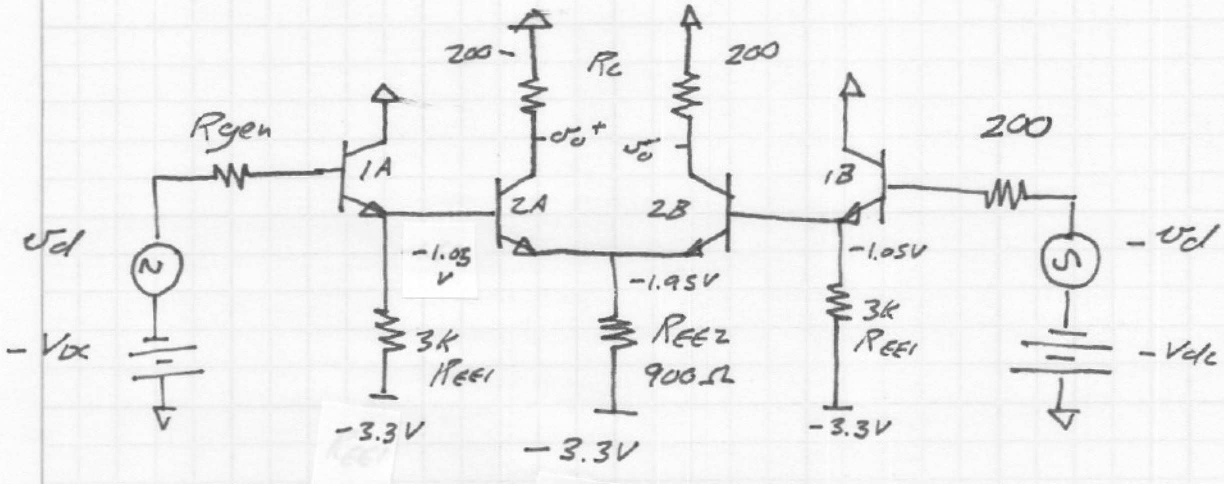
ECE137B Notes set 10

FINAL HF Response example



The generator configuration is a thevenin model of an identical stage driving the present stage.

DC output voltage is −150 mV → Q2A & 2B biased @ $I_E = 0.75$ mA

DC input voltage is similarly −150 mV

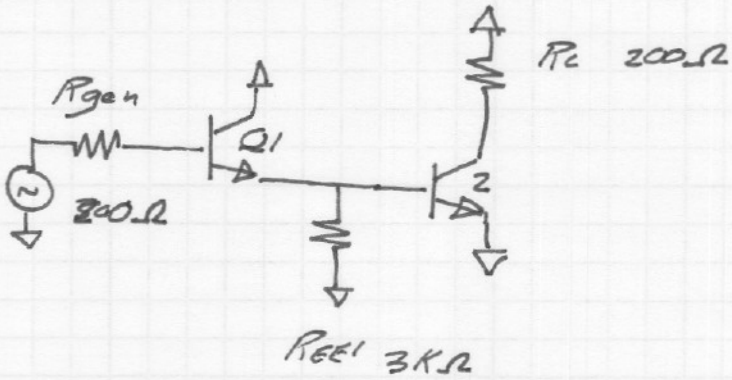
$V_{be1} = V_{be2} = 0.9\ V$; typical SiGe parameters

Q1A/B also biased at 1 mA.

Transistor parameters:

$\tau_f = 1ps$ $\quad C_{je} = 5fF$ $\quad C_{cb} = 10fF$ $\quad \beta = 100$ $\quad V_A = \infty$

half_circuit AC Model:



Mid-band analysis

Q2: CE

$R_{Leq} = R_C = 200\,\Omega$

$g_m = 1/r_e = 1/34.6\,\Omega = 28.8\,mS$

$A_v = -g_m R_{Leq} = -5.78$

$R_{in2} = \beta / g_m = 3.46\,K\Omega$

Q1: EF

$R_{Leq} = R_{EE1} \,||\, R_{in2} = 1.6\,K\Omega$

$r_e = 1/g_m = 34.6\,\Omega$

$A_v = R_{Leq} / (1/g_m + R_{Leq}) = 0.9786$ ← don't round!

$R_{inT} = \beta(1/g_m + R_{Leq}) = 163\,K\Omega$

$R_i = 163k \,||\, 200\,\Omega \cong 200\,\Omega$

$V_{in}/V_{gen} \cong 1$

overall gain = $\underline{-5.65}$ (15 dB; quite high gain/stage for a high frequency amplifier)

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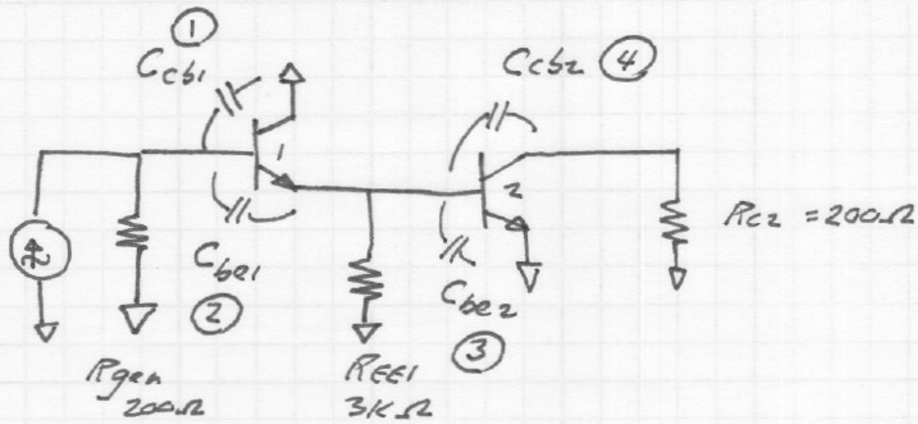
HF analysis:

For both Q1 & Q2:

$C_{be} = g_m \tau_f + C_{je} = 33.9\,fF$, $C_{jc} = C_{bc} = 10\,fF$

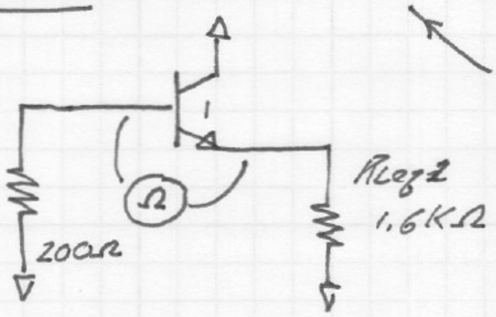
$f_T = 105\,GHz$



$a_1 = R_{11}^{o} C_1 + R_{22}^{o} C_2 + R_{33}^{o} C_3 + R_{44}^{o} C_4$

$R_{11}^{o} C_1 = 10\,fF \cdot (R_{gen} \| R_{in1}) = 10\,fF \cdot 200\Omega = 2\,ps$

$R_{22}^{o} C_2 = 33.9\,fF \cdot 39\Omega = 1.32\,ps$



$R_{22}^{o} = 200\Omega(1 - A_{v1}) + R_{eq2} \| r_{e1}$

$= 200\Omega(1 - 0.9786) + 34.6\Omega$

$= 39\Omega$ (parallel R_{be} term dropped)

$\underline{R_{33}^{o} C_3} = 33.9fF \cdot 36\Omega = 1.22\ ps$

$R_{33}^{o} = R_{out1} \,//\, R_{EE1} \,//\, R_{in2}$

$= (R_{gen}/\beta + r_{e1}) \,//\, R_{EE1} \,//\, \beta r_{e2}$

$= 37\Omega \,//\, 3k\Omega \,//\, 3.5k\Omega = 36\Omega$

$\underline{R_{44}^{o} C_4} = 10fF \cdot 444\Omega = 4.44\ ps$

$R_{44}^{o} = (R_{out1} \,//\, R_{EE1} \,//\, R_{in2})(1 - A_{v2}) + R_{C2}$

$= 36\Omega(1 + 5.78) + 200\Omega = 444\Omega$

$\underline{a_1 = \text{sum of terms} = 9.0ps}$

$$a_2 = R_{11}^{o} C_1 C_2 R_{22}^{1} + R_{11}^{o} C_1 C_3 R_{33}^{1} + R_{11}^{o} C_1 C_4 R_{44}^{1} + R_{22}^{o} C_2 C_3 R_{33}^{2} + R_{22}^{o} C_2 C_4 R_{44}^{2} + R_{33}^{o} C_3 C_4 R_{44}^{3}$$

lets now find those...

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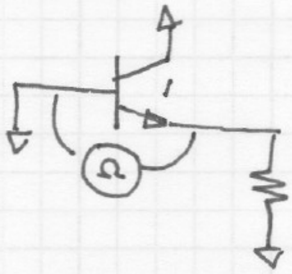
$R_{11}^{0} C_1 C_2 R_{22}' = 200\Omega \cdot 10fF \cdot 33.9fF \cdot 34.6\Omega = 2.35(10^{-24})\,sec^2$

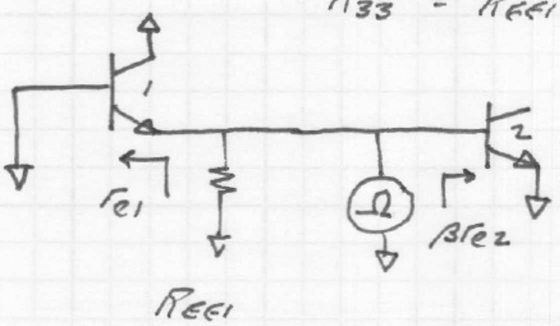


$R_{22}' = r_{e1} \parallel R_{Leq1} \cong r_{e1} = 34.6\Omega$

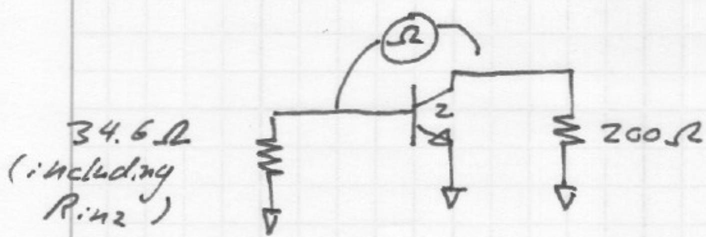
$R_{Leq1} = R_{EE1} \parallel R_{in2} = 1.6K\Omega$

$R_{11}^{0} C_1 C_3 R_{33}' = 200\Omega \cdot 10fF \cdot 33.9fF \cdot 34.6\Omega = 2.36(10^{-24})\,sec^2$

$R_{33}' = R_{EE1} \parallel r_{e1} \parallel \beta r_{e2} \cong r_{e1} = 34.6\Omega$



$R_{11}^{0} C_1 C_3 R_{44}' = 200\Omega \cdot 10fF \cdot 10fF \cdot 435\Omega = 8.7(10^{-24})\,sec^2$

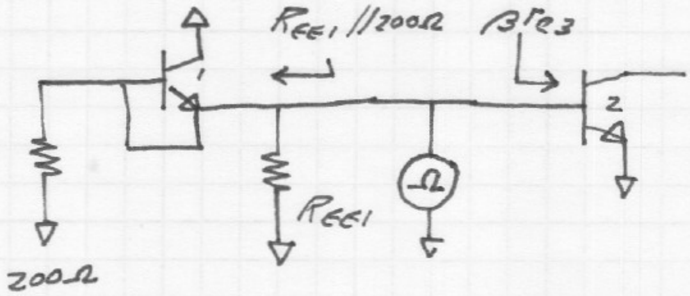


$R_{44}' = 34.6\Omega(1 - A_{v2}) + 200\Omega$

$= 34.6\Omega(6.78) + 200\Omega$

$= 435\Omega$

$R_{22}^{0} C_2 C_3 R_{33}^{2} = 39\Omega \cdot 33.9fF \cdot 33.9fF \cdot 116\Omega = 5.2 \cdot 10^{-24}\ sec^2$

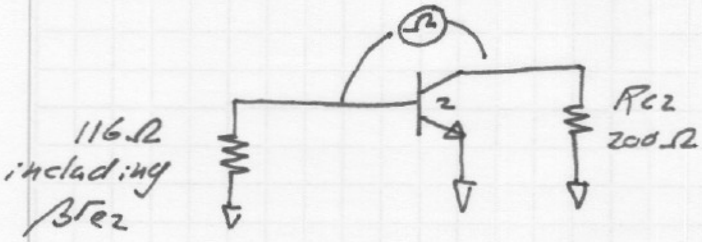


$R_{33}^{2} = R_{EE1} \| 200\Omega \| \beta r_{e3}$

$= 3k \| 200\Omega \| 3.46k$

$= 116\Omega$

$R_{22}^{0} C_2 C_4 R_{44}^{2} = 39\Omega \cdot 33.9fF \cdot 10fF \cdot 986\Omega = 1.3(10^{-23})\ sec^2$

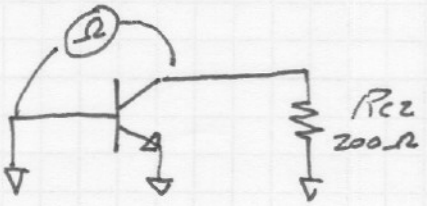


$R_{44}^{2} = 116\Omega(1 - A_{v2}) + R_{c2}$

$= 116\Omega(6.78) + 200\Omega$

$= 986\Omega$

$R_{33}^{0} C_3 C_4 R_{44}^{3} = 36\Omega \cdot 33.9fF \cdot 10fF \cdot 200\Omega = 2.44 \cdot 10^{-24}\ sec^2$



$R_{44}^{3} = R_{c2} = 200\Omega$

a_2 = sum of terms $= 3.4 \cdot 10^{-23}\ sec^2 = (5.84\ ps)^2$

$a_1 = 9.0\ ps$

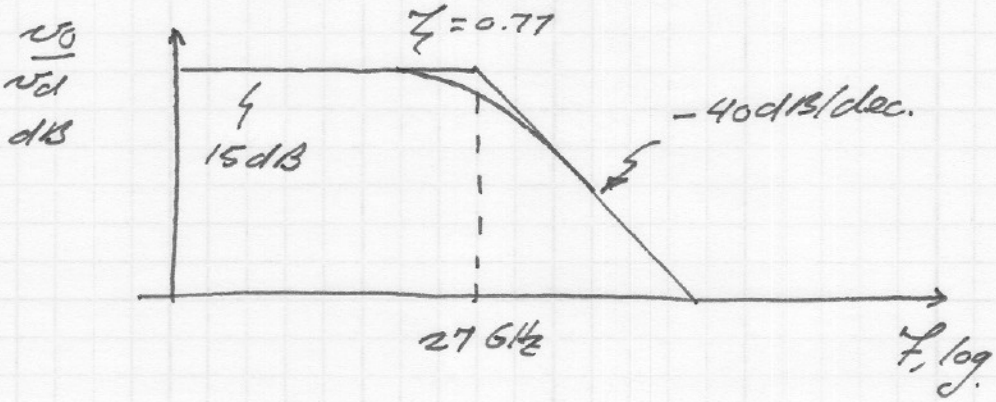
$$1 + a_1 s + a_2 s^2 = 1 + (2\zeta/\omega_n) s + s^2/\omega_n^2$$

$$\omega_n = 1/\sqrt{a_2} = 1.7(10^{11}) \text{ rad/sec} \rightarrow f_n = \frac{\omega_n}{2\pi} = 27.2 \text{ GHz}$$

$$\zeta = a_1/2\sqrt{a_2} = 0.77$$

$\zeta < 1$, so poles are indeed complex.

$\zeta > 0.7071$, so no peaking in frequency response.*



* because $\zeta < 1$, step response will ring slightly