Homework Assignment No. 9 - Solution

17.1

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

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

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

$$\left|A_V(j\omega)\right| = \frac{25\omega^2}{\sqrt{\omega^2 + 1^2}\sqrt{\omega^2 + 20^2}} \quad | \text{ MATLAB: } - 3.19 \text{ Hz}$$

17.4

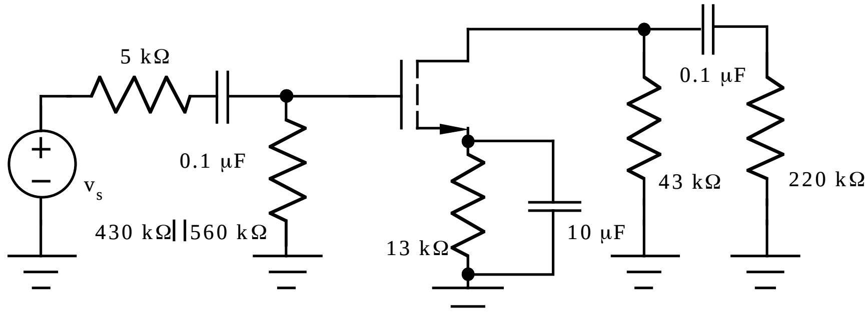
$$A_V(s) = \frac{\left(2\text{x}10^{11}\right)\left(10^{-4}\right)\left(10^{-5}\right)}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)} = \frac{200}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)} \quad | \quad A_{mid} = 200 \quad | \quad F_H(s) = \frac{1}{\left(\frac{s}{10^4}+1\right)\left(\frac{s}{10^5}+1\right)}$$

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

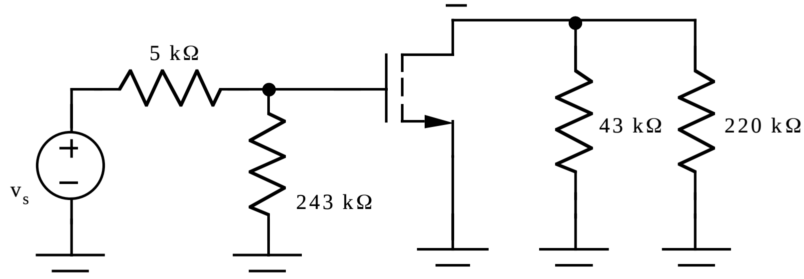
$$f_H \cong \frac{1}{2\pi}\left(\sqrt{\left(\frac{1}{10^4}\right)^2 + \left(\frac{1}{10^5}\right)^2 - 2\left(\frac{1}{\infty}\right)^2 - 2\left(\frac{1}{\infty}\right)^2}\right)^{-1} = 1.58 \text{ kHz}$$

$$\left|A_V(j\omega)\right| = \frac{2\text{x}10^{11}}{\sqrt{\omega^2 + \left(10^4\right)^2}\sqrt{\omega^2 + \left(10^5\right)^2}} \quad | \text{ MATLAB: } 1.58 \text{ kHz}$$

17.10



Low frequency:



Mid-band:

17.10 - Continued

$$g_m = \frac{2I_{DS}}{V_{GS} - V_{TN}} = \frac{2(0.2\,mA)}{1V} = 0.400\,mS$$

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

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

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

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

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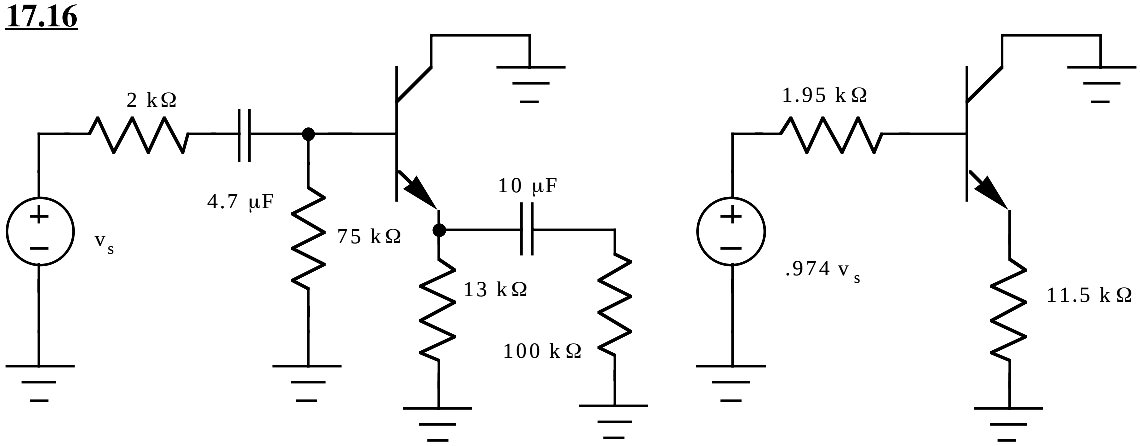
17.16



Low frequency Mid-band

(b) $\mathbf{v_{th}} = \frac{75\,k\Omega}{75\,k\Omega + 2\,k\Omega}\mathbf{v_s} = 0.974\mathbf{v_s}$ | $R_{th} = 75\,k\Omega \| 2\,k\Omega = 1.95\,k\Omega$ | $R_L = 13\,k\Omega \| 100\,k\Omega = 11.5\,k\Omega$

$$r_\pi = \frac{100}{40(0.25\,mA)} = 10.0\,k\Omega \quad | \quad A_{mid} = 0.974\frac{101(11.5\,k\Omega)}{[1.95 + 10.0 + 101(11.5)]\,k\Omega} = 0.964$$

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

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

$$R_{3S} = R_7 + R_4 \left\| \frac{R_{th} + r_\pi}{(\beta_o + 1)} = 100\,k\Omega + 13\,k\Omega \right\| \frac{1.95\,k\Omega + 10.0\,k\Omega}{101} = 100\,k\Omega$$

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

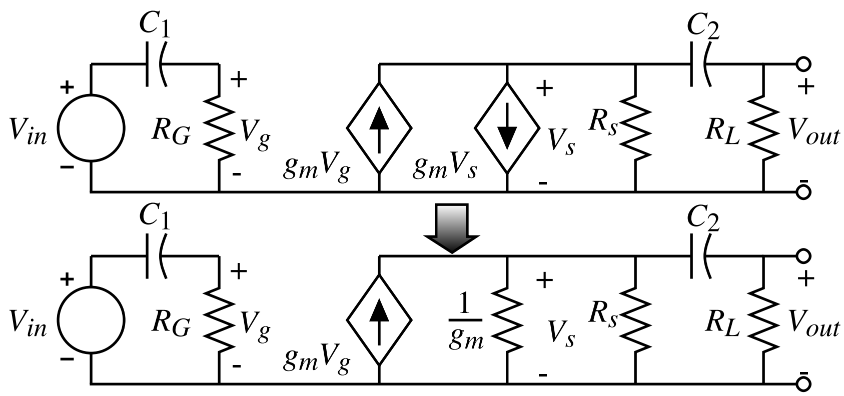
Problem 5

a.) If the g_m of the MOSFET is 0.1mA/V, find the midband gain and the location of all zeros and poles of the circuit shown.

b.) If the amplifier above has two zeros at the origin and a pole at –1 rads/sec and –4 rads/sec., what is the lower –3dB frequency in Hz?

Solution

1.) Small-signal model:



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$$\frac{V_{out}}{V_{in}} = \left(\frac{g_m\,(1/g_m)||R_s}{(1/g_m)||R_s + R_L + \frac{1}{sC_2}} \text{ x } R_L\right)\left(\frac{R_G}{R_G + \frac{1}{sC_2}}\right) = \left(\frac{5\text{k}}{15\text{k} + \frac{1}{sC_2}}\right)\left(\frac{1\text{M}}{1\text{M} + \frac{1}{sC_1}}\right)$$

$$= \left(\frac{1}{3}\right)\left(\frac{s}{s + \frac{1}{15\text{k}\ C_2}}\right)\left(\frac{s}{s + \frac{1}{1\text{M}\ C_1}}\right) = \left(\frac{1}{3}\right)\left(\frac{s}{s + 6.67}\right)\left(\frac{s}{s + 1}\right)$$

$\therefore$ MGB = <u>0.333</u>, two zeros at <u>0 rads/sec</u>. and poles at <u>–1 rad/sec</u> and <u>–6.67 rads/sec</u>.

2.) $\omega_L \approx \sqrt{p_1{}^2 + p_2{}^2 - 2(z_1{}^2 + z_2{}^2)} = \sqrt{1^2 + 4^2 - 2(0)} = \sqrt{17} = 4.123$ rads/sec.

$\therefore \qquad f_L = \frac{4.123}{6.28} =$ <u>0.656 Hz</u>