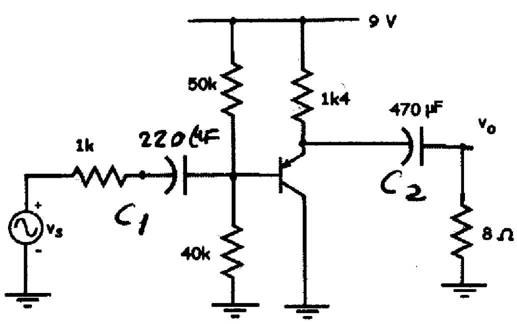
Electronics II * Exam I * March 19, 2008 * 75 minutes

ID number: ERKAYA Name: SOLUTIONS Signature:__________

30 pts 1) Find the low 3 dB cutoff frequency of the amplifier given below. ($\beta = 250$) $f_L =$ 16.96 *Hz*



DC analysis: $V_B \simeq 9 \times \frac{40}{40+50} = 4V$

$V_E = V_B + 0.7 = 4.7V$

$I_E = \frac{9-4.7}{1.4k} = 3.07\ mA$

$I_C \simeq I_E = 3\ mA$, $g_m = \frac{3}{0.025} = 120\ mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{250}{120} = 2.08\ k\Omega$

Possible dominant pole frequencies:

$f_1 = \frac{1}{2\pi C_1 R_{th_1}}$ $\quad R_{th_1} = 1k + 40k \| 50k \| [2k + (250+1)(0.008 \| 1.4)k]$

$= 4.387\ k\Omega$ (C_2 short)

$f_1 = \frac{1}{2\pi\, 220 \times 10^{-6} \times 4387} = 0.16\ Hz$

$f_2 = \frac{1}{2\pi C_2 R_{th_2}}$, $\quad R_{th_2} = 8 + 1400 \| \frac{(1k \| 40k \| 50k) + 2k}{251} \cong 20\ \Omega$ (C_1 short)

$f_2 = \frac{1}{2\pi \times 470 \times 10^{-6} \times 20} = 16.93\ Hz$ → dominant

f_1 must be recalculated with C_2 open ckt

$R_{th_1} = 1k + 40k \| 50k \| [2k + 251 \times 1.4k] = 21.9\ k\Omega$

$f_1 = \frac{1}{2\pi \times 220 \times 10^{-6} \times 21900} = 0.033\ Hz$

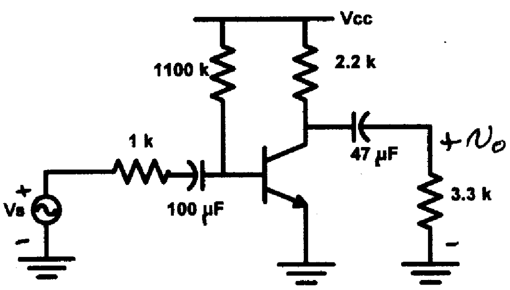
$f_L \cong f_1 + f_2 = 0.033 + 16.93 = 16.96\ Hz$

35 pts 2) Using Miller's theorem, find the high 3dB cutoff frequency of the amplifier given below. Assume $\beta = 200$, $I_C = 1.50$ mA, $C_\mu = 1.2$ pF, $f_T = 400$ MHz, $r_x = 100$ ohms, $r_o = 120$ k

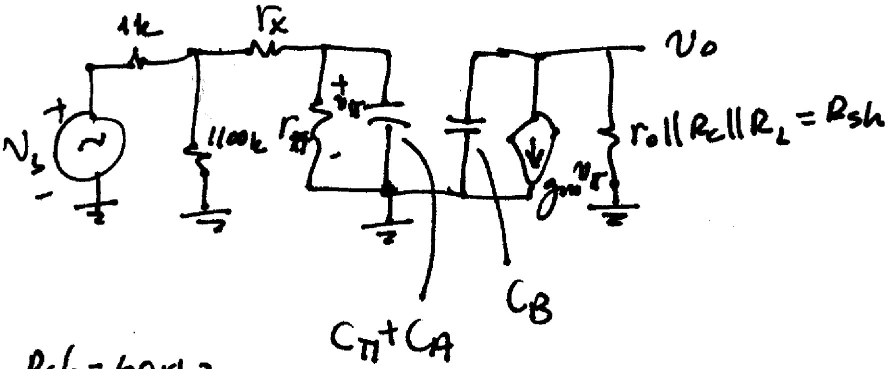
$$g_m = \frac{1.5}{0.025} = 60\,mA/V$$

f_H = 1.61 MHz

$$r_\pi = \frac{\beta}{g_m} = \frac{200}{60} = 3.33\,k\Omega$$



S.S. eq. ckt – Miller's theorem applied on C_μ



$$R_{sh} = 2.2k \| 3.3k \| 120k = 1.3k$$

$$C_A = C_\mu(1 + g_m R_{sh})$$

$$g_m R_{sh} = 60 \times 1.3 = 78$$

$$C_A = 1.2\,pF(1+78) = 94.8\ pF$$

$$C_B \simeq C_\mu = 1.2\ pF$$

$$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu = \frac{60\times10^{-3}}{2\pi\times400\times10^{6}} - 1.2\times10^{-12} = 22.67\times10^{-12}\,F$$

$$C_A + C_\pi = 117.47\ pF$$

pole frequencies

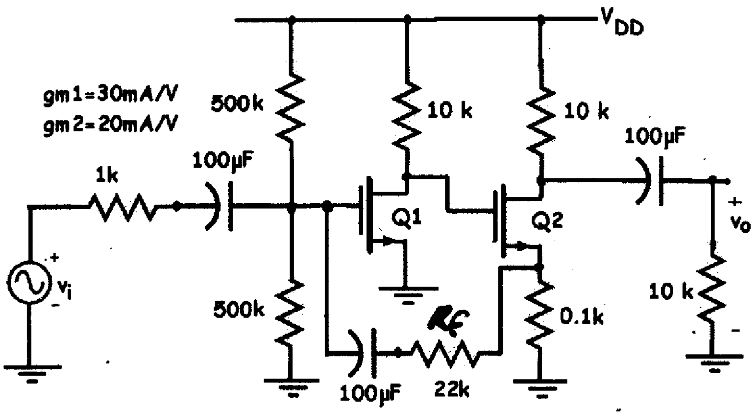
$$f_A = \frac{1}{2\pi(C_A + C_\pi)R_{thA}}, \quad R_{thA} = r_\pi \| [r_x + 1k \| 1100k] = 3.33 \| [0.1 + 1] = 0.826\ k\Omega$$

$$f_A = \frac{1}{2\pi\times117.47\times10^{-12}\times826} = 1.64\times10^{6}\,Hz$$

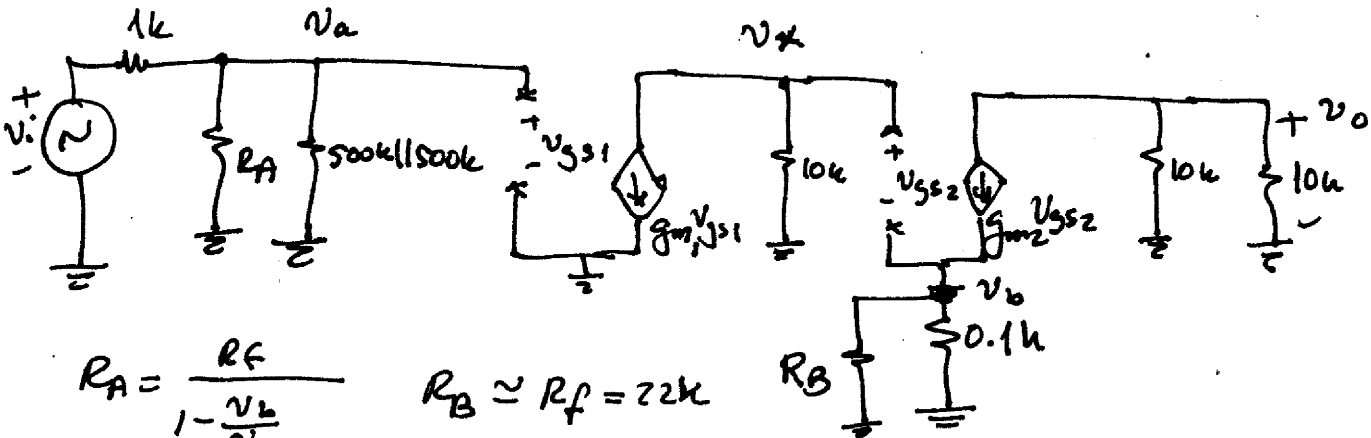
$$f_B = \frac{1}{2\pi C_B R_{sh}} = \frac{1}{2\pi\times1.2\times10^{-12}\times1300} = 102\times10^{6}\,Hz$$

$$f_H = \frac{1}{\frac{1}{f_A} + \frac{1}{f_B}} = 1.61\times10^{6}\,Hz$$

Pts 3) Find the voltage gain of the amplifier given below. $\dfrac{v_o}{v_i} =$ 982



Apply Miller's Theorem on Rf and get small signal eq. ckt.



$$R_A = \frac{R_f}{1-\frac{V_b}{V_a}} \qquad R_B \simeq R_f = 22k$$

$$\frac{V_b}{V_x} = \frac{(R_B\|0.1)\,g_{m2}}{1+(R_B\|0.1)\,g_{m2}} \cong \frac{0.1\times 20}{1+0.1\times 20} = \frac{2}{3}$$

$$\frac{V_x}{V_a} = -g_{m1}\,10k = -300$$

$$\frac{V_b}{V_a} = -300\times\frac{2}{3} = -200$$

$$R_A = \frac{22k}{1+200} = 0.109\,k = 1$$

$$\frac{V_o}{V_x} = \frac{-g_{m2}\,(10k\|10k)}{1+g_{m2}(R_B\|0.1k)} = \frac{-100}{3}$$

$$\frac{V_x}{V_a} = -300$$

$$\frac{V_a}{V_i} = \frac{R_A\|500k\|500k}{1+R_A\|500k\|500k} \sim \frac{R_A}{1+R_A} = \frac{0.109}{1.109} = 0.0982$$

$$\frac{V_o}{V_i} = \frac{V_o}{V_x}\,\frac{V_x}{V_a}\,\frac{V_a}{V_i} = \left(-\frac{100}{3}\right)(-300)(0.0982) = 982$$