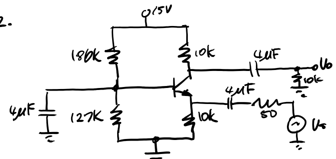
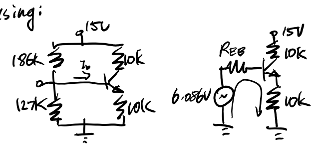
Problem Set 4 (Again)

October 30, 2017 5:49 PM

Q2.



Biasing:



$V_{BB} = 6.086V$

$R_{BB} = 75.47K$

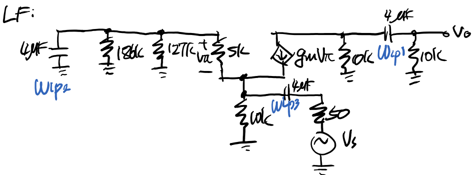
KVL: $V_{BB} = i_b \cdot R_{BB} + 0.7 + (1+\beta) i_b \cdot 10k$

$\rightarrow i_b = \frac{V_{BB} - 0.7}{R_{BB} + (1+\beta)10k} = 4.962\mu A$

$i_c = \beta i_b = 0.496mA.$ $\quad g_m = 0.01985\mho$

$i_e = 0.501mA.$ $\quad r_\pi = \frac{100}{g_m} = 5k\Omega.$

LF:



$W_{Lp1} = (4\mu F \cdot (20k))^{-1} = 12.5 rad/s$

— SCTC test (looking for big freq):

$\tau_{SC}^{CB} = 4\mu F \cdot [186k // 127K // (5K + (1+\beta)(10k//50))]$

$= 0.035s$

$W_{Lp2} = 28.25 rad/s$ X

$\tau_{SC}^{CE} = 4\mu F \cdot [((\frac{1}{1+\beta})(5k) // 10k) + 50]$ ✓

$= 3.97 \times 10^{-4} s$

$W_{Lp3} = 2519 rad/s$

— OCTC test

$\tau_{OC}^{CB} = 4\mu F \cdot [186K // 127K // 5K + (1+\beta)10k]$

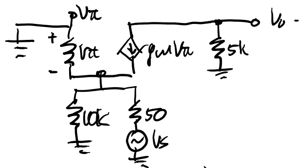
$= 0.281s$

$W_{Lp2} = 3.56 rad/s.$

$W_{Lz2} = \frac{1}{4\mu F (186k // 127K)} = 3.3 rad/s.$

$W_{L3dB} = \boxed{2519 rad/s}$

MB:



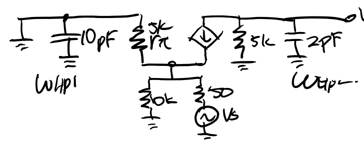
$V_\pi = -V_E$ $\quad V_E = \frac{((\frac{1}{1+\beta})r_\pi // 10k)}{(\frac{1}{1+\beta})r_\pi // 10k + 50} V_s.$

$V_\pi = -0.496 V_s.$

$V_o = -0.01985 \cdot 5k \cdot (-0.496) V_s$

$A_m = \frac{V_o}{V_s} = \boxed{49.256 V/V}$

HF:



$\tau_{Hp1} = 10pF \cdot (5K + (1+\beta)(10k // 50))$

$= 1 \times 10^{-7}s$

$W_{Hp1} = 9.975M rad/s$

$\tau_{Hp2} = 2pF \cdot 5k$

$= 1 \times 10^{-8}s$

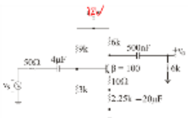
$W_{Hp2} = 100M rad/s$

$\boxed{W_{H3dB} = 9.75M rad/s}$

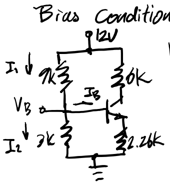
3) For the circuit shown in figure 3:

i. Draw the low frequency circuit, the midband circuit and the high frequency circuit and

ii. Derive the midband gain, A_M, and $F_L(s)$.



Bias Conditions:



$V_B \approx 3V$ since $I_1 \gg I_B$.

$V_E = 2.3V$, $I_E = \frac{2.3V}{2.26k} \approx 1mA$

$I_C \approx 1mA$ $\quad I_1 = \frac{12-3}{9k} = 1mA$

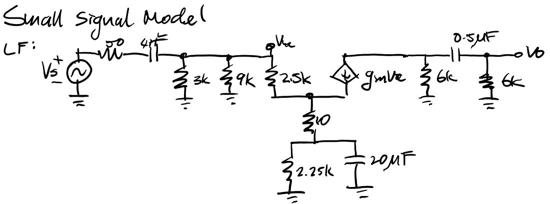
$I_B = \frac{1mA}{100} = 10\mu A.$ $\quad I_2 = 1mA.$

$g_m = \frac{I_C}{V_T} = \frac{1mA}{25mV} = 0.040\mho$

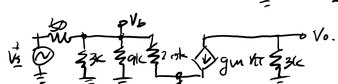
$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.04} = 2.5k\Omega.$

Small Signal Model

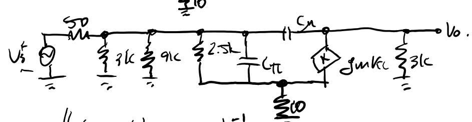
LF:



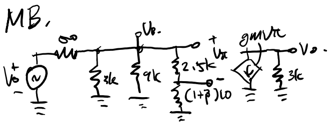
MB:



HF:



MB,



$V_\pi = V_b - V_e$, $\quad V_e = i_e \cdot 10\Omega$

$= i_b \cdot (1+\beta)(10\Omega)$

Voltage divider: $V_b = \frac{3k//9k//(2.5k+(1+\beta)10)}{3k//9K//(2.5k+(1+\beta)10)+50} V_s$

$V_b = 0.965 V_s.$

$i_b = \frac{V_b}{\quad}$

LF: $W_{Lp1} = ((6k + 6k) \cdot 0.5\mu F)^{-1}$

$= 167 rad/s$

OCTC test (want low freq)

$\tau_{OC}^{Cc1} = 4\mu F \cdot (50 + 3k // 9k // (2.5k + (1+\beta)(10 + 2.25k)))$

$= 0.091s$ ✓ $\rightarrow W_{Lp2} = 109 rad/s$

$\tau_{OC}^{CE} = [((3k // 9k) + 2.5k) \cdot (\frac{1}{1+\beta}) + 10) // 2.25k] \cdot 20\mu F.$

$= 0.0028$ X

SCTC test.

$$V_b = \frac{\ldots}{3k // 9K // (2.5k + (1+\beta)10) + 50} \ldots V_s$$

$$V_b = 0.965 V_s.$$

$$i_b = \frac{V_b}{2.5k + (1+\beta)10} = 2.749 \times 10^{-4} V_s$$

$$V_\pi = 0.965 V_s - (2.749 \times 10^{-4}) V_s \cdot (1+\beta)(10)$$

$$V_\pi = 0.687 V_s.$$

$$V_o = -g_m V_\pi (3k)$$

$$= -0.04 \cdot 0.687 V_s \cdot 3k$$

$$\frac{V_o}{V_s} = -82.44$$

$$= 0.0028 \; X$$

SCTC test:

$$\tau_{SC}^{CE} = \left[\left((50 + 2.5k)\left(\frac{1}{1+\beta}\right) + 10\right) // 2.25k\right] \cdot 20\mu F$$

$$= 0.694 \times 10^{-3} s$$

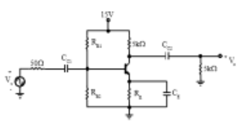
$$\omega_{Lp3} = 1441 \text{ rad/s}$$

$$\omega_{LZ1} = \omega_{LZ2} = 0.$$

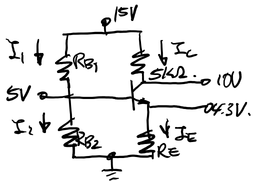
$$\omega_{LZ3} = \frac{1}{R_E \cdot \tau_E} = 22.2 \text{ rad/s}$$

$$F_L(s) = \left(\frac{s}{s+167}\right)\left(\frac{s}{s+109}\right)\left(\frac{s+22.2}{s+1441}\right)$$

4) For the circuit shown in figure 4, use the 1/3rd rule (your choice) to bias the circuit and find C_E, C_{C1}, and C_{C2} that will put the low frequency poles at 1000/s, 100/s and 10/s. Choose the lowest cost combination of capacitors.



Using the first 1/3 rule: $V_B = \frac{1}{3}V_{cc}$, $V_C = \frac{2}{3}V_{cc}$, $I_1 = \frac{I_E}{\sqrt{\beta}}$, $\beta = 100$.



$V_C = 10V$, $V_B = 5V$, $V_E = 4.3V$

$I_E = \frac{5V}{5k} = 1mA$.

$I_B = \frac{I_C}{\beta} = 10\mu A$.

$I_E = 1.01mA$.

$I_1 = \frac{1.01mA}{10} = 101\mu A$.

$I_2 = I_1 - I_B = 91\mu A$

$R_E = \frac{4.3V}{1.01mA} = 4.26k\Omega$.

$R_{B1} = \frac{15 - 5V}{101\mu A} = 99k\Omega$.

$R_{B2} = \frac{5V}{91\mu A} = 54.95k\Omega$.

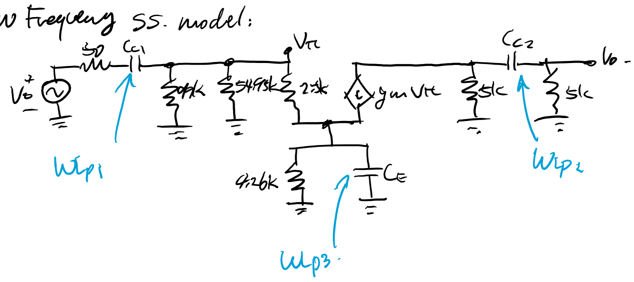
For the best cost efficiency, C_{C2} should short first, C_{C1} should short second, C_E should short last.

Thus 10/s corresponds to C_{C1}, 100/s corresponds to C_{C2}, 1000/s corresponds to C_E.

$$g_m = \frac{I_C}{V_T} = \frac{1mA}{25mV} = 0.04\mho$$

$$r_\pi = \frac{\beta}{g_m} = 2.5k\Omega$$

Low Frequency SS. model:



First $\omega_{Lp1} = \left(C_{C2} \cdot (5k + 5k)\right)^{-1} = 100/s$

$$C_{C2} = \frac{\left(\frac{1}{10}\right)}{10k} = \boxed{1\mu F}$$

Next, with R_E open (OCTC test), we have

$$\omega_{Lp2} = \left\{C_{C1} \cdot \left[50 + 99k // 54.95k // \left((1+\beta)(4.26k) + 2.5k\right)\right]\right\}^{-1} = 10/s.$$

$$\Rightarrow C_{C1} \cdot [\ldots] = \frac{1}{10}s.$$

$$\Rightarrow C_{C1} = \boxed{3.06\mu F}$$

Lastly, with all capacitors shorted (SCTC test), we have

$$\tau_{SC}^{CE} = \frac{1}{\omega_{Lp3}} = \frac{1}{1000}s = C_E \cdot \left[\left((50 // 99k // 54.95k) + 2.5k\right)\left(\frac{1}{1+\beta}\right) // 4.26k\right]$$

$$\Rightarrow C_E = \boxed{39.843\mu F}$$