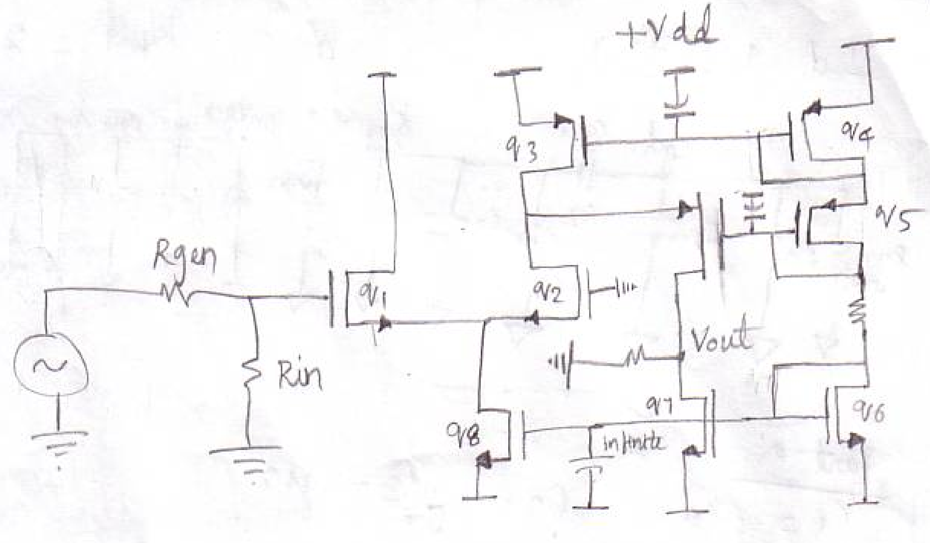


To find Rbias we need Vgs.

$$I_d = g_m(V_{gs} - V_{th})$$

$$V_{gs} = \frac{I_d}{g_m} + V_{th} = \frac{0.2\,mA}{1\,m\mho} + 0.3\,V = 0.5\,V$$

$$R_{bias} = \frac{[6 - 3(V_{gs})]V}{0.2\,mA} = \frac{[6 - 4.5]V}{0.2\,mA} = \underline{\underline{22.5\,k\Omega}}$$

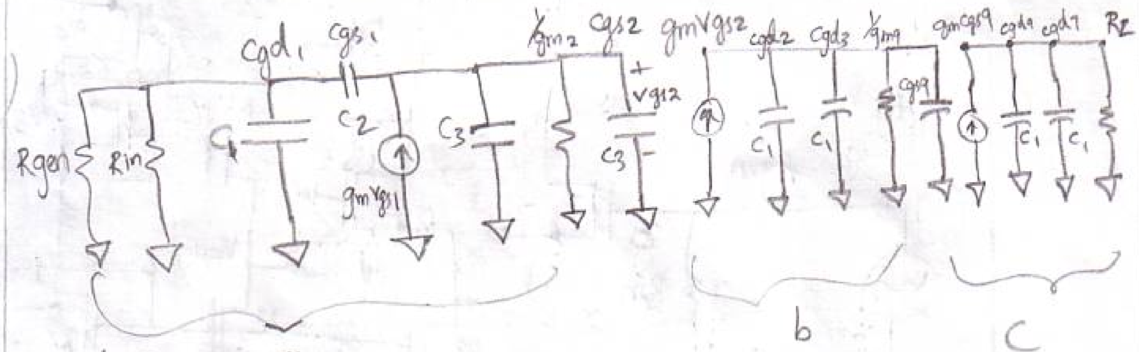
To find Wg we have

$I_{d,8} = 0.4\,mA = 2 \cdot I_{d,6}$ } $W_{g,8} = 2 \cdot W_{g,6} = 4\,um$

$I_{d,3} = 0.4\,mA = 2 \cdot I_{d,4}$ } $W_{g,3} = 2 \cdot W_{g,4} = 4\,um$

$I_{d,7} = I_{d,6} = 0.2\,mA \rightarrow W_{g,7} = W_{g,6} = 2\,um$

$I_{d,9} = I_{d,5} = 0.2\,mA$, $h_{g,9} = 2\,um$



Part a

$C_1 = c_{gd1}$, $C_3 = c_{gd8} + C_{gs2}$

$C_2 = c_{gs1}$

$$a_1 = (R_{11}^{\circ} C_1 + R_{22}^{\circ} C_2 + R_{33}^{\circ} C_3)\ \text{sec}$$

$$R_{11}^{\circ} = R_{gen} \,||\, R_{in} = 10k \,||\, 9k = 909\ \Omega$$

$$R_{22}^{\circ} = R_i(1 - A_v) + r_{e1} \,||\, R_{Leq} = R_i\left(1 - \frac{R_{Leq}}{R_{Leq} + \frac{1}{g_{m1}}}\right) + \frac{1}{g_{m1}} \,||\, \frac{1}{g_{m2}}$$

Here $R_{Leq} = r_{e2} = 1/g_{m2}$.

$$R_{22}^{\circ} = R_i\left(1 - \frac{1/g_{m2}}{\frac{1}{g_{m2}} + \frac{1}{g_{m1}}}\right) + 1000\,\Omega \,||\, 1000\,\Omega$$

$$R_{22}^{\circ} = 909 \times \frac{1}{2} + 500 \simeq 955\ \Omega.$$

$$R_{33}^{\circ} = \frac{1}{\ } \,||\, \frac{1}{\ } = 500\ \Omega$$

the above values we can calculate

$a_1 = [R_{11}^{\circ} C_{gd1} + R_{22}^{\circ} C_{gs1} + R_{33}^{\circ}(C_{gd8} + C_{gs2})]$ sec

$a_1 = 909\,\Omega\, C_{gd1} F + 955\,\Omega\, C_{gs} F + 500\,\Omega\,(C_{gd8} + C_{gs2}) F$

$C_{gd1} = 0.133\ fF$ from $f_T = \dfrac{g_m}{2\pi(C_{gs} + C_{gd})}$

$C_{gs1} = 0.663\ fF$

$\left.\begin{array}{l} C_{gd8} = 0.265\ fF \\ \\ \end{array}\right\}$ for Q_3, Q_8.

$a_1 = (909\,\Omega)(0.133\ fF) + 955\,\Omega(0.663\ fF)$
$+ 500\,\Omega\,(0.265 + 0.663)$

$a_1 = 1.2$ psec

$a_2 = (R_{11}^{\circ} C_1 C_2 R_{22}^{1} + R_{11}^{\circ} C_1 C_3 R_{33}^{1} + R_{22}^{\circ} C_2 C_3 R_{33}^{2})$ sec

$R_{11}^{\circ}, R_{22}^{1}, R_{33}^{1}, R_{22}^{\circ}, R_{33}^{2}$ – units Ω, C_1, C_2, C_3 – units Fara

$R_{22}^{1} = \dfrac{1}{g_{m1}} \| \dfrac{1}{g_{m2}} = 500\,\Omega$ → Resistance as seen from port 2 with Ri

$R_{33}^{1} = R_{33}^{\circ}$ with $R_i = 0$; R_{22}^{1} → is simply R_{22}° with $Ri = 0$

$R_{33}^{1} = 500\,\Omega$; $R_{22}^{3} = R_i = 909\,\Omega$ (see next page

$a_2 = (909\,\Omega)(0.133\ fF)(0.663\ fF)(500\,\Omega) + (909\,\Omega)(0.133\ fF)(0.928\ fF)(500\,\Omega)$
$+ (500\,\Omega)(0.663\ fF)(0.928\ fF)(909)$

$a_2 = 3.75 \times 10^{-25}\ sec^2$

the above values we can calculate
$[R_{11}^{\circ} C_{gd1} + R_{22}^{\circ} C_{gs1} + R_{33}^{\circ}(C_{gd8} + C_{gs2})]$ sec

$909\Omega\, C_{gd1} F + 955\Omega\, C_{gs} F + 500\Omega\,(C_{gd8} + C_{gs2}) F$

$= 0.133$ fF from $f_T = \dfrac{g_m}{2\pi(C_{gs} + C_{gd})}$

$1 = 0.663$ fF

$8 = 0.265$ fF
$.8 = 1.33$ fF } for Q_7, Q_8.

$_1 = (909\Omega)(0.133$ fF$) + 955\Omega(0.663$ fF$)$
$+ 500\Omega\,(0.265 + 0.663)$ fF

$_1 = 1.2$ p sec

$a_2 = (R_{11}^{\circ} C_1 C_2 R_{22}^{1} + R_{11}^{\circ} C_1 C_3 R_{33}^{1} + R_{22}^{\circ} C_2 C_3 R_{33}^{2})$ sec^2
$R_{11}^{\circ}, R_{22}^{1}, R_{33}^{1}, R_{22}^{\circ}, R_{33}^{2}$ – units Ω, C_1, C_2, C_3 – units Farad

$R_{22}^{1} = \dfrac{1}{g_{m1}} \| \dfrac{1}{g_{m2}} = 500\Omega$ → Resistance as seen from port 2 with $R_i = 0$

$R_{33}^{1} = R_{33}^{\circ}$ with $R_i = 0$; R_{22}^{1} → is simply R_{22}° with $R_i = 0$

$R_{33}^{1} = 500\Omega$; $R_{22}^{3} = R_i = 909\Omega$ (see next page)

$a_2 = (909\Omega)(0.133\text{fF})(0.663\text{fF})(500\Omega) + (909\Omega)(0.133\text{fF})(0.928\text{fF})(500\Omega)$
$+ (500\Omega)(0.663\text{fF})(0.928\text{fF})(909)$

$a_2 = 3.75 \times 10^{-25}$ sec^2

In the calculation of a_2 we had the term $R_{22}^{0} C_2 C_3 R_{33}^{2}$

We can equal this term as

$$R_{22}^{0} C_2 C_3 R_{33}^{2} = R_{22}^{3} C_2 C_3 R_{33}^{0}$$

R_{22}^{3} is the resistance at port 2 with port 3 shorted.

Thus $R_{22}^{3} = R_i = 909\ \Omega$

For capacitances

$$C_{gd7} = C_{gd9} = 0.133\ fF$$

$$C_{gd2} + C_{gd3} + C_{gs9} = 0.133\ fF + 0.265\ fF + 0.663\ fF$$

$$C_{gd2} + C_{gd3} + C_{gs9} = 1.06\ fF$$

From $1 + 1.22 \times 10^{-12} s + 3.75 \times 10^{-25} s^2 = 0$

we have

$$s = (-1.62 \pm j0.1932) \times 10^{10}.$$

Thus we have $\omega_n = \frac{1}{\sqrt{a_2}} \frac{rad}{sec} = \frac{1}{\sqrt{3.75\times10^{-25}}} \frac{rad}{sec} = 1.63\times10^{12} \frac{rad}{sec}$

$f_P = 2.6\times10^{11}\ Hz$

$f_P = 260\ GHz$ — Natural frequency

Thus there is a $-40\,dB$ roll off at 260GHz

Part b

$C_1 = (C_{gd2} + C_{gd3} + C_{gs9})F$, $R_{11}^{o} = \frac{1}{g_{m9}} = 1000\,\Omega$

$C_1 = 1.06\ fF$

$a_1 = C_1 R_{11}^{o} = 1.06\ p\,sec$

$f_{P1} = \frac{1}{2\pi\times1.06\,p\,sec} \simeq 0.15\times10^{12}\ Hz$

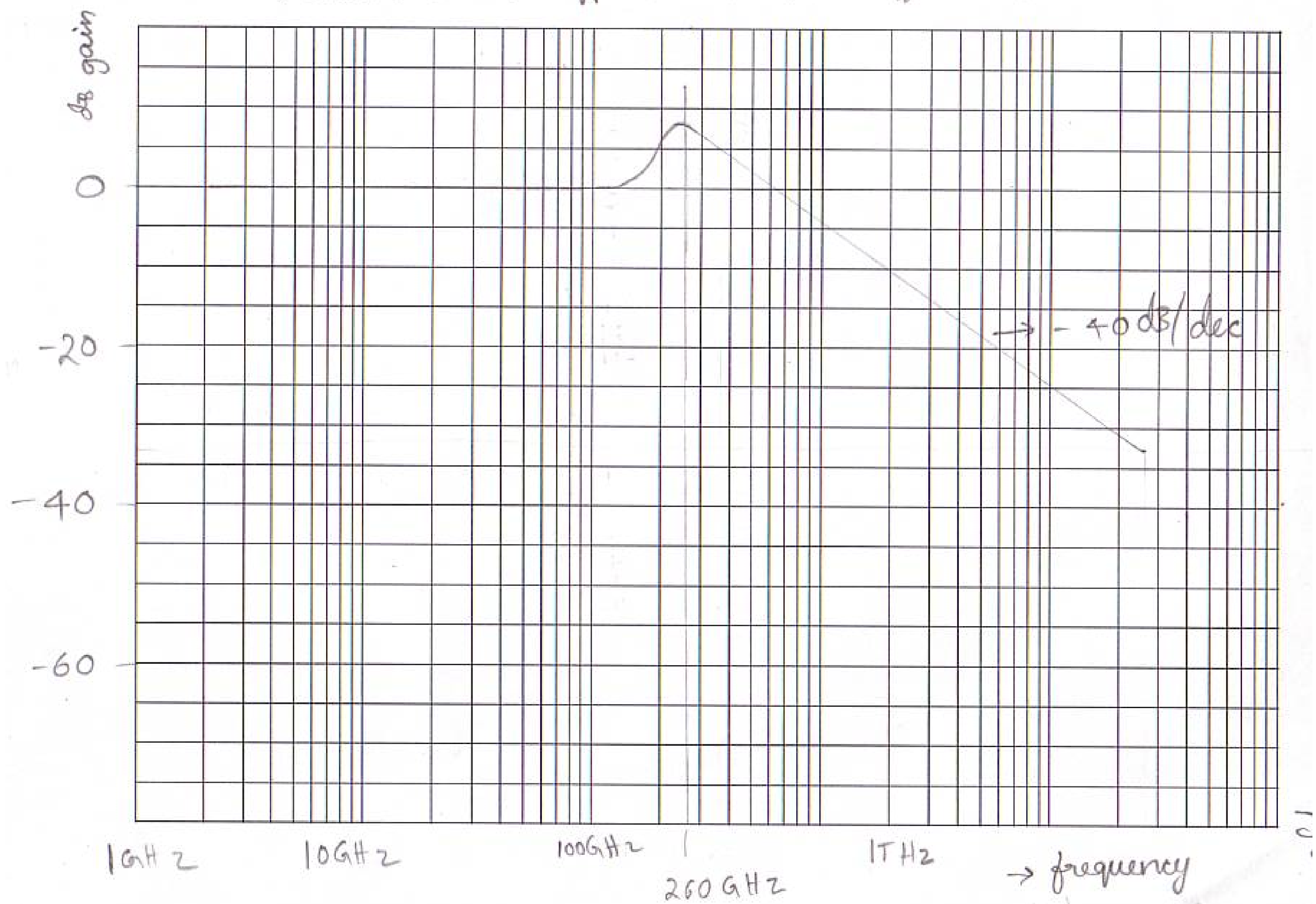
$$\boxed{f_P = 150\ GHz}$$

Part c

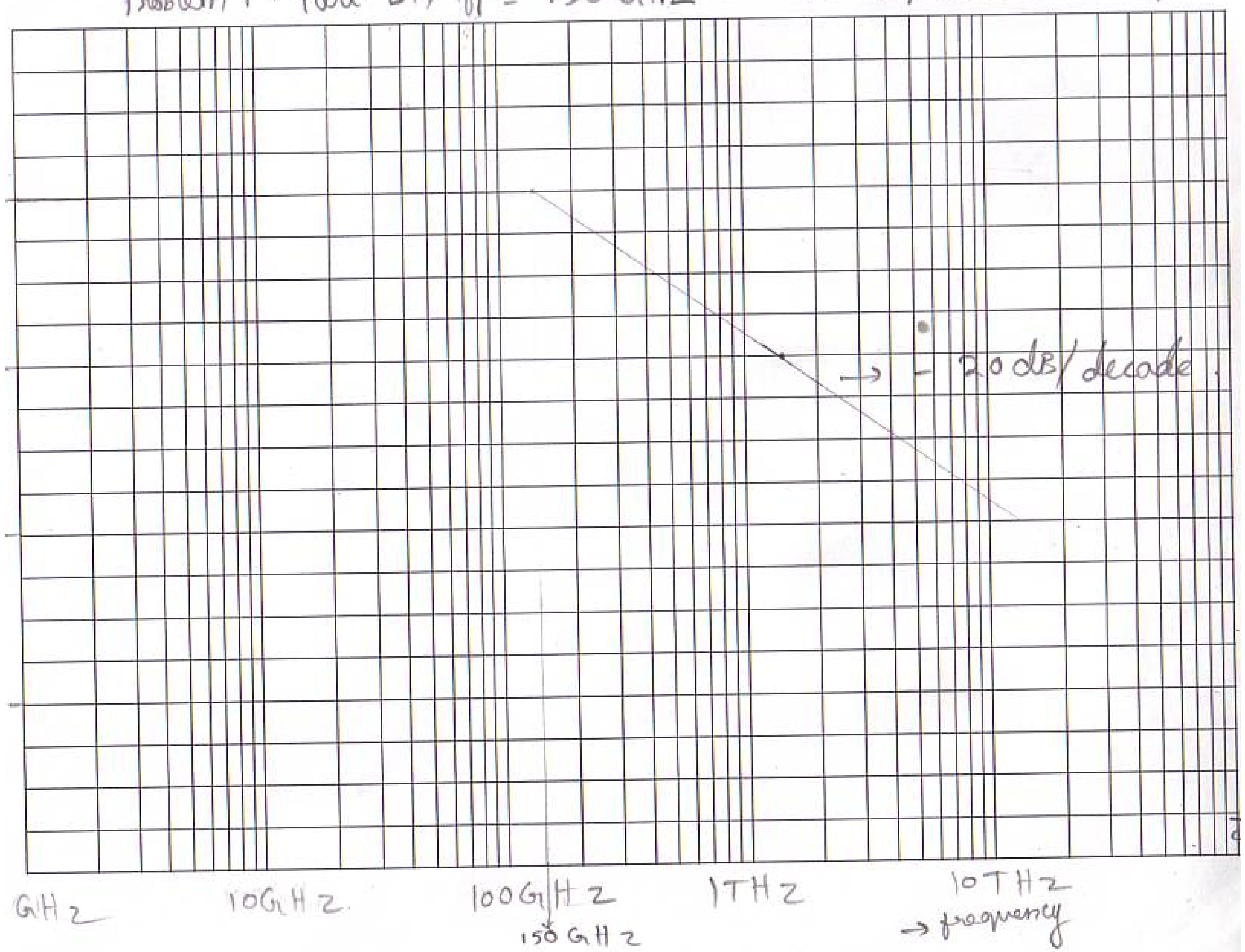
$C_1 = C_{gd9} + C_{gd7} = 0.13263\,fF + 0.13263\,fF$

$C_1 = 0.265\ fF$

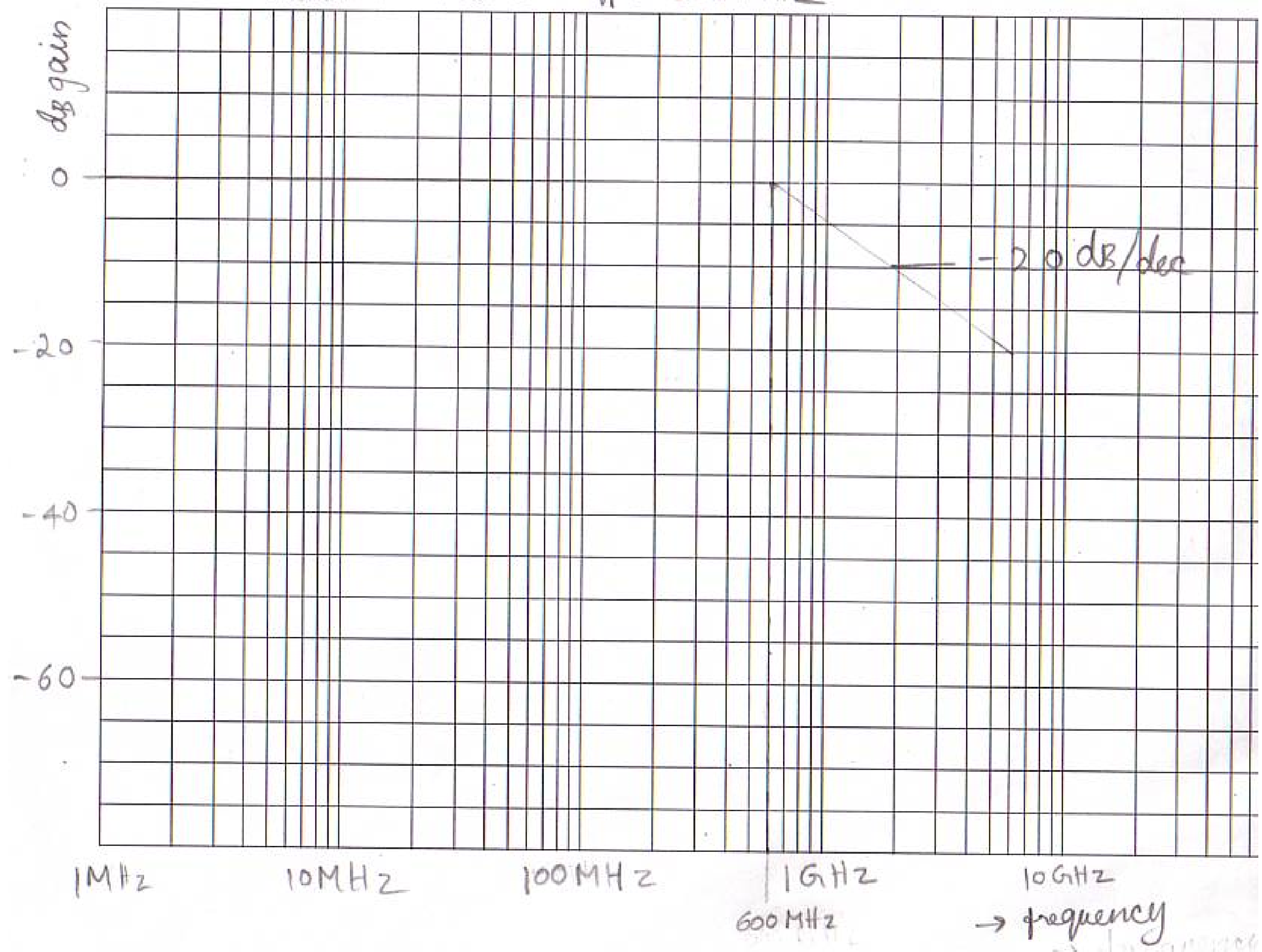
Problem 1 Part A - f_p = 260GHz, roll off = - 40 dB/decade



Problem 1 - Part B $\rightarrow f_p = 150$ GHz $\rightarrow$ -20 dB/decade roll off



Problem 1 - Part C- f_p = 600 MHz



$R_{11}^{o} = R_L = 1M\Omega$

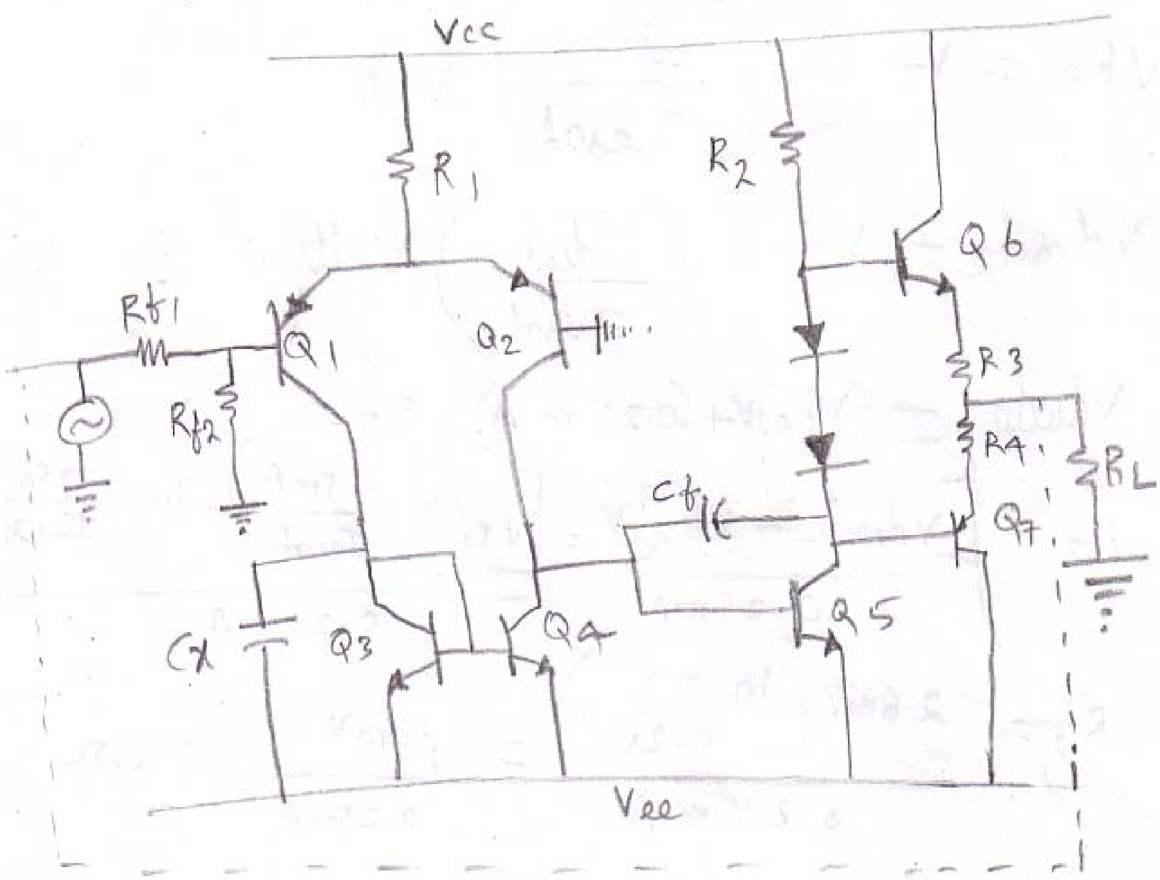
$a_1 = C_1 R_{11}^{o} = 0.26526 fF \times 10^6 \Omega$

$a_1 = 0.26526 \, ns$

$$f_{pc} = \frac{0.159}{2.6 \times 10^{-10}} = \boxed{6 \times 10^8 \, Hz}$$

$= 600 \, MHz$

Problem 2



$$R_1 = \frac{[V_{cc} - 0.7]\,\text{Volts}}{[2 I_e]\,A} = \frac{(3 - 0.7)\,\text{Volts}}{2\cdot\left(0.2mA + \frac{0.2mA}{100}\right)}$$

$$R_1 = 5.7k\Omega$$

$$R_2 = \frac{(V_{cc} - 0.7)V}{(I_{c5})A} = \frac{2.3V}{0.5mA} = 4.6\ V$$

$$I_c = \left(I_{e\,sat} \times e^{\frac{V_{be}}{V_T}}\right) A$$

$$V_{be} = V_T \ln\left(\frac{I_c}{I_{esat}}\right) \text{Volts}$$

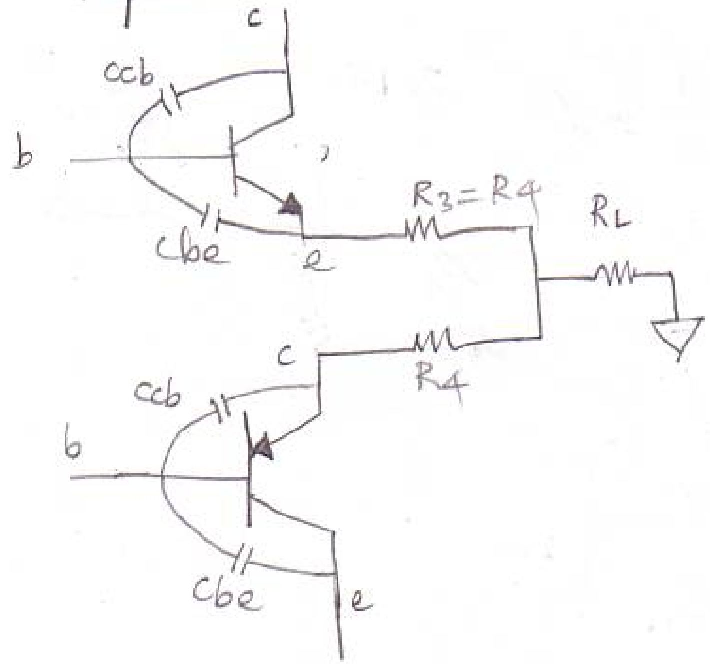
$$V_{diode} = V_T \ln\left(\frac{I_{diode}}{I_{esat}}\right) \text{Volts}$$

$$V_{diode} = (V_{be})V + (0.25\ mA)\cdot R_3\,\Omega$$

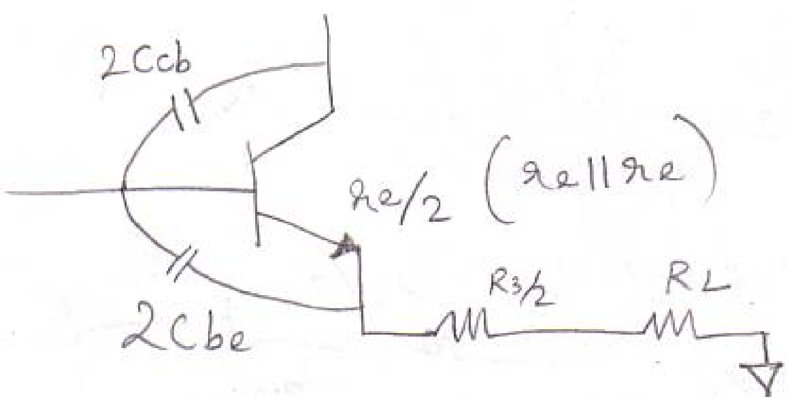
$$R_3 = \frac{[V_{diode} - V_{be}]V}{0.25mA} = \frac{\left[V_T\left(\ln\left(\frac{0.5mA}{I_{esat}}\right) - \ln\left(\frac{0.25mA}{I_{esat}}\right)\right)\right]V}{0.25mA}$$

$$R_3 = \frac{26mV\left(\ln\frac{0.5}{0.25}\right)}{0.25mA} = \frac{18mV}{0.25mA} = 72\Omega$$

Q_6 and Q_7 can be equivalently (pg 11) represented as



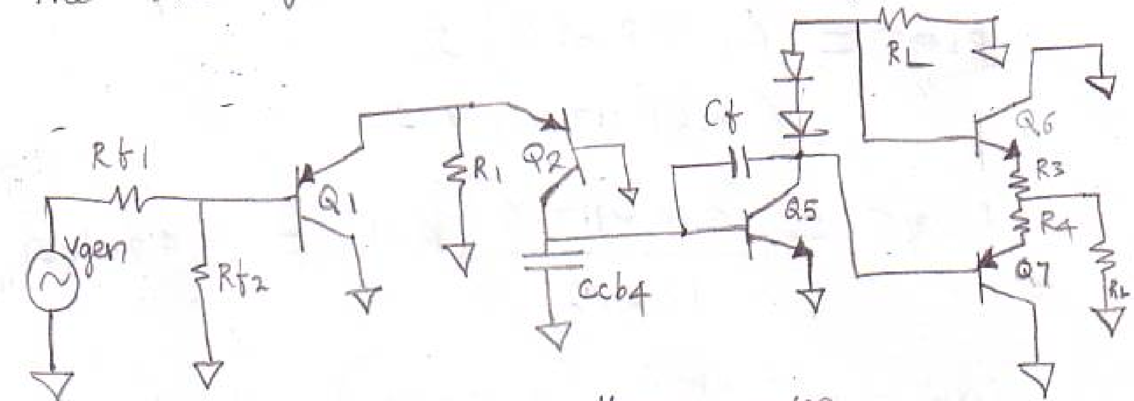
$\Downarrow$



Inorder to calculate the gain around the feedback loop we should determine

AV1, AV2, AV5, AV6.

The AC equivalent circuit is as follows.



Let us consider the voltage gain from the output to the input

$$AV_6 = \left(\frac{RLeq\,6\ \Omega}{(re\,6 + RLeq\,6)\Omega} \times \frac{RL\ \Omega}{(R_3+R_4)\Omega} \right)$$

$AV6 = 0.85$

$AV_5 = -gm5\left(\frac{1}{\Omega}\right) RLeq5\,(\Omega)$

$$gm5 = \frac{0.5\,mA}{26\,mV}$$

$RLeq5 = (R_2 \,\|\, Rint6)\,\Omega$

$RLeq5 = [4.6\,K\Omega \,\|\, Rint6\ \Omega]$

$Rint6 = [\beta\,(re6 + R_3 + RL)]\,\Omega$

$$R_{int6} = \beta(r_{e6} + R_3 + R_L)\ \Omega$$

$$R_{int6} = 100(104 + 72 + 1000)\ \Omega$$

$$R_{int6} = 100\ (1176) = 117.6\ k\Omega$$

$$R_{Leq5} = (R_2 \parallel R_{int6})\ \Omega$$

$$= (4.6 \parallel 117.6)\ k\Omega$$

$$R_{Leq5} = \left(\frac{4.6 \times 117.6}{122.2}\right) k\Omega = 4.426\,k\Omega$$

$$A_{V5} = -\frac{0.5mA}{26mA}(4.426k)$$

$$A_{V5} = -85$$

$$A_{V2} = g_{m2}\left(\frac{1}{\Omega}\right) R_{in5}\ \Omega$$

$$R_{in5} = \beta r_{e5}$$

$$A_{V2} = \frac{0.2mA}{26mV}(100) \times \frac{26mV}{0.5mA} = 40$$

$$A_{V1} = \frac{(R_{f2} \parallel R_{inT1})\Omega}{(R_{f1} + R_{f2} \parallel R_{inT1})\Omega} \times \frac{(R_{Leq1})\Omega}{(r_{e1} + R_{Leq1})\Omega}$$

$$A_{V1} = 0.0969 \times 0.49 = 0.047$$

$R_{f1} = 9k$, $R_{f2} = 1k$, $R_{inT1} = \beta\,(r_{e1} + R_1 \parallel r_{e2})\,\Omega$

$$R_{inT1} = 100\left(\frac{26mV}{0.2mA} + 5.7k\Omega \parallel \frac{26mV}{0.2mA}\right)\Omega$$

$$R_{inT1} = 25.7k\Omega$$

$$R_{Leq1} = \left(R_1(\Omega) \parallel \left(\frac{1}{g_{m2}}\right)\frac{1}{\Omega}\right) = 5.7\,k \parallel 130\Omega \simeq 129\Omega$$

Thus, voltage gain A_V is given by

$$A_V = A_{V1} \cdot A_{V2} \cdot A_{V3} \cdot A_{V4}$$

$$= 0.047 \times 40 \times -85 \times 0.85$$

$$A_V = -140$$

The dominant poles

we have for $\underline{PNP}$.

$C_{be1} = C_{je} + \tau_f g_m$

$= 50\,fF + (5\,ps)\left(\dfrac{0.2mA}{26mV}\right)$

$C_{be1} = 88.5\,fF$; $C_{be2} = 88.5\,fF$

$C_{be5} = C_{je} + \tau_f g_m$

$= 10\,fF + (1\,ps)\left(\dfrac{0.5mA}{26mV}\right)$

$C_{cb2} = 100\,fF$

$\underline{NPN}$

$C_{be5} = 29.231\,fF$

$C_{be6} = C_{je} + \tau_f g_m$

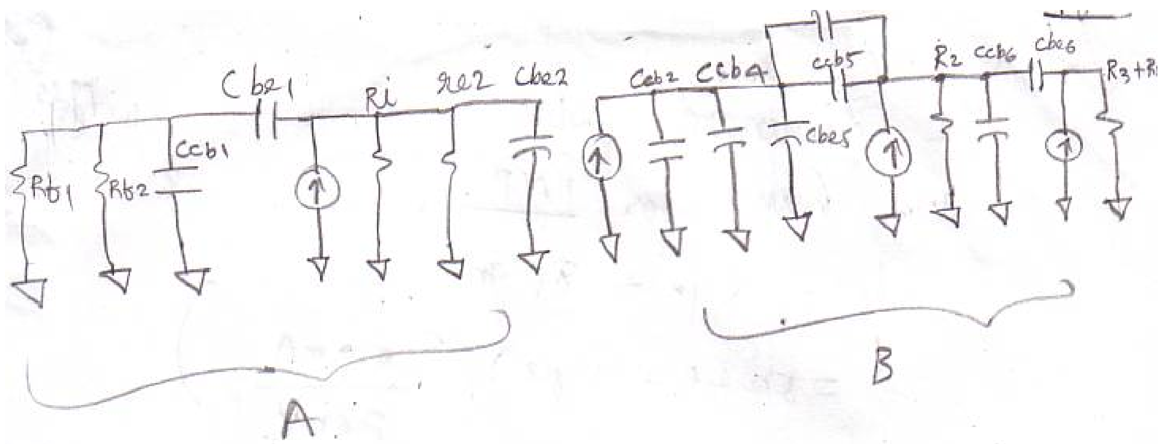
$= 10\,fF + (1\,ps)\left(\dfrac{0.25mA}{26mV}\right)$

$C_{be6} = 19.62\,fF$

$C_{cb5} = 20\,fF$

$C_{cb6} = 20\,fF$

$C_{cb4} = 20\,fF$



Part A

$$a_1 = C_{cb1}(R_i \,||\, R_{inT1}) + C_{be1}\left(\left(R_i(1-A_1) + R_{Leq1}\right) || R_{be1}\right) + C_{be2} R_{Leq1} \rightarrow (1)$$

$$R_{inT1} = (\beta+1)(r_{e1} + R_1 || r_{e2})$$
$$\simeq 100\,(130+127)\,\Omega$$

$$R_{Leq} = R_1 || r_{e2}$$
$$= 5.7k\Omega || 130\,\Omega$$
$$R_{Leq} = 127\,\Omega$$

$$R_{inT1} \simeq 25.7\,k\Omega$$

$$R_{be1} = \beta r_{e1}\,\Omega$$
$$= 100\,(130)\,\Omega$$
$$= 13\,k\Omega$$

$$A_1 = \frac{R_{Leq1}}{R_{Leq1} + r_{e1}}$$

From the values of R and C and (1) we get

$$a_1 = 138\ p\,sec.$$

$$a_2 = (R_i \,||\, R_{inT1})\,(r_{e1} \,||\, R_{Leq1})\left(C_{cb1} C_{be1} + C_{cb1} C_{be2} + C_{be1} C_{be2}\right) \rightarrow (2)$$

$$a_2 = 1.45 \times 10^{-21}\ sec^2.$$

$1 + a_1 s + a_2 s^2 = 0.$

$s_1 = -9.616 \times 10^{10}$; $s_2 = -7.292 \times 10^9$ 1/s

$f_{p2} = 15.304$ GHz

$f_{p1} \simeq 1.18$ GHz

Part b

$C_1 = (C_{cb2} + C_{cb4} + C_{be5})F = 100fF + 20fF + 29.23fF$

$C_1 = 149.23 fF$

$C_2 = C_f + C_{cb5} = 10.02 pF$

$C_3 = 20 fF$

$C_4 = 1.96 \times 10^{-14} F$

$a_1 = (R_{11}^\circ C_1 + R_{22}^\circ C_2 + R_{33}^\circ C_3 + R_{44}^\circ C_4)$ sec

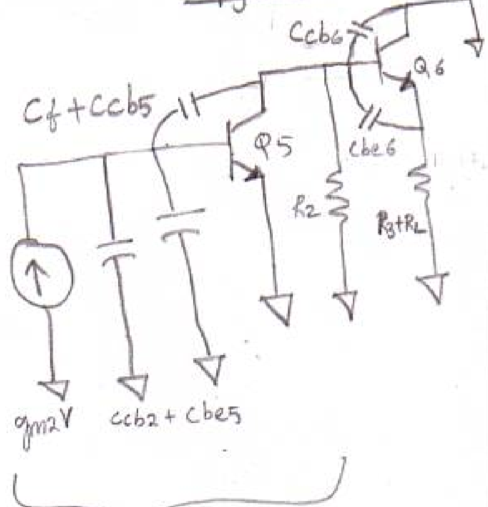
$R_{11}^\circ, R_{22}^\circ, R_{33}^\circ \rightarrow$ units Ω ; $C_1, C_2, C_3 \rightarrow$ units F

$R_{11}^\circ = \beta r_{e5} \Omega = 100 \cdot \dfrac{26mV}{0.5mA} = 5200 \Omega$

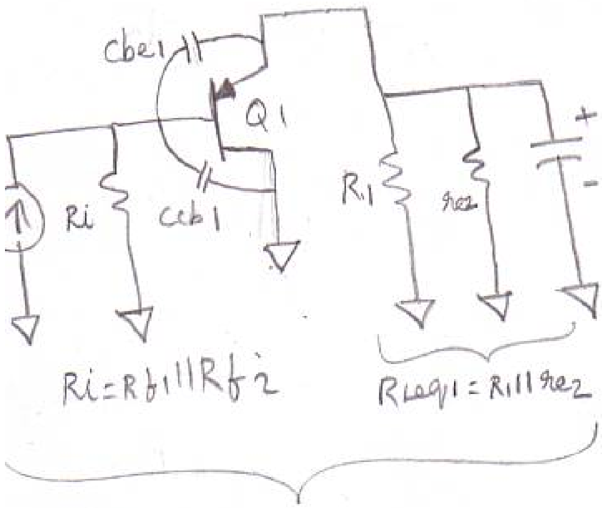
$R_{22}^\circ = 5200\Omega(1 - A_{v5}) + 4.6 k\Omega \,||\, (\beta(r_{e6} + 1072))$

$= 5200\Omega(1 + 85.13) + 4426.84\Omega$

$R_{22}^\circ = 452 k\Omega$; $R_{22}' = R_{33}' = R_2 \,||\, R_{inT6} = 4.426 k\Omega$



Part B



Part A

we also have

$R_{33}^2 = R_2 \,||\, r_{e5}$

$R_{33}^2 = 4.6k \;||\; \left(\frac{26\,mV}{0.5\,mA}\right) = 51.42\,\Omega.$

$R_{44}^2 = R_{be6} \,||\, r_{e5} \simeq r_{e5} \simeq 52\,\Omega.$

$R_{44}^3 = r_{e6} \,||\, (R_3 + R_L)$

$= 104 \;||\; 1072$

$R_{44}^3 = 94.8\,\Omega \;;\; R_{44}^1 = R_{44}^0 = 462\,\Omega$

$$R_{33}^{\circ} = \left(R_2\,\Omega \,||\, \left(\beta\left(r_{e6} + R_3 + R_L\right)\Omega\right)\right)$$

$$R_{33}^{\circ} = 4.6\,k\Omega \,||\, \beta\left(r_{e6} + 1072\right)\Omega = 4.6\,k\Omega \,||\left(100\left(104 + 1072\right)\right)\Omega$$

$$R_{33}^{\circ} = 4426\ \Omega \quad ; R_{44}' = R_{44}^{\circ} = 462\ \Omega$$

$$R_{44}^{\circ} = \left[R_{33}^{\circ}\left(1 - A_{v6}\right)\Omega + \left(1072 \,||\, r_{e6}\right)\Omega\right] ||\, \beta r_e\ \Omega$$

$$R_{44}^{\circ} = 462\ \Omega$$

$$a_1 = (5200\Omega)(149.23\,fF) + (452\,k\Omega)(10.02\,pF) + (4426\Omega)(20\,fF) + (462\Omega)(19.6\,fF)$$

$a_1 \simeq 4.53\ \mu secs$

a_1 is in μ secs – Its likely that a_1 contributes to the dominant pole.

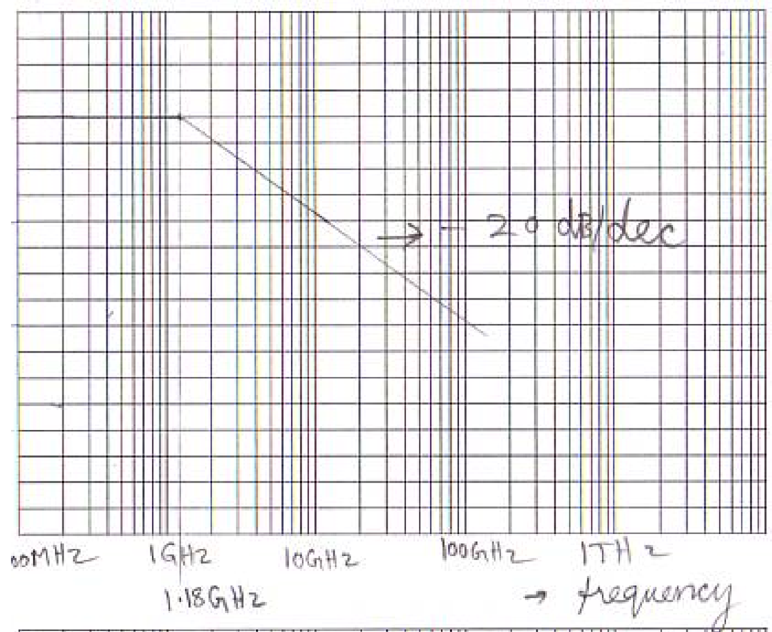
$$a_2 = \left(R_{11}^{\circ} C_1 C_2 R_{22}^{1} + R_{11}^{\circ} C_1 C_3 R_{33}^{1} + R_{11}^{\circ} C_1 C_4 R_{44}^{1} + R_{22}^{\circ} C_2 C_3 R_{33}^{2} + R_{22}^{\circ} C_2 C_4 R_{44}^{2} + R_{33}^{\circ} C_3 C_4 R_{44}^{3}\right) sec^2$$

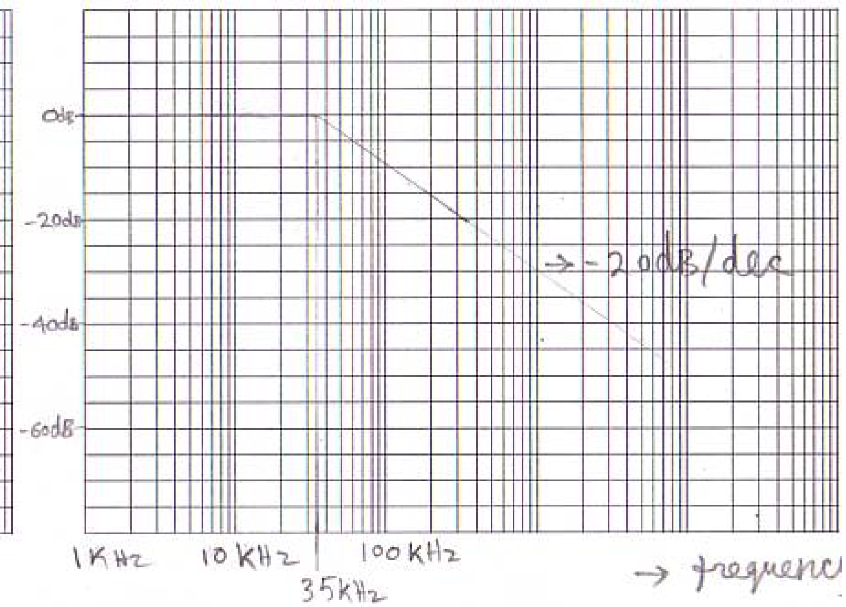
$$a_2 = (5200\Omega)(149.23\,fF)(10.02\,pF)(4426\Omega) + (5200\Omega)(149.23\,fF)(20\,fF)(4426\Omega)$$
$$+ (5200)(149.23\,fF)(19.6\,fF)(462\Omega)$$
$$+ (452\,k\Omega)(149.23\,fF)(20\,fF)(51.42\Omega)$$
$$+ (452\,k\Omega)(10.02\,pF)(19.6\,fF)(52\Omega) + (4426\Omega)(20\,fF)(19.6\,fF)(94.8\Omega)$$

From the orders of magnitude of the terms in a_2 we can say that a_2 is of the order of 10^{-17} sec^2.

Thus the dominant pole is $f_{p1} = \dfrac{0.159}{a_1} = 35\ kHz$

($\frac{a_2}{a_1}$ is in 10^{-11} sec which is $<< a_1$, Hence SPA works here)

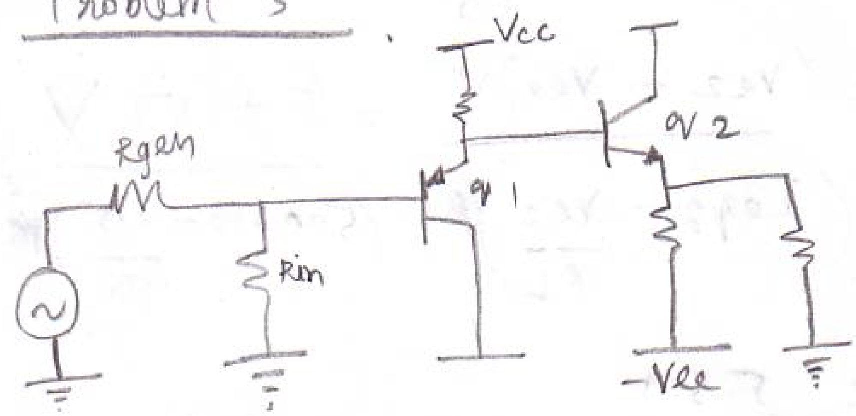

→ -20 dB/dec
00MHz
1GHz
10GHz
100GHz
1THz
1.18GHz
→ frequency


0dB
-20dB
-40dB
-60dB
→ -20dB/dec
1KHz
10KHz
100KHz
35KHz
→ frequenc

Thus the 2 dominant poles are

1.18 GHz and 35 KHz

Problem 3



(a) DC bias

$$I_{bq1} = \frac{(I_{cq1})A}{\beta} = \frac{100mA}{50} = 2mA$$

$$V_{b1} = I_{bq} \quad R_{gen} // R_{in} = 2mA \cdot 250\Omega = 0.5V$$

$$V_{e1} = 0.5 + 0.7 = 1.2V$$

$$R_{e1} = \frac{(V_{cc} - V_{e1})V}{\left[(\beta+1)I_{b1} + \frac{500}{50}\right]A} = \frac{(3.8)V}{102mA + 10mA} = 34\Omega$$

$$V_{e2} = V_{e1} - 0.7 = 0.5\ V$$

$$R_{e1} = \frac{(V_{cc} - V_{e1})\,V}{\left((\beta+1)I_{B1} + \frac{500}{50}\right)A} = \frac{3.8\ V}{102\,mA + 10\,mA} = 34\,\Omega$$

$$R_{e2} = \frac{(V_{e2} - V_{ee})\,V}{\left(I_{eq2} - \frac{V_{e2}}{R_L}\right)A} = \frac{(5 + .5)\ V}{\left(500 + 10 - \frac{0.5}{50}\right)mA}$$

$$R_{e2} = \frac{5.5\ V}{(500 + 10 - 10)\,mA} = 11\,\Omega.$$

Mid-Band Gain

$$\frac{V_{out}}{V_{gen}} = \frac{V_{in}}{V_{gen}} \cdot \frac{V_{out}}{V_{in}}$$

$$\frac{V_{out}}{V_{gen}} = \frac{(R_{in} \,||\, R_{inQ1})\,\Omega}{(R_{gen} + R_{in} \,||\, R_{inQ1})\,\Omega} \cdot A_{V1} \cdot A_{V2}$$

$$A_{V1} = \frac{(R_{e1} \,||\, R_{in\,Q2})\,\Omega}{\left(\frac{1}{g_{m1}} + R_{e1} \,||\, R_{in\,Q2}\right)\Omega}$$

$$R_{in}Q_2 = \beta(r_{e2} + R_{Leq})\,\Omega \simeq 452\,\Omega$$

$$R_{in}Q_1 = \beta(r_{e1} + R_{e1} \| R_{in}Q_2)\,\Omega \simeq 1.6\,k\Omega$$

$$r_{e1} = \left(\frac{1}{g_{m1}}\right)\Omega = \left(\frac{V_T}{I_{e1}}\right)\frac{V}{A} = 0.26\,\Omega$$

$$R_{e1} = 34\,\Omega$$

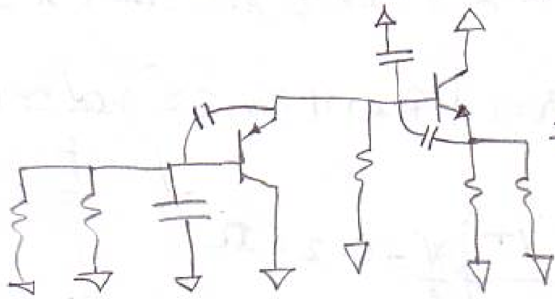
$$R_{Leq} = (R_{e2} \| R_{Load})\,\Omega$$

$$R_{Leq} = 11\,\Omega \,\|\, 50\,\Omega = 9\,\Omega$$

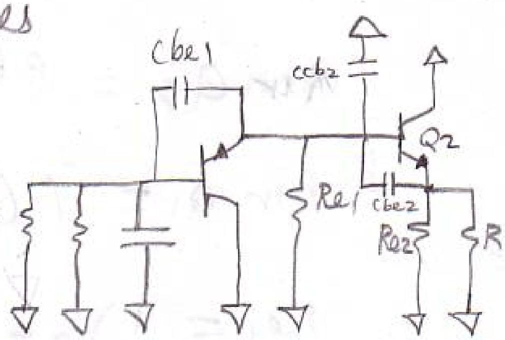
$$\frac{V_{out}}{V_{gen}} = \underbrace{\frac{(381)\,\Omega}{(500 + 381)\,\Omega}}_{0.4324} \; \underbrace{\frac{(31.62)\,\Omega}{(0.26 + 31.62)\,\Omega}}_{0.9918} \cdot \underbrace{\frac{(9)\,\Omega}{(0.052 + 9)\,\Omega}}_{0.9942}$$

$$\frac{V_{out}}{V_{gen}} = 0.426$$

(b) MOTC to find poles



$\Rightarrow$



$C_1 = c_{cb1} = 100\,fF$

$C_2 = c_{be1} = C_{je} + g_{m1}\tau_f = 40fF + \frac{100}{26} \times 2pF = 7.723pF$

$C_4 = c_{be2} = c_{je} + g_{m2}\left(\frac{1}{\Omega}\right)sec = 40fF + \frac{500}{26}\,2pF$

$= 38.5\,pF \quad \left(\text{Note: } \frac{1}{\Omega}\,sec = \text{Farad}\right)$

$a_1 = \left[C_1 R_{11}^o + C_2 R_{22}^o + C_3 R_{33}^o + C_4 R_{44}^o\right]\Omega$

$R_{11}^o = (R_i \,||\, R_{inQ1})\,\Omega$

$= 250\Omega \,||\, 1.6k\Omega$

$R_{11}^o = 216\,\Omega$

$R_{22}^o = \beta r_{e1}\Omega \,||\, \left(R_i(1-A_{v1}) + R_{e1} \,||\, R_{inQ2}\right)\Omega$

$\simeq 9.37\,\Omega$

$R_{33}^o = R_{e1}\Omega \,||\, \left(r_{e1}\Omega + \frac{R_i}{\beta}\Omega\right) || R_{inQ2}(\Omega) = 34\Omega \,||\, 445\Omega \,||\, (0.26 + \ldots$ Ω

$R_{33}^o = 4.5\,\Omega$

$$R_{44}^{0} = \left[R_{be2} \parallel \left(R_{e1} \parallel R_{outQ1} (1 - A_{V2}) + R_{Leq_{Q2}} \right) \right] \Omega$$

$$R_{44}^{0} \simeq 2\,\Omega$$

$$a_1 = C_1 R_{11}^{0} + C_2 R_{22}^{0} + C_3 R_{33}^{0} + C_4 R_{44}^{0} \rightarrow (1)$$

$$a_1 = 21.6\,\text{psec} + 72.36\,\text{ps} + 0.45\,\text{psec} + 77\,\text{psec}$$

Thus we have

$$a_1 = 171.41\,\text{secs}$$

$$a_2 = \left(R_{11}^{0} C_1 C_2 R_{22}^{1} + R_{11}^{0} C_1 C_3 R_{33}^{1} + R_{11}^{0} C_1 C_4 R_{44}^{1} + R_{22}^{0} C_2 C_3 R_{33}^{2} + R_{22}^{0} C_2 C_4 R_{44}^{2} + R_{33}^{0} C_3 C_4 R_{44}^{3} \right) \text{sec}^2 \rightarrow (2)$$

$R_{11}^{0}, R_{22}^{1}, R_{33}^{1}, R_{44}^{1}, R_{33}^{2}, R_{22}^{0}, R_{44}^{2}, R_{44}^{3}, R_{33}^{0} \rightarrow$ units – Ω, $C_1, C_2, C_3, C_4 \rightarrow$ units

$$R_{22}^{1} = \beta r_{e1}\,\Omega \parallel \left(R_{e1} \parallel R_{in\,Q2} \parallel r_{e1} \right) \Omega = 0.26\,\Omega$$

$$R_{33}^{1} = R_{22}^{1} = 0.26\,\Omega$$

$$R_{44}^{1} = \left\{ (R_{e1} \parallel r_{e1})\Omega (1 - A_{V2}) + \left(R_{Leq} \parallel \frac{1}{g_{m2}} \right) \Omega \parallel R_{be2}\,\Omega \simeq r_{e2} \simeq 0.052 \right.$$

$$R_{33}^{2} = (R_{e1} \parallel R_i \parallel R_{in\,Q2})\Omega = 30\,\Omega$$

$$R_{44}^{2} = \left[(R_{e1} \| R_i)\Omega(1-A_{V2}) + \left(R_{Leq}\ \frac{1}{g_{m2}}\right)\Omega \right] \| R_{be2}$$

$R_{44}^{2} \simeq r_{e2} = 0.052\ \Omega$

$R_{44}^{3} = 0.052\ \Omega$

From (2) and the above values we get

$a_2 = 4.610 \times 10^{-22}\ sec^2$.

We have $a_1 \gg \frac{a_2}{a_1}$ so we can use separated pole approximation

$f_{p1} = 159\ GHz \times \frac{1}{171.4} = 927\ MHz$

$f_{p2} = \frac{0.159}{(a_2/a_1)} = 159\ GHz \times \frac{1}{2.69} = 59.1\ GHz$

For the Bode plot we have

$$20 \log\left(\frac{V_{out}}{V_{in}}\right) = 20 \log(0.426)$$

$$= -7.39\ dB$$

Problem 3 $f_{p1} = 900\,MHz$; $f_{p2} = 60\,GHz$