Homework Assignment No. 9 – Solutions

1.) Problem 17.1 (17.1) of the text.

$A_v(s) = 25\dfrac{s^2}{(s+1)(s+20)}$ | $A_{mid} = 25$ | $F_L(s) = \dfrac{s^2}{(s+1)(s+20)}$ | Poles: -1,-20 | Zeros: 0,0

yes, $s = -20$ | $A_v(s) \approx 25\dfrac{s}{(s+20)}$ | $\omega_L = 20\dfrac{rad}{s}$ | $f_L = \dfrac{\omega_L}{2\pi} \cong \dfrac{20}{2\pi} = 3.18Hz$

$$f_L = \frac{1}{2\pi}\sqrt{20^2 + 1^2 - 2(0)^2 - 2(0)^2} = 3.19Hz$$

$$|A_v(j\omega)| = \frac{25\omega^2}{\sqrt{\omega^2+1^2}\sqrt{\omega^2+20^2}}$$ | MATLAB: -3.19 Hz

2.) Problem 17.4 (17.4) of the text.

$$A_v(s) = \frac{(2x10^{11})(10^{-4})(10^{-5})}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)} = \frac{200}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)}$$ | $A_{mid} = 200$ | $F_H(s) = \dfrac{1}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)}$

Poles: $-10^4, -10^5 \ \dfrac{rad}{s}$ | Yes: $A_v(s) \approx \dfrac{200}{\frac{s}{10^4}+1}$ | $\omega_H \cong 10^4\dfrac{rad}{s}$ | $f_H \cong \dfrac{10^4}{2\pi} = 1.59kHz$

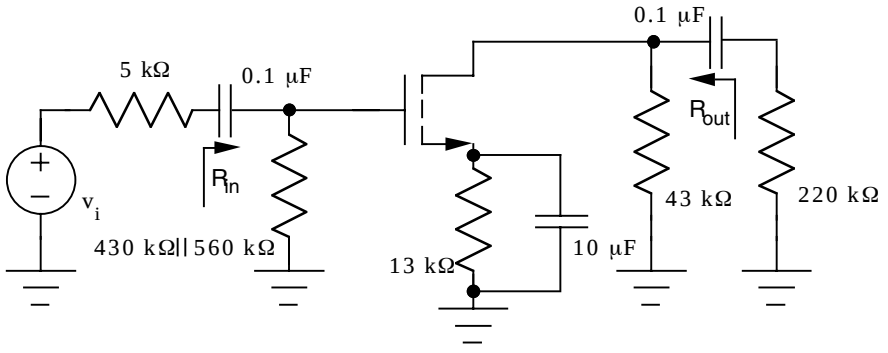
$$f_H \cong \frac{1}{2\pi}\left(\sqrt{\left(\frac{1}{10^4}\right)^2 + \left(\frac{1}{10^5}\right)^2 - 2\left(\frac{1}{\infty}\right)^2 - 2\left(\frac{1}{\infty}\right)^2}\right)^{-1} = 1.58\ kHz$$

$$|A_v(j\omega)| = \frac{2x10^{11}}{\sqrt{\omega^2 + (10^4)^2}\sqrt{\omega^2 + (10^5)^2}}$$ | MATLAB: $f_H = 1.58$ kHz

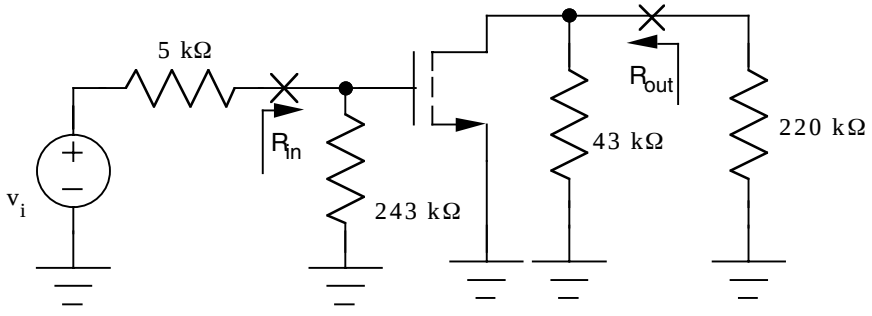
3.) Problem 17.10 (17.10) of the text.

(a.)

Low frequency:



Mid-band:



Problem 17.10 - Continued

(b.)

$$A_{vt} = \frac{v_d}{v_g} = -g_m R_L = -g_m\left(R_{out}\|R_3\right) \quad | \quad A_{mid} = \frac{R_{in}}{R_I + R_{in}} A_{vt} \quad | \quad g_m = \frac{2I_D}{V_{GS} - V_{TN}} = \frac{2(0.2mA)}{1V} = 0.400mS$$

$R_{in} = 243k\Omega$ | $R_{out} = R_D\|r_o \cong R_D = 43k\Omega$ assuming $\lambda = 0$ since it is not specified.

$$A_{mid} = -\left(\frac{243k\Omega}{5k\Omega + 243k\Omega}\right)(0.400mS)\left(43k\Omega\|220k\Omega\right) = -14.1$$

$$\omega_1 = \frac{1}{\left(10^{-7}F\right)(243k\Omega + 5k\Omega)} = 40.3\frac{rad}{s} \quad | \quad \omega_2 = \frac{1}{\left(10^{-7}F\right)(43k\Omega + 220k\Omega)} = 38.0\frac{rad}{s}$$

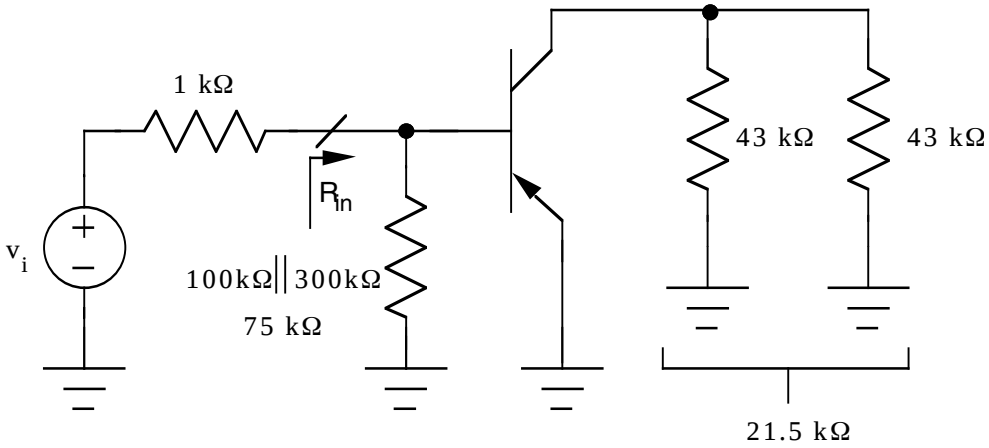
$$\omega_3 = \frac{1}{\left(10^{-5}F\right)\left(13k\Omega\left\|\frac{1}{g_m}\right.\right)} = \frac{1}{\left(10^{-5}F\right)(13k\Omega\|2.5k\Omega)} = 47.7\frac{rad}{s} \quad | \quad \omega_Z = \frac{1}{\left(10^{-5}F\right)(13k\Omega)} = 7.69\frac{rad}{s}$$

Using Eq. (17.16): $f_L \cong \frac{1}{2\pi}\sqrt{(40.3)^2 + (38.0)^2 + (47.7)^2 - 2(7.69)^2} = 11.5\ Hz$

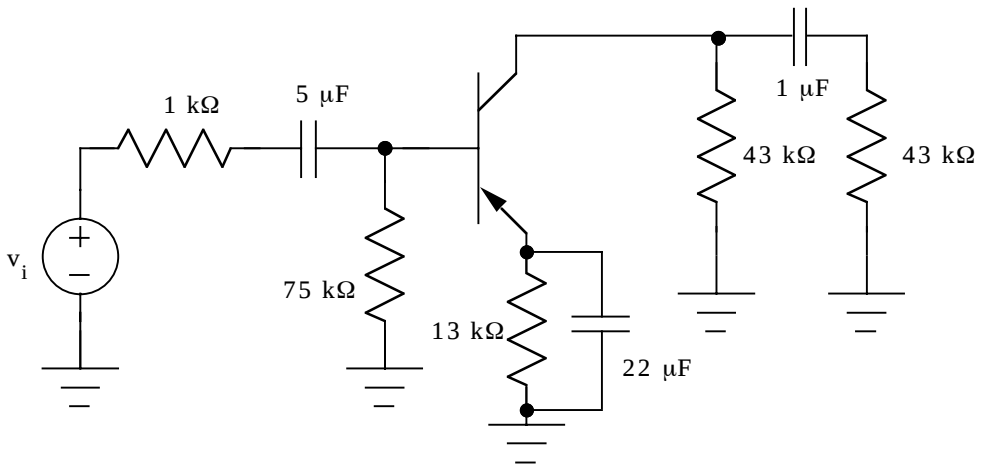
4.) Problem 17.18 (17.13) of the text

(a.)

Mid-band:



Low frequency:



Problem 17.18 (17.13) - Continued

$(b)\ g_m = 40I_C = 40(0.164mA) = 6.56mS$ | $r_\pi = \dfrac{\beta_o}{g_m} = \dfrac{100}{6.56mS} = 15.2k\Omega$ | $r_o = \infty$ (V_A not given)

$R_{in} = R_1 \| R_2 \| r_\pi = 100k\Omega \| 300k\Omega \| 15.2k\Omega = 12.6k\Omega$ | $R_L = R_C \| R_3 = 43k\Omega \| 43k\Omega = 21.5k\Omega$

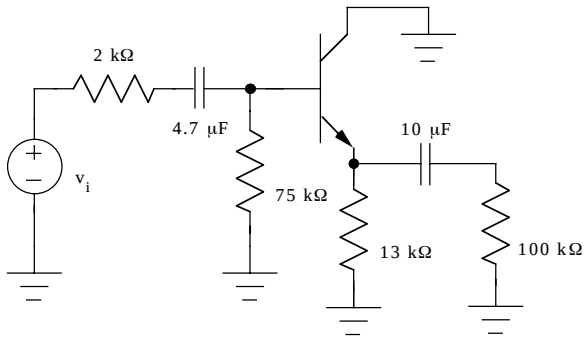
$$A_{mid} = \frac{R_{in}}{R_I + R_{in}} g_m R_L = \frac{12.6k\Omega}{1k\Omega + 12.6k\Omega}(6.56mS)(21.5k\Omega) = -131$$

SCTC: $R_{1S} = R_I + R_{in} = 1k\Omega + 12.6k\Omega = 13.6k\Omega$ | $R_{th} = R_1 \| R_2 \| R_I = 100k\Omega \| 300k\Omega \| 1k\Omega = 987\Omega$

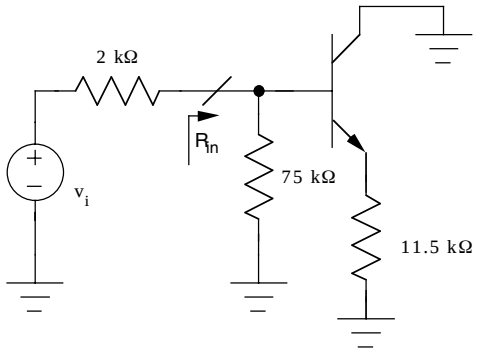
$$R_{2S} = R_E \left\| \frac{R_{th} + r_\pi}{\beta_o + 1} = 13k\Omega \right\| \frac{987\Omega + 15.2k\Omega}{101} = 158\Omega$$ | $R_{3S} = R_C + R_3 = 43k\Omega + 43k\Omega = 86k\Omega$

$$f_L \cong \frac{1}{2\pi}\left[\frac{1}{5x10^{-6}(13.6k\Omega)} + \frac{1}{22x10^{-6}(158\Omega)} + \frac{1}{1x10^{-6}(86k\Omega)}\right] = \frac{(14.7 + 288 + 11.6)}{2\pi} = 50.0\ Hz$$

5.) Problem 17.23 (17.16) of the text.



Low frequency



Mid-band

$(b)\ R_{in} = R_1 \| R_2 \| r_\pi + (\beta_o + 1)R_L$ | $R_L = 13k\Omega \| 100k\Omega = 11.5k\Omega$ | $r_\pi = \dfrac{100}{40(0.25mA)} = 10.0k\Omega$

$$R_{in} = R_1 \| R_2 \| \left[r_\pi + (\beta_o + 1)R_L \right] = 100k\Omega \| 300k\Omega \| \left[10.0k\Omega + (101)11.5k\Omega\right] = 70.5k\Omega$$

$$A_{mid} = \frac{R_{in}}{R_I + R_{in}} \frac{(\beta_o + 1)R_L}{R_{in}} = 0.972 \frac{101(11.5k\Omega)}{\left[2 + 10.0 + 101(11.5)\right]k\Omega} = 0.963$$ | $R_B = R_1 \| R_2 = 75k\Omega$

$$R_{1S} = R_I + R_B \left\| \left[r_\pi + (\beta_o + 1)R_L \right] = 2k\Omega + 75k\Omega \right\| \left[10.0k\Omega + (101)11.5k\Omega\right] = 72.5k\Omega$$

$$\omega_1 = \frac{1}{(72.5k\Omega)4.7x10^{-6}} = 2.94\frac{rad}{s}$$

$$R_{3S} = R_7 + R_E \left\| \frac{R_B \| R_I + r_\pi}{(\beta_o + 1)} = 100k\Omega + 13k\Omega \right\| \frac{1.95k\Omega + 10.0k\Omega}{101} = 100k\Omega$$

$$\omega_3 = \frac{1}{10^{-5}(10^5)} = 1\frac{rad}{s} \qquad f_L \cong \frac{(2.94 + 1)}{2\pi} = 0.627Hz$$