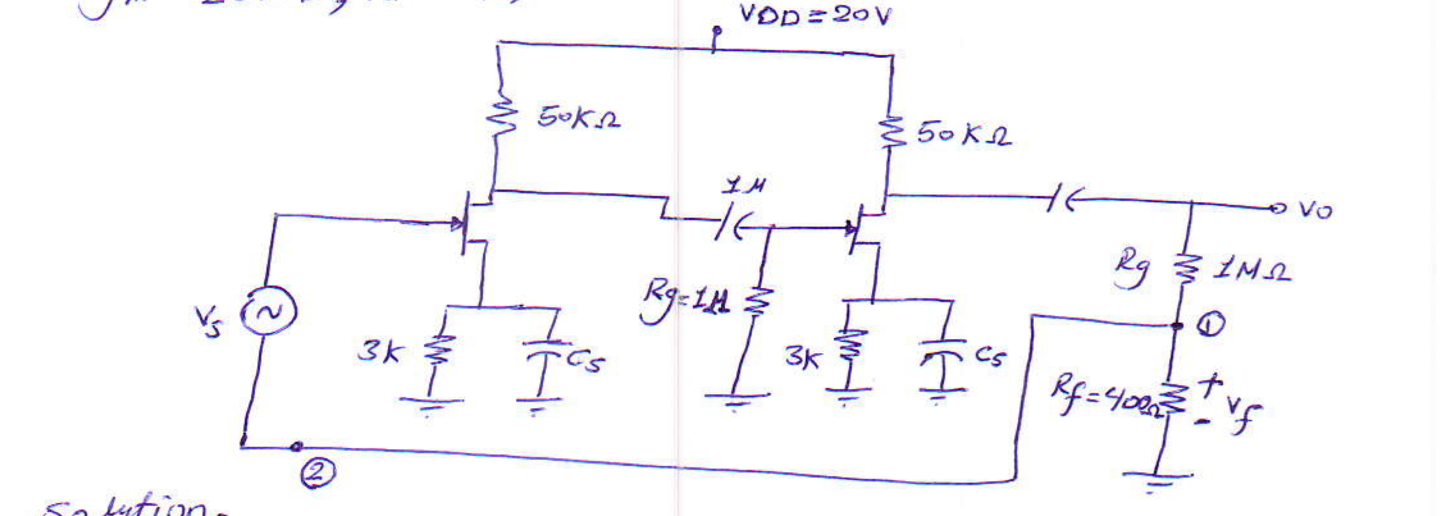


$C_\pi = C_{be_1} = C_{be_2} = 2PF$;

$C_\mu = C_{bc_1} = C_{bc_2} = 5PF$;

Ex: For the circuit shown below; find Avf and Zof, given that

$g_m = 20\,mS$, $r_d = 10k$,



Solution:

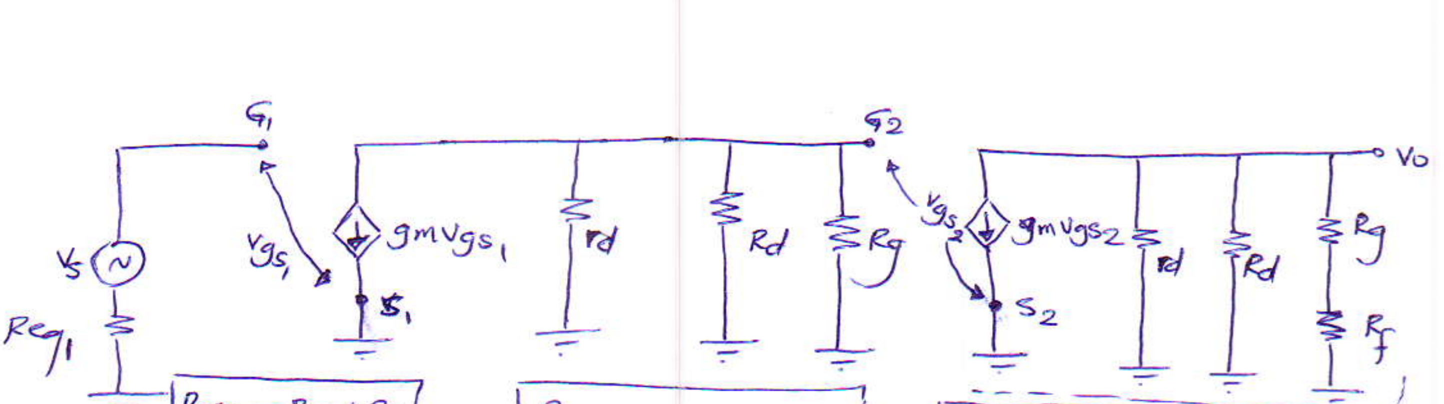
Step① F.B type is Voltage-series (Voltage amplifier)

نلاحظ من الشكل اعلاه بانه النقطة رقم① تم اخذها من فولتية الخرج لذلك فهي Voltage اما نقطة رقم② فانه مقاومة الـ Rf تكون عليها فولتية (V_f) يتم مقارنتها مع فولتية المصدر (V_s) وبالتالي هي series

Step② To find i/p circuit ($V_o = 0$)

Step③ To find o/p circuit ($I_i = 0$)

Steps ② and ③ will be appear in step④



$\boxed{R_{eq_1} = R_g \,//\, R_f}$ $\boxed{R_{eq_2} = r_d \,//\, R_d \,//\, R_g}$ $\boxed{R_{eq_3} = r_d \,//\, R_d \,//\, (R_g + R_f)}$

$R_{eq_1} = 1M // 400\Omega \simeq \boxed{400\ \Omega}$, $R_{eq_2} = 10K // 50K // 1M = \boxed{8.26K\Omega}$

$R_{eq_3} = r_d // R_d // (R_g + R_f) = 10K // 50K // (1M + 400) \simeq \boxed{8.26K\Omega}$

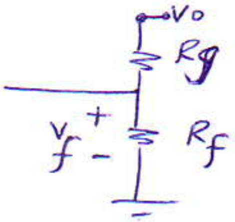
$V_{gs_1} = V_{g_1} - \cancel{V_{s_1}} \xrightarrow{} 0 = V_s$

$\frac{V_{o1}}{V_s} = A_{v_1} \Rightarrow A_{v_1} = -g_m R_{eq_2} = A_{v_2}$

$\Rightarrow A_{v_1} = -20 \cancel{* 10^{-3}} * 8.26 \cancel{* 10^{3}} = \boxed{-165.2} = A_{v_2}$

$\therefore A_{v_T} = A_{v_1} \cdot A_{v_2} = (-165.2)(-165.2) = \boxed{27291}$

$D = 1 + \beta A$; $\beta = \frac{V_f}{V_o}$



$V_f = V_o * \frac{R_f}{R_f + R_g}$

$\Rightarrow \beta = \frac{V_f}{V_o} = \frac{400}{400 + 10^6} = \boxed{4 * 10^{-4}}$

$\therefore D = 1 + \beta A_{v_T} = 1 + (4 * 10^{-4})(27291) \simeq \boxed{12}$

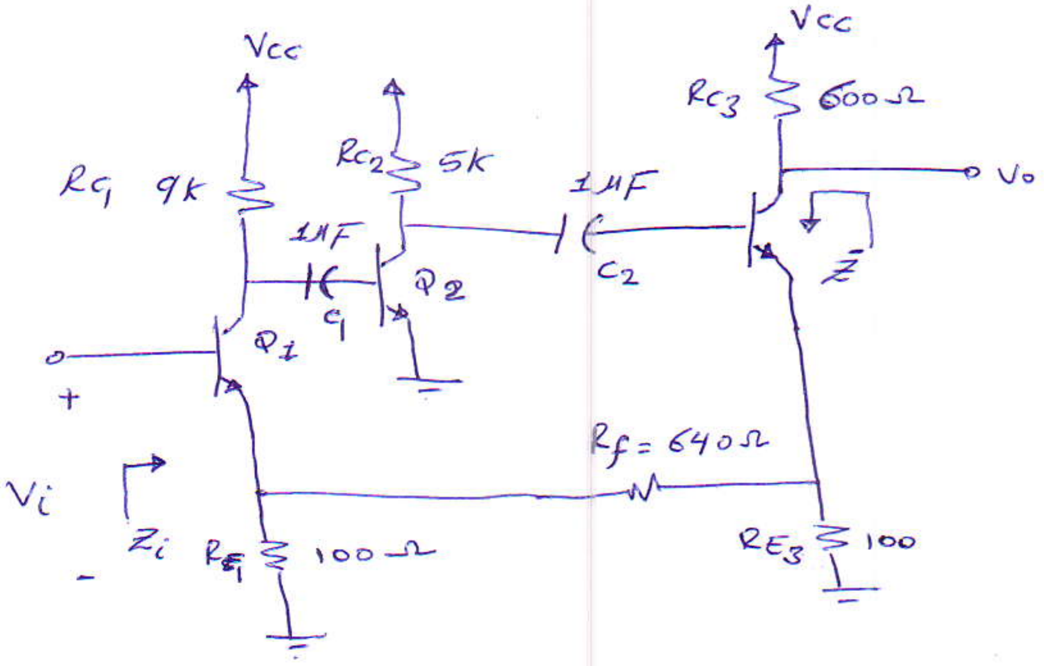
$\Rightarrow A_{vf} = \frac{A_{vT}}{D} = \frac{27291}{12} = \boxed{2274.25}$

$Z_{of} = Z_o / (1 + \beta A_{v_T}) = (R_{eq_3}) / (12)$

$\therefore Z_{of} = \frac{8.26K}{12} = \boxed{688\Omega}$ decrease due to voltage sampling

Ex: For the circuit shown below, determine A_{vf}, Z_{if}, Z_{of}, $\bar{Z}$ and f_L (After and before feedback)?

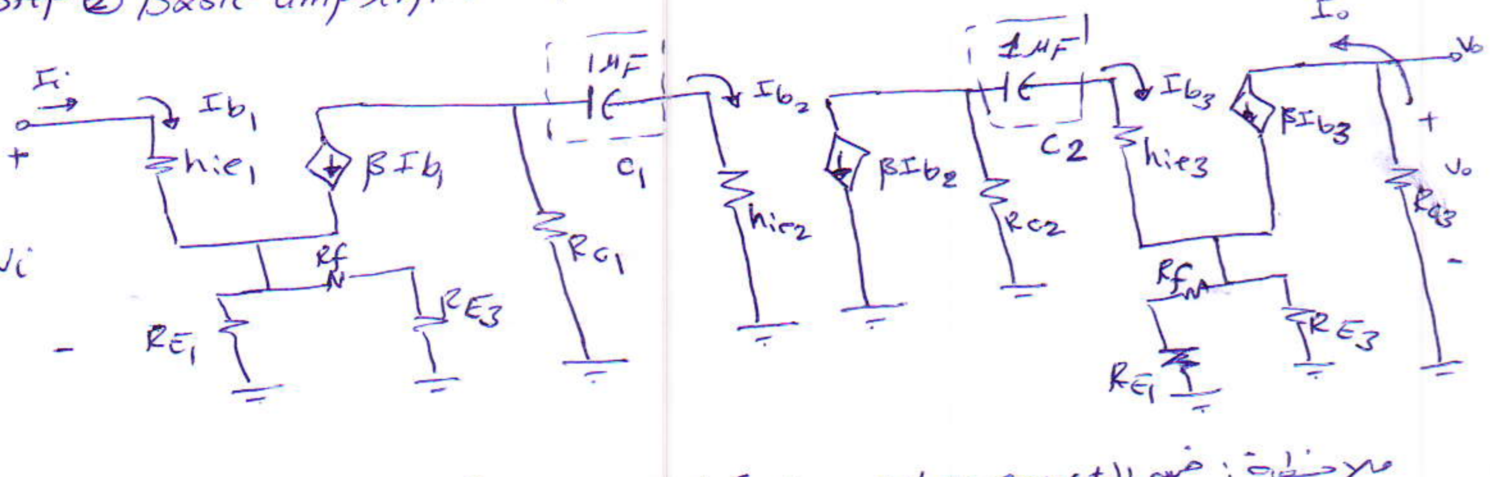
$I_{C_1} = 0.6\,mA$, $I_{C_2} = 1\,mA$, $I_{C_3} = 4\,mA$, $h_{fe} = 100$



Solution:

step① F.B type is current - series

step② Basic amplifier circuit without F.B



ملاحظة: ضمن الـ ac equivalent لا يجب ان توضع المتسعات ولكنه وضعت لغرض التوضيح وهو تم تمثيل كيف يتم احتساب قيم المقاومات (Rth) لكل متسعة

$\therefore$ F.B type is current - series $\therefore A = \frac{I_o}{V_i}$ (transconductance amplifier)

$$A = \frac{I_o}{V_i} \quad ; \quad V_i = I_i Z_b = I_{b_1} Z_b = I_{b_1} (hie_1 + (1+\beta)(R_{E_1} // (R_f + R_{E_3}))$$

$re_1 = 41.7\,\Omega$

$re_2 = 25\,\Omega$ $\quad\quad \therefore V_i = I_{b_1} (13067.62) \leftarrow$ بعد تعويض القيم

$re_3 = 6.25\,\Omega$

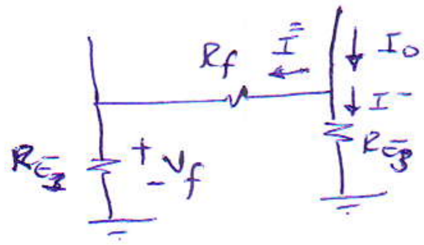
$$I_o = \beta I_{b_3} = \boxed{100\, I_{b_3}}$$

$$I_{b_3} = \frac{-\beta I_{b_2} R_{c_2}}{R_{c_2} + hie_3 + (1+\beta)(R_{E_3} // R_f + R_{E_1})} = \boxed{-34.43\, I_{b_2}}$$

$$I_{b_2} = \frac{-\beta I_{b_1} R_{c_1}}{R_{c_1} + hie_2} = \boxed{-78.26\, I_{b_1}}$$

$$\therefore A = \frac{(-78.26)(-34.43)(100)\cancel{I_{b_1}}}{\cancel{I_{b_1}}(13067.62)} \approx \boxed{20.7}\ A/V$$

$$\beta = \frac{V_f}{I_o}$$



$$V_f = I^= R_{E_1}$$

$$= \frac{I_o * R_{E_3}}{R_{E_3} + R_f + R_{E_1}} * R_{E_1} \quad FD \quad \beta = \boxed{11.9\,\Omega}$$

$$D = 1+\beta A = 1+(11.9)(20.7) = \boxed{247.33}$$

$$A_f = \frac{A}{D} = \frac{20.7}{247.33} \simeq \boxed{83.7\,mA/V}$$

$$Z_{if} = D Z_i = D\left(h_{ie_1} + (1+\beta)(R_{E_1} \parallel R_f + R_{E_3})\right) \simeq \boxed{5.24\,M\Omega}$$

$$\bar{Z} = \frac{R_{C2} + h_{ie_3}}{\beta_3+1} + (R_{E_3} \parallel R_f + R_{E_1}) = \boxed{143.8\,\Omega}$$

$$Z_{of} = D\bar{Z} = 247.33 * 143.8 \simeq \boxed{35.6\,K\Omega}$$

$$f_{Lc_1} = \frac{1}{2\pi R_{th_1} C_1} \;;\quad R_{th_1} = h_{ie2} + R_{c_1} = 2.5K + 9K = \boxed{11.5\,K\Omega}$$

$$\Rightarrow f_{Lc_1} = \frac{1}{2\pi(11.5K)(1\mu)} = \boxed{13.84\,HZ} \text{ before F.B}$$

$$\text{After F.B } (f_{Lc_1})_F = \frac{f_{Lc_1}}{D} = \frac{13.84}{247.33} = \boxed{0.056\,HZ}$$

تقريباً صفر
بعد اضافة ال F.B

$$f_{Lc_2} = \frac{1}{2\pi R_{th_2} C_2} \;;\quad R_{th_2} = R_{c_2} + h_{ie_3} + (1+\beta)(R_{E_3} \parallel R_f + R_{E_1})$$

$$= \boxed{14.5\,K\Omega}$$

$$\Rightarrow f_{Lc_2} \simeq \boxed{11\,HZ} \text{ before F.B}$$

$$\text{After F.B } (f_{Lc_2})_F = \frac{11}{247.33} = \boxed{0.044\,HZ}$$

Tikrit University	**2012- 2013**	**Subject: Electronic II**
College of Eng.	**Class: Third**	**Date: 18/11/2012**
Dept. of Electrical Eng.	**First Attempt**	**Time: 2 hours**

Q1: *The circuit shown in figure (1) has $\beta=120$, $V_{CE}=4.47V$, $C_{be}=40pF$, $C_{bc}=1.5pF$, $C_{ce}=5pF$, $C_{wi}=4pF$ and $C_{wo}=8pF$.*

1. *Find the bandwidth, if cutoff frequency of C_c is 2.895Hz?*
2. *Sketch the frequency response using Bode plot?*
3. *Calculate the frequency and $(Av/Av_{mid})dB$ at which the gain drops to 50% of its maximum value?* ***40 Mark***

Q2:

a) *For the circuit shown in figure (2) has $\beta_1=200$, $\beta_2=150$, $hie_1=20k\Omega$, $hie_2=7.5k\Omega$.* ***50 Mark***

1. *Find A_{vf} and Z_{if}?*
2. *If the first stage adds 1V as a noise voltage before F.B, determine the noise value for two stages before and after F.B?*

b) *What are the effect of negative feedback on gain and bandwidth? Confirm your answer by drawing and equations.* ***10 Mark***

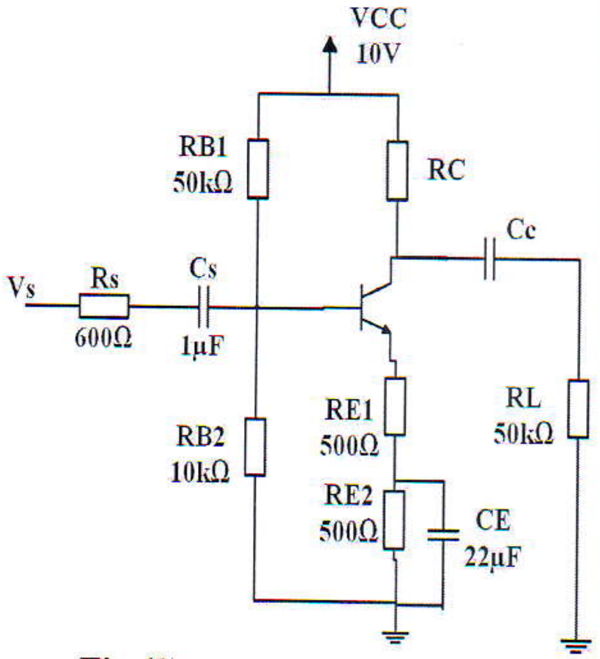


Fig (1)

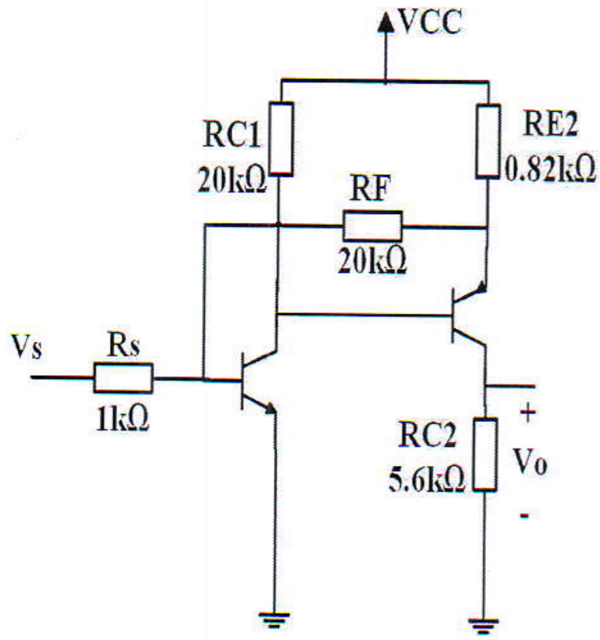


Fig (2)

Lecturer **Good Luck**

Saad Gazai Muttlak

Tikrit University	**2012- 2013**	**Subject: Electronic II**
College of Eng.	**Class: Third**	**Date: 18/11/2012**
Dept. of Electrical Eng.	**First Attempt**	**Time: 2 hours**

Q1: *The circuit shown in figure (1) has $\beta=120$, $V_{CE}=4.47V$, $C_{be}=40pF$, $C_{bc}=1.5pF$, $C_{ce}=5pF$, $C_{wi}=4pF$ and $C_{wo}=8pF$.*

1. *Find the bandwidth, if cutoff frequency of C_c is 2.895Hz?*
2. *Sketch the frequency response using Bode plot?*
3. *Calculate the frequency and $(Av/Av_{mid})dB$ at which the gain drops to 50% of its maximum value?* ***40 Mark***

Q2:

a) *For the circuit shown in figure (2) has $\beta_1=200$, $\beta_2=150$, $hie_1=20k\Omega$, $hie_2=7.5k\Omega$.* ***50 Mark***

1. *Find A_{vf} and Z_{if}?*
2. *If the first stage adds 1V as a noise voltage before F.B, determine the noise value for two stages before and after F.B?*

b) *What are the effect of negative feedback on gain and bandwidth? Confirm your answer by drawing and equations.* ***10 Mark***

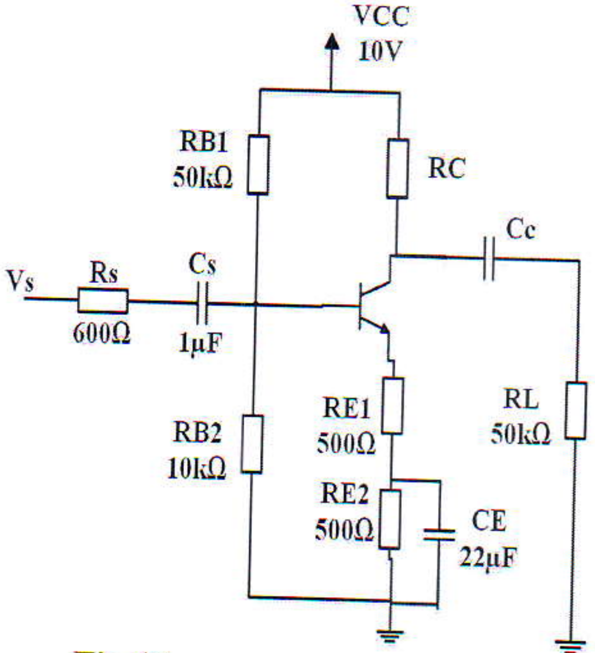


Fig (1)

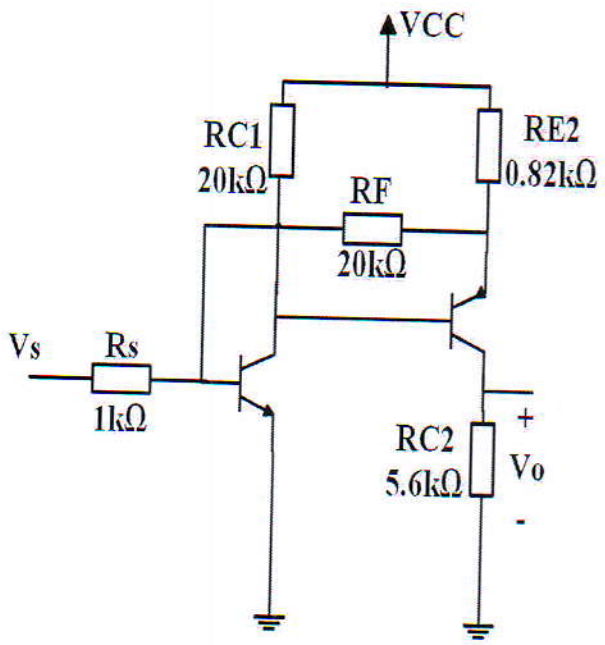


Fig (2)

Lecturer

Saad Gazai Muttlak

Good Luck

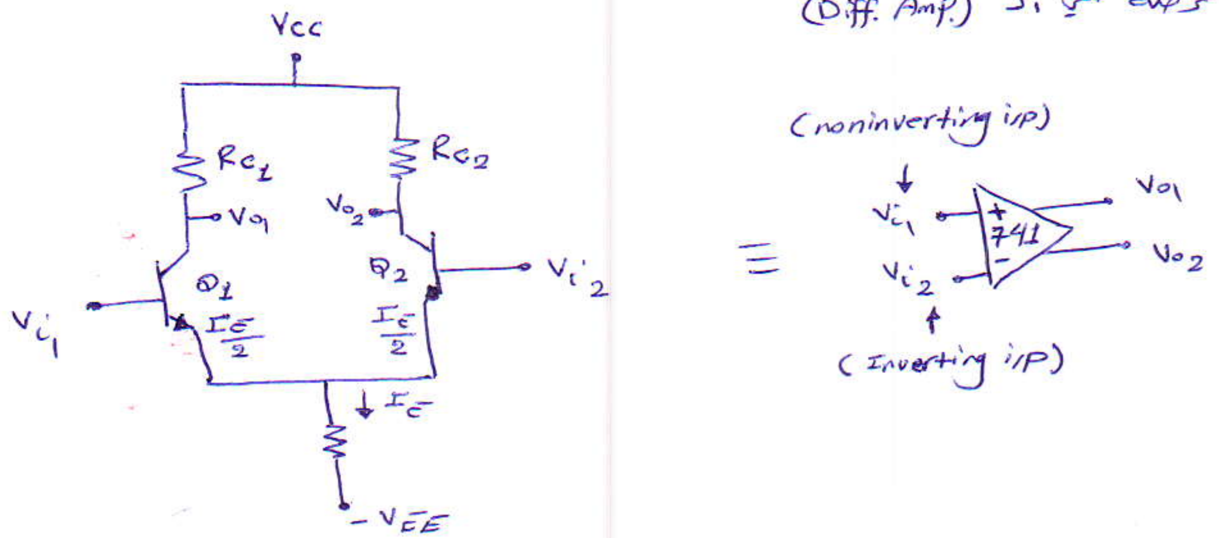
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1
8
6
4
3
2
1

Differential and Operational Amplifier:

Differential Amplifier circuit:

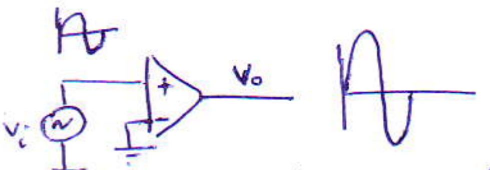
Differential Amplifier circuit: is an arrangment of transistors which allow the difference between two signal sources to be amplified and the output is proportional to the difference between these two inputs as shown in figure below.

يستخدم ال (Differential Amp) بصورة واسعة في الدوائر المتكاملة (IC) كمرحلة إدخال (I/p stage) حيث ان (IC 741) يحتوي بداخله على 24 ترانزستور وتتكون الدائرة ضمن ال IC من عدة مراحل حيث ان اول مرحلة هي ال (Diff. Amp)



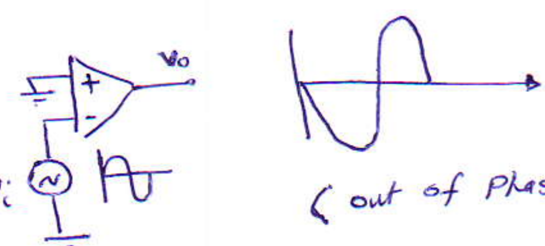
* يجب ان يكون كلا الترانزستورين Q_1 و Q_2 متوائمين (match) لان اي اختلاف بينهما يؤدي الى اختلاف احد التيارين عن الآخر.

① **Single-Ended Input:** Single ended i/p operation results when the i/p signal is connected to one i/p with the other i/p connected to ground as shown below.



(the same of phase)

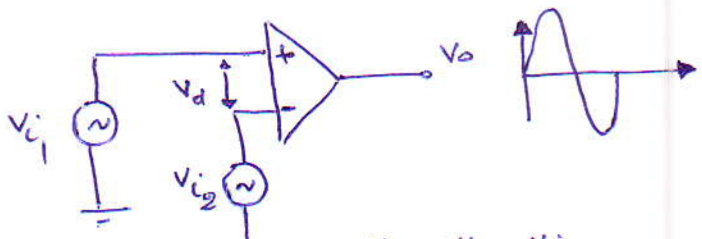
or



(out of phase)

② Double-Ended (Differential) Input :

من المحتمل ان كلا الطرفين تطبق عليهما فولتية وبالتالي فان نتيجة الإخراج تكون بنفس طور نتيجة طرح الفولتيتين وكما موضح في الشكل ادناه، حيث اذا كانت نتيجة الطرح موجبة فان الإخراج يكون كذلك موجب والعكس بالعكس

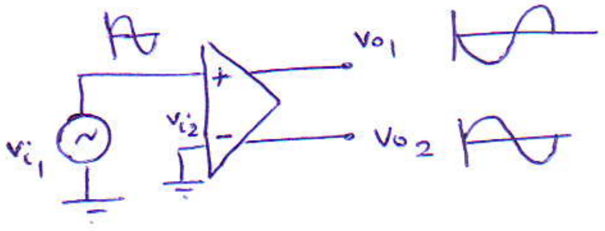


$$V_d = V_{i_1} - V_{i_2}$$

Double-Ended (Differential) operation

③ Double-Ended output :

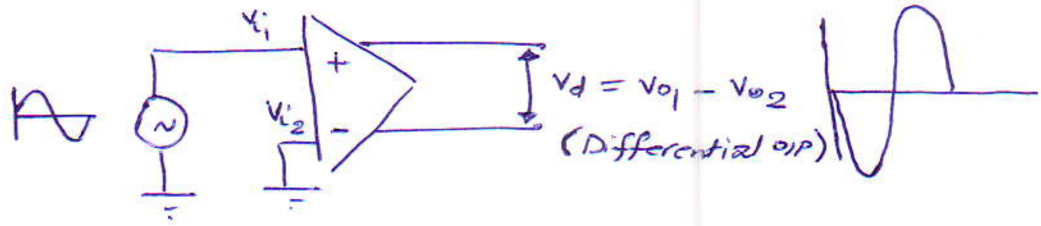
* The signal applied to the plus i/p results in two amplified outputs of opposite polarity as shown below.



* يكون V_{o1} عكس قطبية الإدخال V_i لان الإخراج يكون من CE ترانستور وهو يعطي 180° فرق طور .

* The 2nd case is the same operation with single o/p measured between output terminals (not with respect to ground).

يتبع

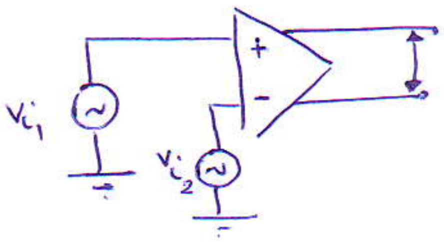


For example $V_{o_1} = -10$ and $V_{o_2} = 10 \Rightarrow V_d = -10 - (10) = \boxed{-20}$
and can be called floating output signal

* Note:

* بمعنى ان الاخراج يكون طرفيا بين V_{o_1} و V_{o_2} ولايكون مربوط على (ground)

* The figure shown below is called differential i/p, differential o/p operation (fully differential operation)

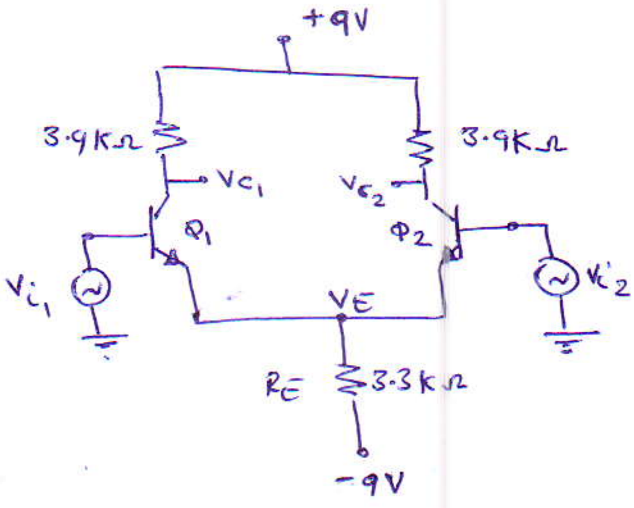


$V_o = A_d V_d$; $V_d = V_{i_1} - V_{i_2}$

④ Common-Mode operation:

عندما يتم ادخال نفس قيمة الفولتية عند طرفي الادخال فان الاخراج يكون صفر (Differential i/p)
$V_{i_1} = V_{i_2}$
وذلك لان قيمة $V_d = V_{i_1} - V_{i_2}$. حيث اذا كان الاخراج يساوي صفر فان قيمة الـ signal of Noise
تم رفضها وتسمى هذه الحالة common mode rejection ولكن في الحقيقة لايكون الاخراج
يساوي صفر بل انه يكون قيمة صغيرة لذلك تم استخدام D.C offset

Ex: Determine I_E, I_{C_1}, I_{C_2}, V_{C_1} and V_{C_2} in the circuit below?



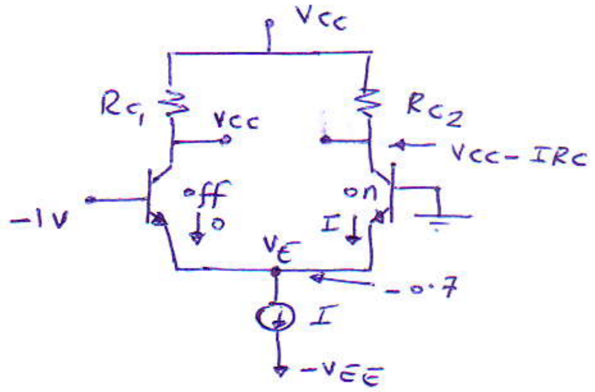
Solution:

$$I_E = \frac{-V_{BE} + V_{EE}}{R_E} = \frac{9-0.7}{3.3K\Omega} = \boxed{2.5mA}$$

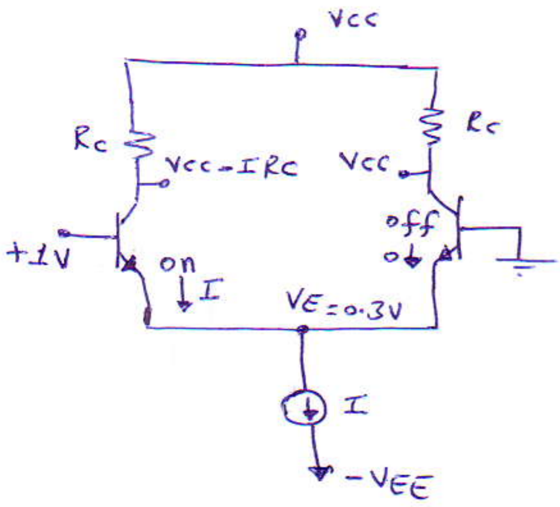
$$I_{C_1} = I_{C_2} = \frac{I_E}{2} = \frac{2.5mA}{2} = \boxed{1.25mA}$$

$$V_{C_1} = V_{C_2} = V_{CC} - I_C R_C = 9 - (1.25 * 10^{-3})(3.9 * 10^{3}) = \boxed{4.125V}$$

Basic Operation: To see how the BJT differential pair works, can be obtained two cases below.

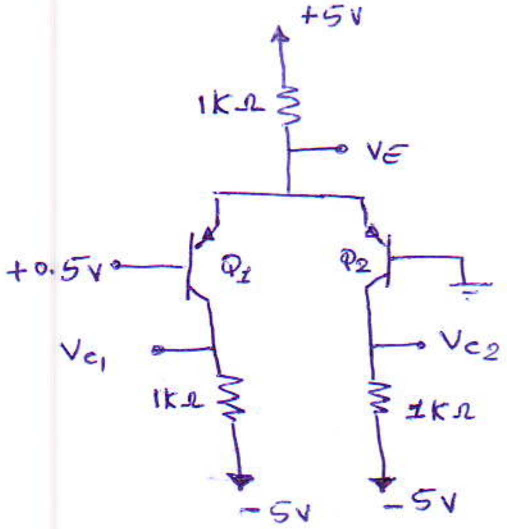


Case 1



Case 2

Ex: Find V_E, V_{C_1} and V_{C_2} in the circuit below? Assume $V_{BE} = 0.7$, $\alpha \simeq 1$



Solution:

Q_1 is off and Q_2 is on

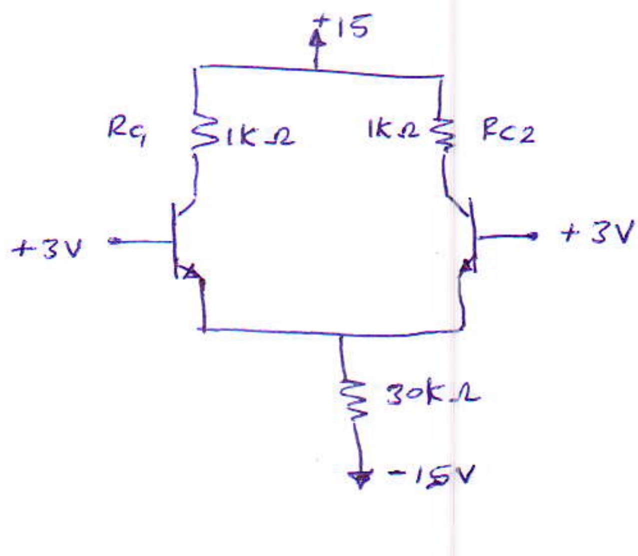
$V_E = V_{BE_2} = 0.7V$

$I_E = \dfrac{V_{EE} - V_E}{R_E} = \dfrac{5 - 0.7}{1K} = 4.3mA \simeq I_{C_2}$ because $I_{C_1} = 0$

$V_{C_2} = I_{C_2} R_C - V_{CC} = (4.3mA)(1K) - 5 = -0.7V$

$V_{C_1} = -5V$ because Q_1 is off, thus $I_{C} = 0$

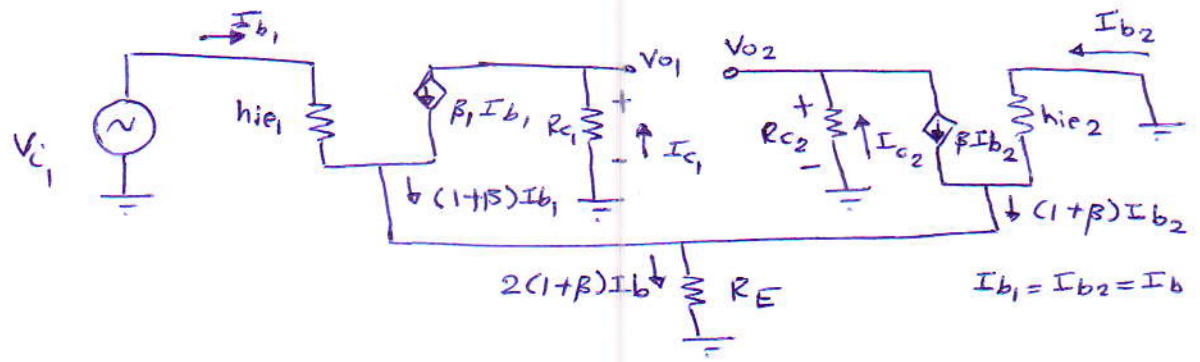
H.w: Determine V_E, V_{C_1} and V_{C_2} in the circuit below?



Ac Operation of Circuit:

① Single-Ended Ac voltage gain:

To calculate the single-ended voltage gain ($\frac{V_o}{V_i}$), apply signal to one input with the other connected to ground as shown below in ac equivalent circuit.



Assume two transistors are well matched, then

$$I_{b_1} = I_{b_2} = I_b$$

$$r_{i_1} = r_{i_2} = r_i = h_{ie} = \beta r_e$$

R_E (very large) ideally infinite.

$$\Rightarrow I_b = \frac{V_{i_1}}{2 r_i} = \frac{V_{i_1}}{2\beta r_e} \quad \text{--- ①}$$

$V_o = -I_c R_c = -\beta I_b R_c$ ---- ② substitute equation ① in ② and we get:

$$V_o = -\cancel{\beta}\left(\frac{V_{i_1}}{2\cancel{\beta} r_e}\right) R_c \Rightarrow \boxed{\frac{V_o}{V_{i_1}} = \frac{-R_c}{2 r_e}}$$

ملاحظة: في الحقيقة ان مقاومة R_E هي توازي h_{ie_2} ولكن نجعل قيمة R_E كبيرة لغرض جعل قيمة المقام قليلة وبالتالي زيادة الكسب ولكن هناك محددات وهي لا يمكن زيادة R_E بنسبة كبيرة جداً عملياً لان التيار يقل وبالتالي فان الترانزستور يتأثر بسبب تأثر الـ Biasing لذلك نلجأ للـ current source

② Double-Ended Ac Voltage gain:

In this case the signals applied to both inputs, the differential voltage gain is:

$$\boxed{A_d = \frac{v_o}{v_d} = \frac{-R_C}{r_e}} \qquad V_d = V_{i_1} - V_{i_2}$$

③ Common-Mode operation of Circuit:

It should also Provide as small an amplification of the signal common to both inputs.

From the Previous ac equivalent circuit in Page 64 we can write:

$$V_i - I_b r_i - 2(\beta+1) I_b R_E = 0$$

$$\Rightarrow I_b (r_i + 2(\beta+1) R_E) = V_i \qquad \therefore I_b = \frac{V_i}{r_i + 2(1+\beta) R_E} \quad \cdots ①$$

$\because V_o = -\beta I_b R_C \quad \cdots ②$ subs. ① in ② and we get:

$$\boxed{\frac{V_o}{V_i} = \frac{-\beta R_C}{r_i + 2(1+\beta) R_E}} = A_c$$

نلاحظ ان قيمة الكسب المشترك
(في حالة ادخال فولتية متساوية لطرفي
ال Diff Amp) يكون قليل حيث ان
قيمة هنا الكسب تمثل علاقة عكسية
مع noise rejection

Constant current source :

لغرض جعل المقاومة المنظورة عبر الـ Emitter للـ Differential Amplifier هي عالية وبنفس الوقت قيمة التيار غير قليلة هي بالإستعانة بـ Active load وهو مصدر تيار من ترانسستورات ومقاومات حيث يعطي قيمة تيار ثابتة وكذلك مقاومة عالية.

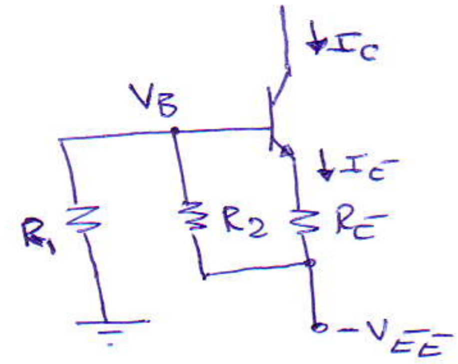
① Bipolar Transistor constant current source :

I_C is desired constant current source shown in figure below and it's set by Resistor R_1 and (R_2, R_E) and also V_{EE}

$$V_B = \frac{(-V_{EE})\,R_1}{R_1 + R_2}$$

$$V_E = V_B - 0.7V$$

$$I_E \simeq I_C = \frac{V_E - (-V_{EE})}{R_E}$$



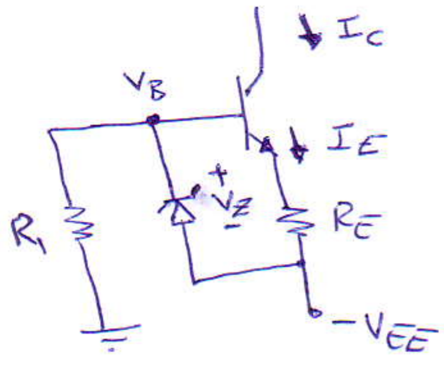
* نلاحظ من الدائرة اعلاه بان قيمة تيار I_C لاتعتمد مطلقاً على Differential التي تكون عادةً عند الـ collector circuit

② Transistor– Zener constant current source :

يتم استبدال المقاومة R_2 بـ Zener diode لزيادة استقرارية الدائرة حيث عند زيادة درجة الحرارة تقل VBE وبالتالي يزداد تيار الـ I_E وتزداد فولتية V_E وبالتالي يتغير قيمة تيار I_C لذلك نستخدم الـ Zener لغرض الاستقرارية للـ I_C وكما موضح في الشكل

يتبع

$$I_C \simeq I_E = \frac{V_Z - V_{BE}}{R_E}$$



constant current source/ using Zener diode

* نلاحظ من المعادلة اعلاه بأن تيار I_C
لا يعتمد مطلقاً على V_{EE} وبالتالي زادت
استقرارية تيار (I_C)

③ MOSFET constant source :

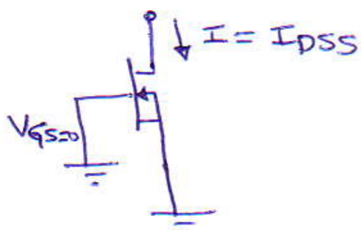
The MOSFET transistor provides an excellent constant current source. If the MOSFET device is biased at $V_{GS} = 0$, the constant current is set at I_{DSS}.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

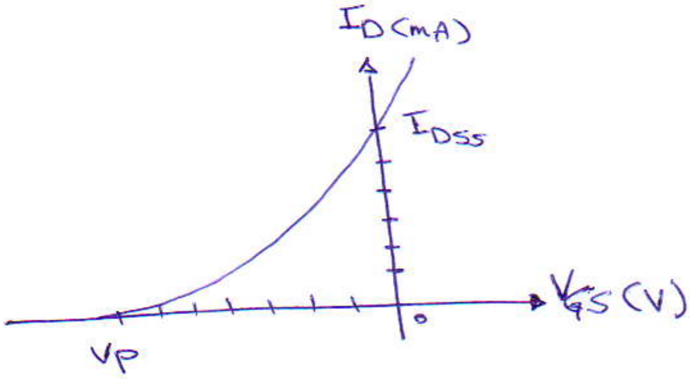
where $V_{GS} = 0$

$\Rightarrow I_D = I_{DSS}$ (constant current)

and high input impedance



Depletion MOSFET

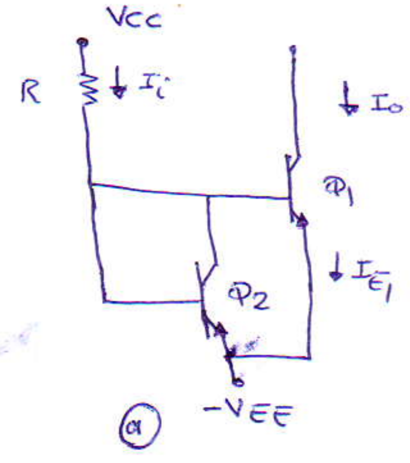


* نلاحظ عندما تكون فولتية $V_{GS} = 0$
فان التيار المار يكون هو I_{DSS}

(4) Current Mirror constant current source:

(a) current mirror forlowcurrent values:

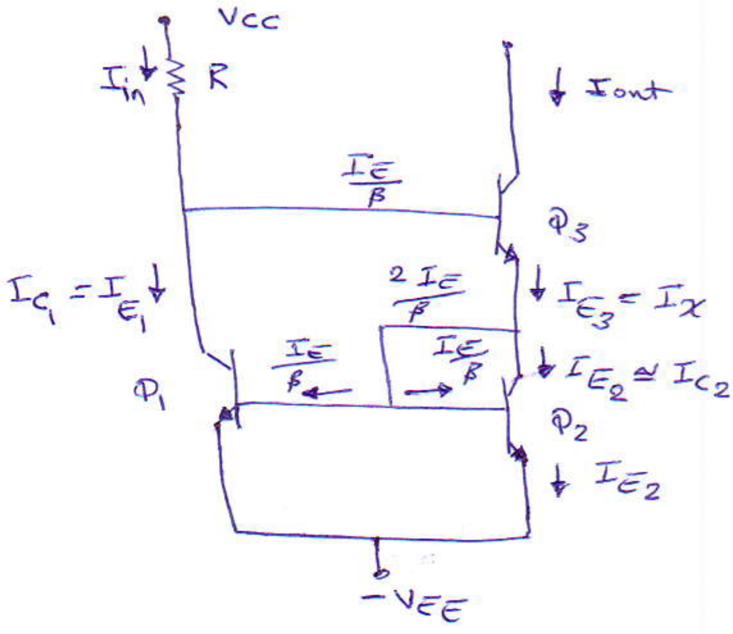
The current source (I_o) will remain at the constant valve set by Vcc and R



* نلاحظ ان قيمة تيار (I_o) تكون قليلة لانها تساوي عادة (βI_{B_1})

(b) Current mirror with higher current and o/p impedance:

* يستخدم الـ current mirror في الدوائر المتكاملة حيث يتم صنع الترانزستورات بنفس الوقت لضمان ان يكونان متطابقان identical or (matched) حيث يكون تيار (I_E) لـ Q_2 و Q_1 نفس التيار وبالتالي فان التيار المار بـ Q_1 والمحدد من الـ Vcc يكون نفس التيار لـ Q_2 وكأنها مرآة تعكس الصورة لذلك تسمى بـ current mirror

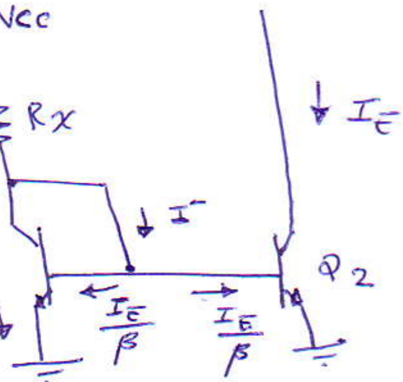


(b) current source with higher o/p impedance

$$\therefore \boxed{I_{C_1} \cong I_{E_1} \cong I_x}$$

* Identical or matched تعني ان قيمة V_{BE} متساوية لكلا الترانزستورين وكذلك الـ β

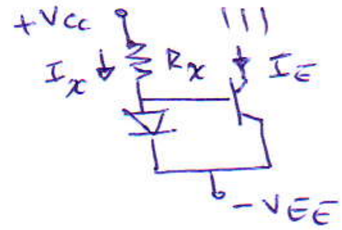
Analysis of current Mirror circuit:



$$I_B = \frac{I_E}{1+\beta} \simeq \frac{I_E}{\beta}$$

and $I_C \simeq I_E$

I_E (for both transistor is the same)



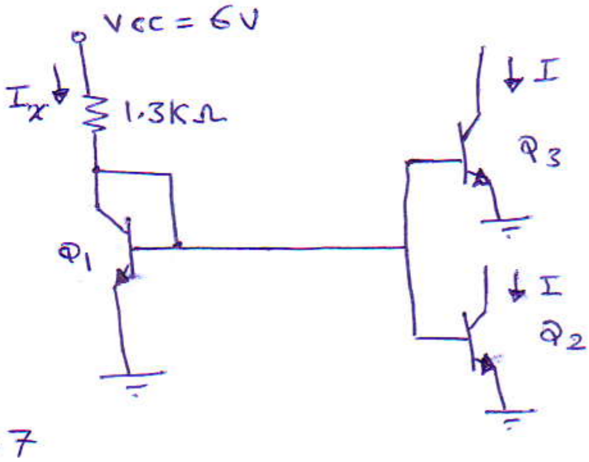
$$I^- = \frac{I_E}{\beta} + \frac{I_E}{\beta} = \frac{2I_E}{\beta}$$

$$I_x = I_E + I^- = I_E + \frac{2I_E}{\beta} = \frac{(\beta+2)}{\beta} I_E \simeq \boxed{I_E}$$

$$I_x = \frac{V_{CC} - V_{BE}}{R_x}$$

∴ نلاحظ ان التيار I_x يساوي نفس التيار I_E في الـ Q_2 (current mirror)

Ex: Calculate the current I through each of transistor Q_2 and Q_3 in the circuit below?



Solution:

$$I_x = I_E + \frac{3I_E}{\beta}$$

$$= \left(\frac{\beta+3}{\beta}\right) I_E \simeq I_E$$

$$I \simeq I_x = \frac{V_{CC} - V_{BE}}{R_x} = \frac{6 - 0.7}{1.3\,K\Omega}$$

$$\boxed{I = 4.08\,mA}$$

Ex: Design a current mirror source for a differential amplifier with current 1mA for each transistor if $V_{CC} = 12V$ and $V_{EE} = -6V$.

Solution:

$I_{E_1} = I_{E2} = 1mA$ (given)

$\Rightarrow I_o = I_{E_1} + I_{E2} = \boxed{2mA}$

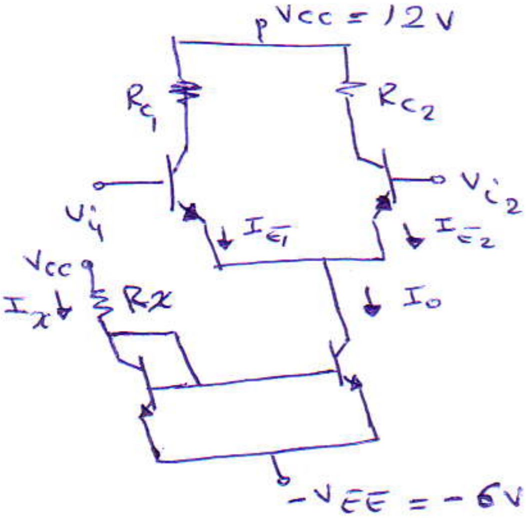
∵ Active load is a current mirror

∴ $I_o = I_x = \boxed{2mA}$

$$\Rightarrow R_x = \frac{V_{CC} + V_{EE} - V_{BE}}{I_x}$$

$$= \frac{12 + 6 - 0.7}{2m} = \boxed{8.65 k\Omega}$$

* ملاحظة : رسم الدائرة هو جزء من الحل وهو غير معطى في السؤال



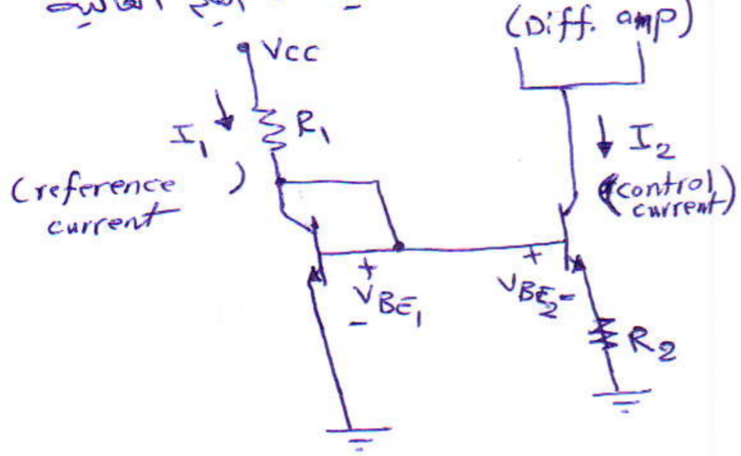
* ملاحظة: اذا كانت قيمة تيار I_x تساوي مثلاً 20μA فان قيمة المقاومة R_x تصبح (865k) وهذه القيمة كبيرة يصعب او قد يكون مستحيل تصنيعها داخل الـ (IC) لذلك يجب ان تكون قيم التيارات منطقية وبالتالي تكون قيم المقاومات منطقية! بالاضافة الى ذلك فان قيم التيارات العالية نسبياً تضمن ان كلا الترانزستورين في دائرة الـ (Diff) لها قيمة (biasing) جيدة.

5 Widlar current source:

for the current mirror example we see: a small reference current implies a large reference resistor, which is not always possible with conventional Integrated Circuit technology.

* لاحظنا من المثال السابق قيم التيارات الصغيرة جداً تحتاج قيم مقاومات كبيرة جداً لذلك نحتاج الى ربط جديد هو widlar لتلافي هذه القيم العالية

$$\boxed{I_2 = \frac{KT}{R_2} \ln\left(\frac{I_1}{I_2}\right)}$$



KT: thermal voltage (26mV at 300K)

Ex: Determine the value of resistor required for the widlar current source, if the reference current is 1mA and the control current is 10 μA (I_2).

Solution:

$$R_2 = \frac{KT}{I_2} \ln\left(\frac{I_1}{I_2}\right)$$

$$\Rightarrow R_2 = \frac{26\,mV}{10\,\mu A} \ln\left(\frac{1mA}{10\,\mu A}\right) = \boxed{12K\Omega}$$

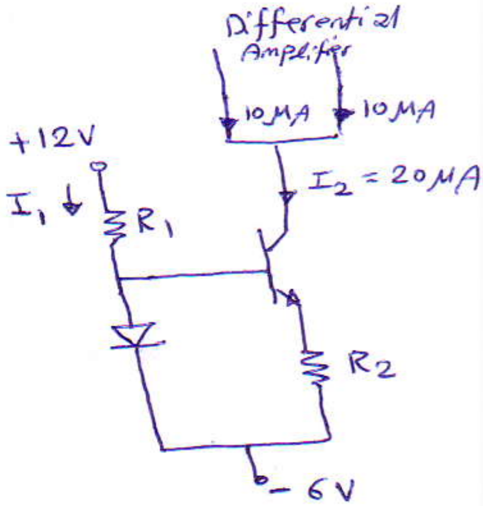
* نلاحظ مع قيمة تيار صغيره لل I_2 وهي (10μ) فان قيمة المقاومة مقبولة وهي (12k) وبالامكان تصنيعها داخل الـ (IC)

Ex: Design widlar current mirror source to obtain the current at each transistor for differential amplifier equal to 10 μA and the reference is 1 mA. (Vcc = 12V and VEE = −6V)

<u>Solution:</u>

$$R_1 = \frac{V_{CC} + V_{EE} - V_{diode}}{I_1 \text{ (reference)}}$$

$$= \frac{12 + 6 - 0.7}{1mA} = \boxed{17.3 K\Omega}$$

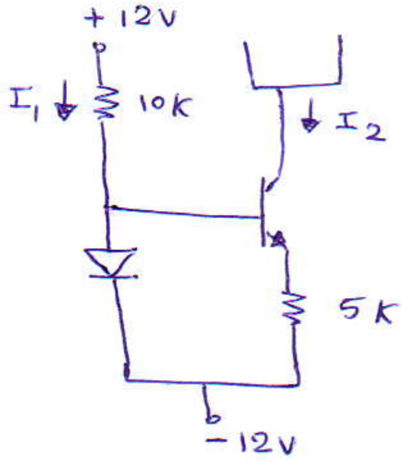


$$R_2 = \frac{KT}{I_2} \ln\left(\frac{I_1}{I_2}\right)$$

$$= \frac{26mV}{20 \mu A} \ln\left(\frac{1mA}{20 \mu A}\right) = \boxed{4.9 k\Omega}$$

Ex: Calculate the source circuit currents for the figure shown below?

<u>Solution:</u>



$$I_1 = \frac{12 + 12 - 0.7}{10k} = \boxed{2.33 mA}$$

$$I_2 = \frac{KT}{R_2} \ln\left(\frac{I_1}{I_2}\right)$$

$$\Rightarrow I_2 = \frac{26mV}{5k} \left(\ln\left[\frac{2.33 * 10^{-3}}{I_2}\right]\right)$$

H.w: Try and error to find I_2 value.

Input Resistance :

For differential amplifier with two inputs, there are two values of Rin (input resistance).

1- Rin (diff) : difference mode resistance, which exist between two inputs.

2- Rin (cm) : common mode resistance, which exist between each input and ground

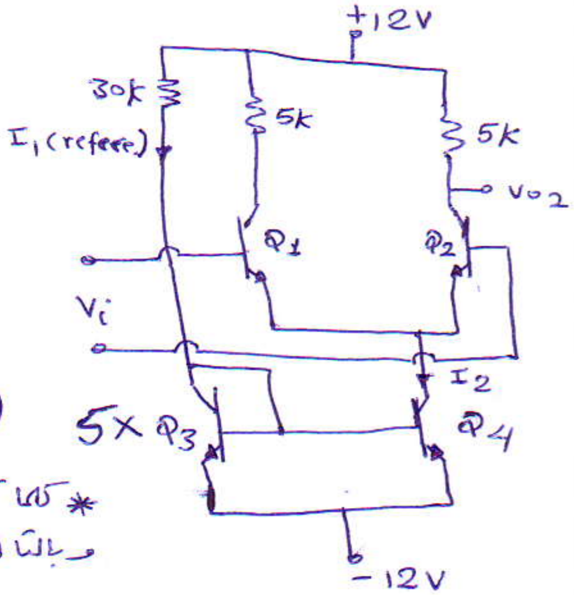
* $R_{in}(diff) = 2h_{ie} = 2\beta r_e$

* $R_{in}(cm) = 2\beta R_E$ (R_E is the emitter resistance; if R_E is replaced with current mirror source, the o/p resistance associated with the current source)

Ex: For the circuit shown below, determine the differential and common mode input resistances. The early voltage is 90V and β is 200. Assume that the Area of Q4 is one to fifth that of Q3.

to be continue

Solution:



$$I_1 = I_{reference} = \frac{V_{CC} + V_{EE} - V_{BE}}{R_x}$$

$$= \frac{12+12-0.7}{30K} = \boxed{776\,\mu A}$$

$$\therefore I_2 = \frac{I_1}{5} \text{ (because of emitter area)}$$

* كلما كانت مساحة ال (emitter) أكبر كان تيار ال trans. أكبر
وبالتالي فان تيار Q_3 خمسة اضعاف تيار Q_4

$$\Rightarrow I_2 = \frac{776}{5} = \boxed{155\,\mu A}$$

$$I_{E_1} = I_{E_2} = \frac{I_2}{2} = \frac{155\mu}{2} = \boxed{77.5\,\mu A}$$

$$r_e = \frac{26mV}{77.5\mu} = \boxed{335\,\Omega} = r_{e1} = r_{e2}$$

$$R_{in}(diff.) = 2h_{ie} = 2\beta r_e = 2(200)(335) = \boxed{134\,K\Omega}$$

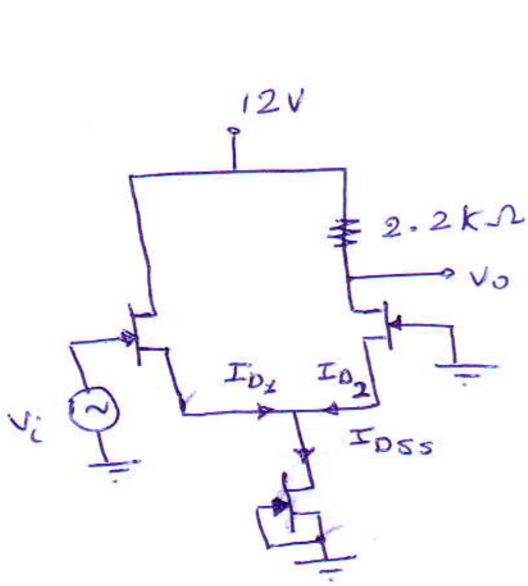
$$R_{in}(cm) = 2\beta R_E \qquad R_E: \text{(associated with current source)}$$

$$R_o(Q_4) = \frac{\text{early voltage}}{I_2} = \frac{90}{155\mu} = \boxed{580\,k\Omega} \text{ that equivalent to } R_E$$

$$\Rightarrow R_{in}(cm) = 2\beta R_E = 2(200)(580k) = \boxed{232\,M\Omega}$$

Ex: For the circuit shown below, determine the gain, assume $g_{mo} = 10\,mS$.

Solution:



$$A_V = \frac{1}{2} g_m R_L = \frac{1}{2} g_m R_D$$

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

for the FET current source, when $V_{GS} = 0 \Rightarrow I_D = I_{DSS}$

$$\therefore I_{D_2} = \frac{I_{DSS}}{2}$$

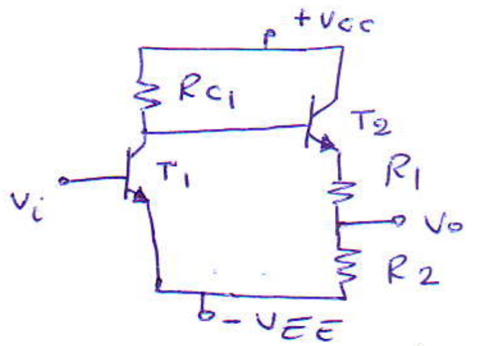
$$\Rightarrow \frac{\cancel{I_{DSS}}}{2} = \cancel{I_{DSS}}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \Rightarrow \frac{V_{GS}}{V_P} = \boxed{0.293}$$

$$\therefore g_m = 10m\,(1 - 0.293) = \boxed{7.07m\,S}$$

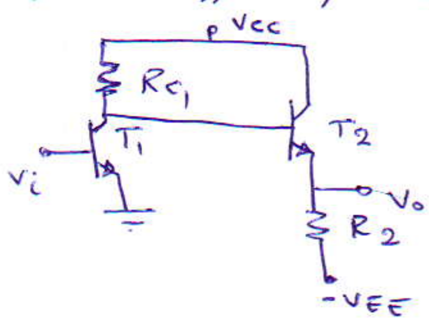
$$\therefore A_V = \frac{1}{2}(7.07m)(2.2K) = \boxed{7.7}$$

Ex: For the circuits shown below, calculate the o/p impedance.

(1)



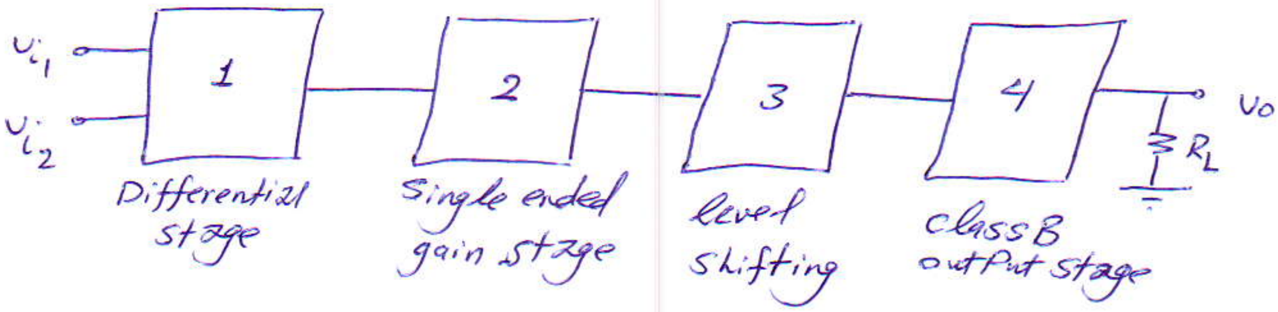
$$R_o = R_2 \,//\, \left(R_1 + \frac{h_{ie2} + R_{C1}}{\beta_2}\right)$$



$$R_o = R_2 \,//\, \left(\frac{h_{ie2} + R_{C1}}{\beta_2}\right)$$

Operational Amplifier Schematic:

A simplified schematic of an complete OP-Amp is shown in fig. below.

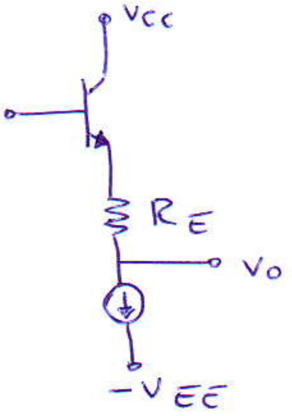


① $Ad_1 = \frac{-R_C}{r_e}$

② $Ad_2 = -\frac{R_C}{2r_e}$

* الفائدة من الـ (Diff. stage) هي الكسب اما المرحلة الثانية
وهي زيادة الكسب كذلك وحسب القانون الموضح ثانياً

③ D.c level shifting:



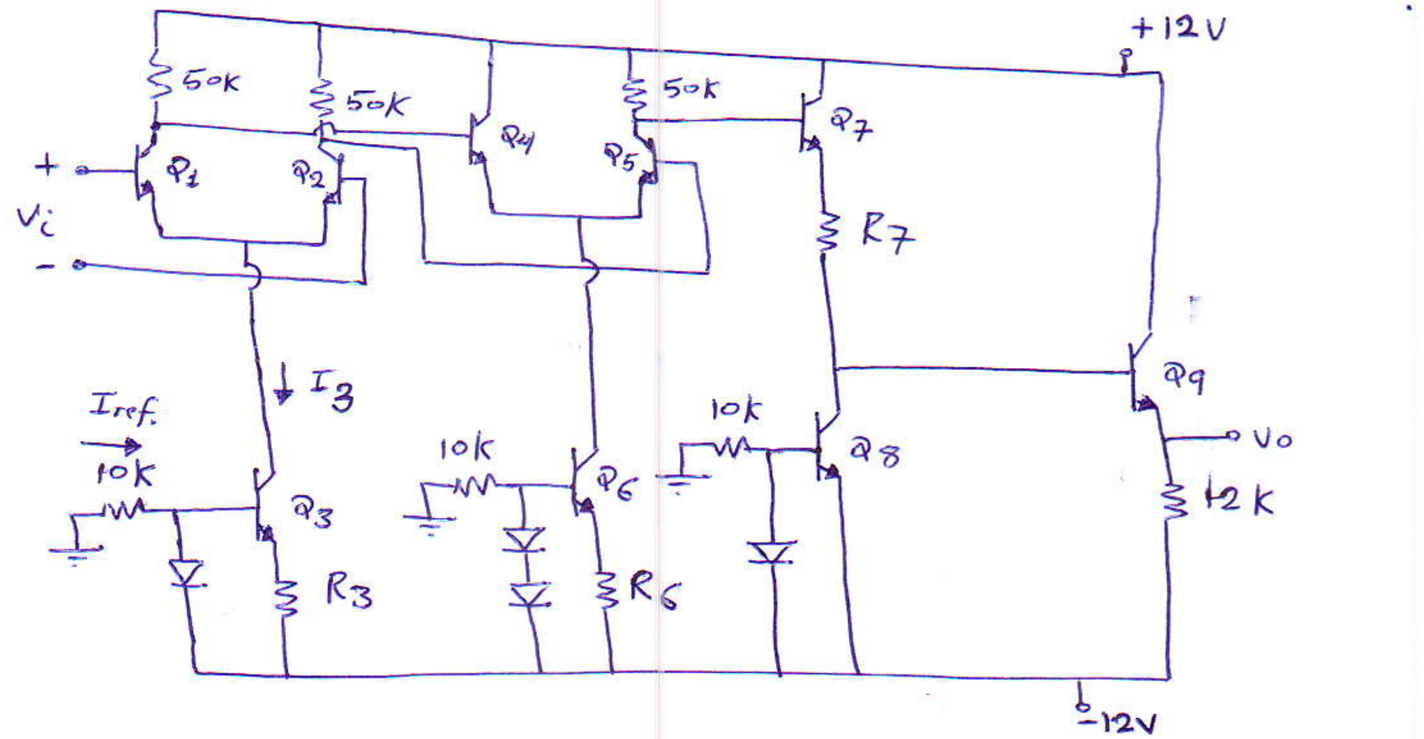
* المرحلة الثالثة وظيفتها هي حجب الـ D.C في الدورة حيث
ان المستمرة صعبة التصنيع ضمن الـ IC لذلك نلجأ الى
مرحلة ثالثة تقوم بقطع الـ D.C وهي عبارة عن
emitter follower trans. وهي تقوم بجعل الـ D.C voltage
من Vcc (+ve) في الادخال الى تقريباً -VEE (-ve)
في الاخراج وبالتالي طرح القيمتين وتكون نتيجة الدورة
تساوي صفر عند الـ D.C وكأنها مستمرة مربوطة قبل الـ (Vo) ←

④ class B output stage:

* وهو عبارة عن مرحلة تسمح ان تكون مقاومة الإخراج قليلة وكذلك تكون دائرة سوق
تيار (current driver) بمعنى تعطي قيم تيارات عالية ويستخدم فيها مكبر من نوع
class B Power amplifier

Ex: For the circuit shown below calculate:

1. R_3 and R_6 to obtain the current in Q_1 and Q_2 equal to $100\,\mu A$.
2. R_7 to obtain the output voltage swing to zero.
3. R_{in} and R_o
4. Gain, if ($\beta = 100$).
5. Is the level shifting stage prevents the D.C voltage in output?



Solution:

1.

$$I_{ref} = \frac{V_{EE} - V_{diode}}{R_x} = \frac{12 - 0.7}{10k} = \boxed{1.13\,mA}$$

$\because$ I_1 and I_2 are equal to $100\,\mu A$

$$\Rightarrow I_3 = I_1 + I_2 = \boxed{200\,MA}$$

$$\therefore R_3 = \frac{KT}{I_3} \ln\left(\frac{I_{ref}}{I_3}\right)$$ widlar current source

$$= \frac{25\,mV}{200\,MA} \ln\left(\frac{1.13\,mA}{200\,\mu A}\right) = \boxed{216.45\,k\Omega}$$ تقريبا

$$R_6 = \frac{V_{diode} + V_{diode} - V_{BE}}{I} = \frac{0.7}{200\mu} = \boxed{3500\,k\Omega}$$

(2)

$$R_7 = \frac{V_{CC} - 50k * I_5 - V_{BE7} - V_{BE9}}{I_{R7}} = \frac{12 - 50k * 100\mu - 0.7 - 0.7}{1.13\,mA} = \boxed{4.95\,k\Omega}$$

(3)

$$R_{in} = 2h_{ie} = 2\beta r_e = 2\beta * \frac{25\,mv}{100\mu A} = \boxed{50\,k\Omega}$$ (high input impedance)

$$R_o = 12k // \left(\frac{\frac{50k + h_{ie7}}{\beta_7} + R_7 + h_{ie9}}{\beta_9} \right)$$

$$h_{ie7} = \beta r_{e7} = 100 * \frac{25\,mv}{1.13\,mA} = \boxed{2.2\,k\Omega}$$

$$h_{ie9} = \beta r_{e9} = 100 * \frac{25\,mV}{I_{E9}} \qquad I_{E9} = (\cancel{V_o}^{0} + V_{EE})/12k = \frac{12\,V}{12k} = \boxed{1\,mA}$$

$$\therefore h_{ie9} = \boxed{2.5\,k\Omega} \Rightarrow R_o = \boxed{79\,\Omega}$$ (low output impedance)

(4)

$$A_{vT} = A_{v1} * A_{v2}$$

$$A_{v1} = -\frac{R_L^-}{r_{e2}} = -\left(\frac{50k // h_{ie4}}{r_{e2}} \right) \qquad h_{ie4} = \beta r_{e4} = 100 * \frac{25\,mv}{100\mu A} = \boxed{25\,k\Omega}$$

$$\Rightarrow A_{v1} = \frac{-(50k // 25k)}{250} = \boxed{-66.66} \qquad r_{e2} = \frac{25\,mv}{100\mu A} = \boxed{250\,\Omega}$$

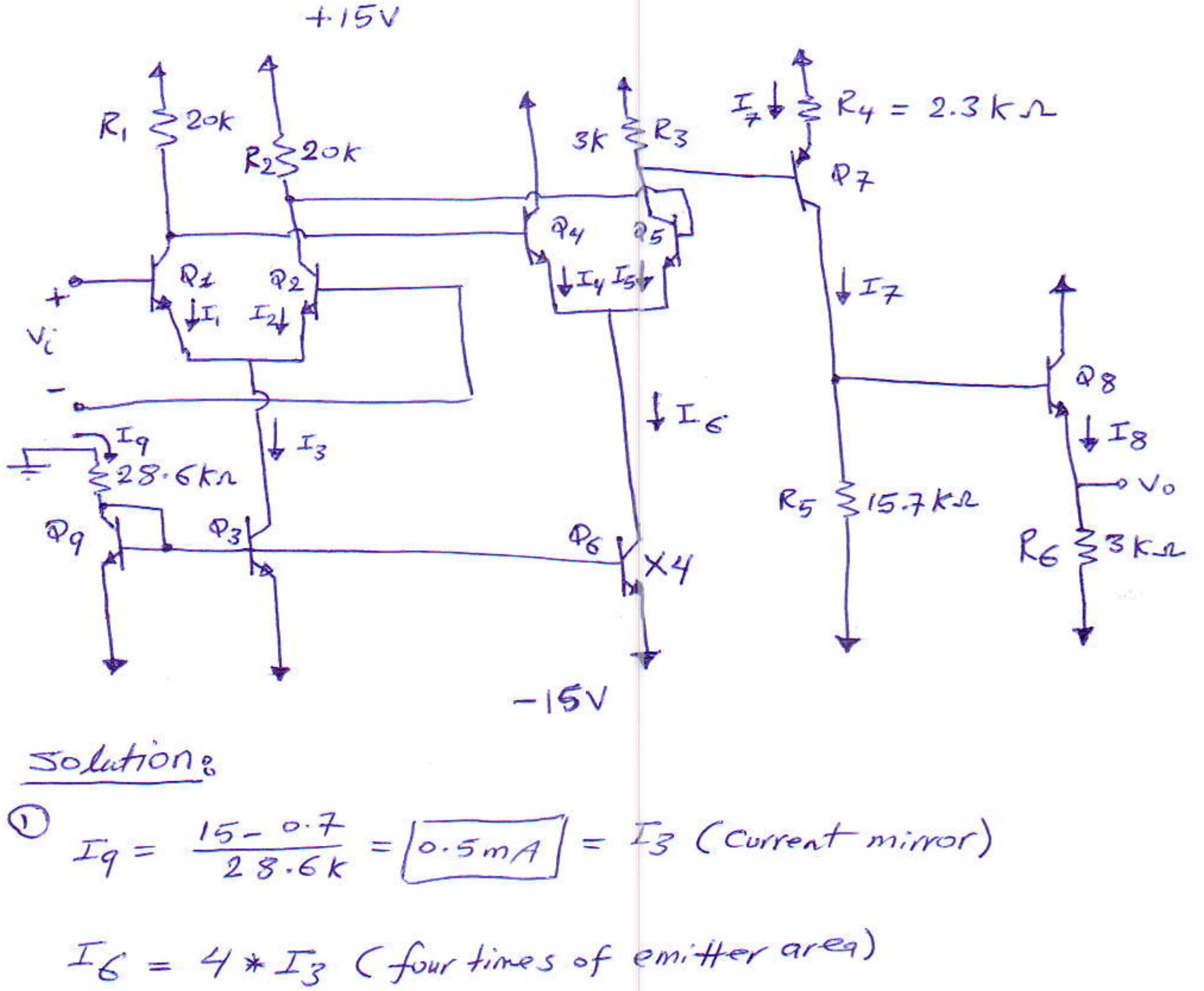
$$A_{v2} = -\frac{R_L^-}{2r_{e5}} = \frac{-50k}{2 * 250} = \boxed{-100}$$

$$A_{vT} = -66.66 * -100 = \boxed{6666.66}$$

(5) H.w.

Ex: For the circuit shown below, determine:

1. The currents in all branches, if the emitter area of Q_6 has four times the area of each of Q_9 and Q_3.
2. The power dissipation in this circuit.
3. The input bias current of the op-amp, if all transistors have $\beta = 100$.
4. $R_{in}(diff)$ and R_o.
5. Is the level shifting stage prevents D.C voltage in output
6. The voltage gain.



Solution:

① $I_9 = \frac{15 - 0.7}{28.6k} = \boxed{0.5mA} = I_3$ (current mirror)

$I_6 = 4 * I_3$ (four times of emitter area)

$\Rightarrow I_6 = 4 * 0.5mA = \boxed{2mA}$

يتبع

$$I_1 = I_2 = \frac{I_3}{2} = \frac{0.5mA}{2} = \boxed{0.25mA}$$

$$I_4 = I_5 = \frac{I_6}{2} = \frac{2mA}{2} = \boxed{1mA}$$

$$I_7 = I_{E_7} = \frac{3K * 1mA - V_{BE7}}{R_4} = \frac{3V - 0.7}{2.3k} = \boxed{1mA}$$

$$I_8 = \frac{\cancel{V_{EE}} - \cancel{V_{EE}} - V_{BE8} + I_7 R_5}{3k\Omega} = \frac{1m * 15.7k - 0.7}{3k\Omega} = \boxed{5mA}$$

(2)

$$P = IV$$

$$P_{diss} = I_{D.C} * V_{D.C}$$

* حساب القدره المستهلكة في اي دائره يكون نتيجة تأثير المصادر الـ D.C حيث يتم جمع التيارات لكل مصدر ومن ثم استخدام قانون القدره.

$$P_{diss(total)} = P^- + P^=$$

$$P^- = (I_1 + I_2 + I_4 + I_5 + I_7 + I_8)\, V_{CC}$$
$$= (0.25 + 0.25 + 1 + 1 + 1 + 5) * 15 = \boxed{127.5mW}$$

$$P^= = (I_3 + I_9 + I_6 + I_7 + I_8) * V_{EE}$$
$$= (0.5 + 0.5 + 2 + 1 + 5) * 15 = \boxed{135mW}$$

$$P_{diss} \text{ or } P_D = P^- + P^= = 127.5 + 135 = \boxed{262.5mW}$$

(3) $I_{bias} = I_{B1} = I_{E1}/\beta+1 = \frac{0.25mA}{101} \simeq \boxed{2.5\mu A}$

(4) $R_{in(diff)} = 2\beta r_e \qquad r_e = \frac{25mV}{0.25mA} = \boxed{100\Omega}$

$\Rightarrow R_{in(diff)} = 2(100)(100) = \boxed{20k\Omega}$ high input impedance

$$R_o = 3k \parallel \left(\frac{R_5 + h_{ie8}}{1+\beta}\right) = 3k \parallel \left(\frac{15.7k + (\frac{25mV}{5mA})(100)}{101}\right) = \boxed{152\Omega}$$

low o/p impedance

(5) $V_o = -V_{EE} + R_5 I_7 - 0.7 = -15 + (15.7k)(1mA) - 0.7 = 0V$

or

$V_o = 3k * I_8 - V_{EE} = 3k * 5mA - 15 = 0V$ level shifting Prevents the D.C voltage in o/p

يتبع

6
$$A_v = \frac{v_o}{v_{id}} = \frac{R_6 * i_{e8}}{R_{id} * i_i}$$

$$\frac{i_{e8}}{i_i} = \frac{i_{e8}}{i_{b8}} \cdot \frac{i_{b8}}{i_{c7}} \cdot \frac{i_{c7}}{i_{b7}} \cdot \frac{i_{b7}}{i_{e5}} \cdot \frac{i_{e5}}{i_{b5}} \cdot \frac{i_{b5}}{i_{c2}} \cdot \frac{i_{c2}}{i_i}$$

$$\frac{i_{e8}}{i_{b8}} = \beta + 1 = \boxed{101} \; ; \; \frac{i_{b8}}{i_{c7}} = \frac{R_5}{R_5 + Z_{b8}} = \frac{15.7K}{15.7K + (101)(3K) + (\frac{25m}{5m})(100)}$$

$$\Rightarrow \frac{i_{b8}}{i_{c7}} = \boxed{0.049} \; ; \; \frac{i_{c7}}{i_{b7}} = \beta = \boxed{100} \; ; \; \frac{i_{b7}}{i_{c5}} = \frac{R_3}{R_3 + Z_{b7}}$$

$$\Rightarrow \frac{i_{b7}}{i_{c5}} = \frac{R_3}{R_3 + h_{ie7} + (1+\beta)(R_4)} = \frac{3K}{3K + (100)(\frac{25mV}{1mA}) + (101)(2.3K)} = \boxed{0.0126}$$

$$\frac{i_{c5}}{i_{b5}} = \beta = \boxed{100} \; ; \; \frac{i_{b5}}{i_{c2}} = \frac{R_1 + R_2}{R_1 + R_2 + 2h_{ie(4,5)}}$$

$$\Rightarrow \frac{i_{b5}}{i_{c2}} = \frac{20K + 20K}{40K + 2(100)(\frac{25mV}{1mA})} = \boxed{0.888}$$

$$\because i_{c2} \approx i_{e2} \quad \therefore \frac{i_{c2}}{i_i} = \beta = \boxed{100}$$

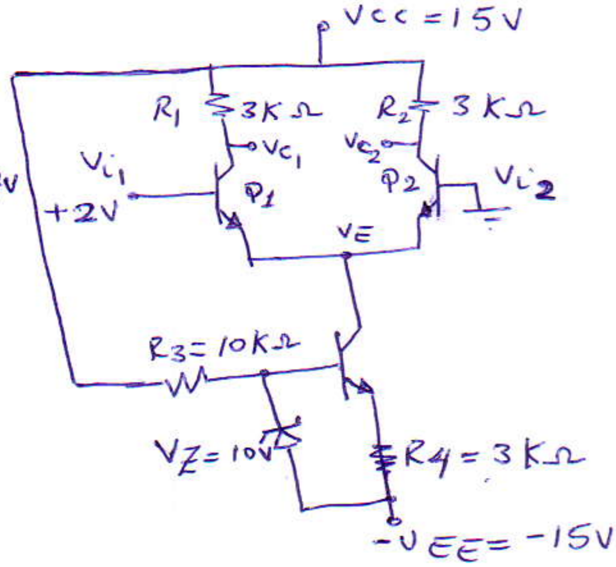
$$\Rightarrow \frac{i_{e8}}{i_i} = (101)(0.049)(100)(0.0126)(100)(0.888)(100)$$
$$= \boxed{55373.4}$$

$$\Rightarrow A_v = \frac{3K}{20K} * 55373.4 = \boxed{8306 \text{ V/V}}$$

H.W :

① for the circuit shown below; find

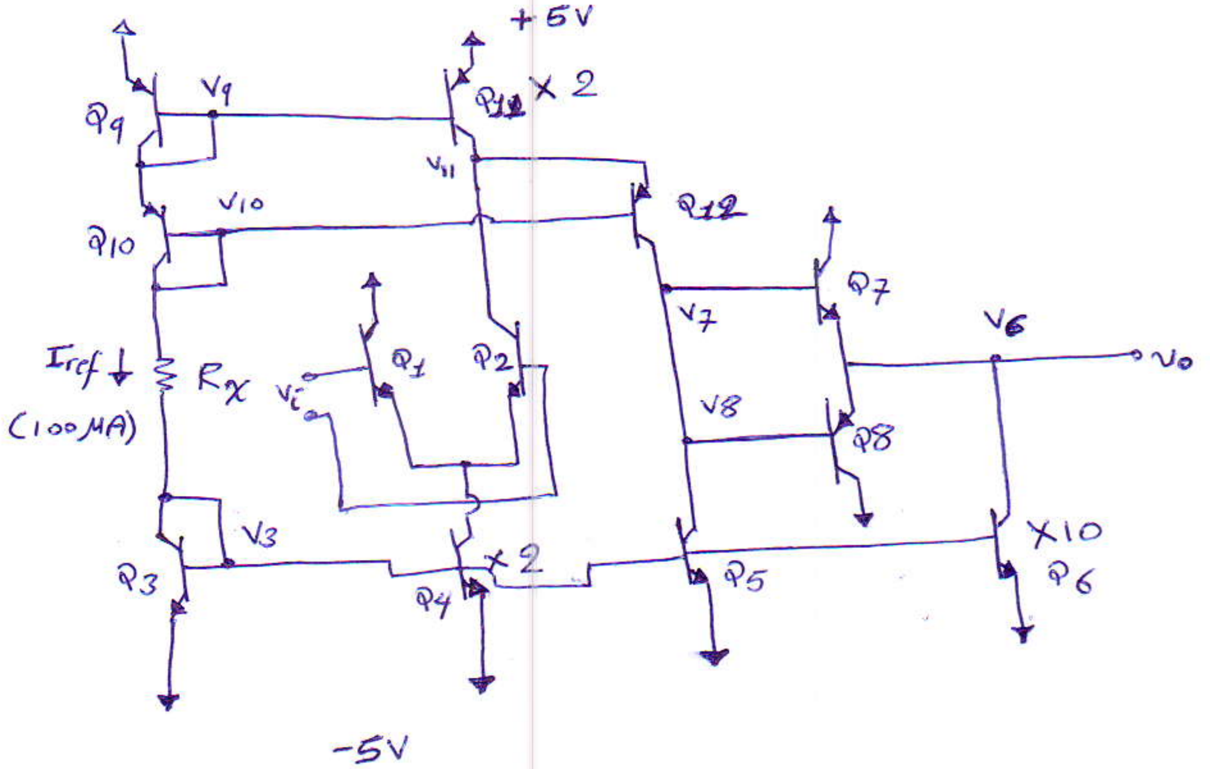
ⓐ V_{C_1} and V_{C_2} ? ⓑ If $V_{i_1} = 0V$ and $V_{i_2} = 1.7V$ Repeat Part a ?



Ans : ⓐ $V_{C_1} = 5.7V$; $V_{C_2} = 15V$

ⓑ $V_{C_1} = 15V$; $V_{C_2} = 5.7V$

② For the circuit shown below; find the Voltages and Currents in each branch as indicated on the circuit.



Ans: $I_{ref} = I_3 = I_{10} = I_9$; $I_4 = 200\mu A$, $I_1 = I_2 = 100\mu A$; $I_{11} = 200\mu A$

$I_{12} = I_5 = 100\mu A$, $I_6 = 1mA$, $I_8 = 0mA$, $I_7 = I_6 = 1mA$

Q_8 (off); $V_7 = V_8 = 0.7V$; $V_{10} = 3.6V$; $V_9 = 4.3V$; $V_3 = -4.3V$

$V_{11} = 4.3V$; $R = 79 K\Omega$; $V_6 = 0V$.