Homework Assignment No. 14 - Solutions

1.) Find the loop gain of the amplifier shown. Assume that $g_m = 1 \text{mS}$ and $r_{ds} = \infty$ for all MOSFETs and that $R = 10 \text{k}\Omega$ and $C = 100 \text{nF}$.

**Solution**

Use the model shown to find the loop gain.

This circuit consists of three identical stages with each transfer function given as

$$A(s) = \frac{-g_m R}{sRC+1}$$

Therefore,

$$T(s) = \frac{v_r}{v_x} = \left(\frac{-g_m R}{sRC+1}\right)^3 = \left(\frac{-10}{s/10^3 + 1}\right)^3 = \frac{1000}{(s/10^3 + 1)^3} \rightarrow T(s) = \frac{1000}{(s/10^3 + 1)^3}$$

2.) Problem 18.71 (18.49) of the text.

(a) $T = A\beta = \frac{2 \times 10^{14} \pi^2}{(s + 2 \times 10^5 \pi)(s + 2 \times 10^3 \pi)} \left(\frac{1}{5}\right)$ \hspace{1cm} Yes, it is a second-order system and will have some phase margin, although $\Phi_M$ may be vanishingly small.

(b) For $\omega \gg 2\pi \times 10^5$, $|T(j\omega)| \approx \frac{4 \times 10^{13} \pi^2}{\omega^2}$ and $|T(j\omega)| = 1$ for $\omega = 1.987 \times 10^7 \text{rad/s}$

$$\angle T(j1.987 \times 10^7) = -\tan^{-1}\frac{1.987 \times 10^7}{2000\pi} - \tan^{-1}\frac{1.987 \times 10^7}{2 \times 10^5 \pi} = 178.2^o \rightarrow \Phi_M = 1.83^o$$ \hspace{1cm} A very small phase margin.
3.) Problem 18.86 (18.61) of the text.

\[ A_{vl} = \frac{V_{vl}}{V_{o2}} = -\frac{1}{sRC} \]
\[ V_{o2} = \left( 1 + \frac{2R}{2R} \right) V_i = 2V_i \]

\[ (V_i - V_{vl}) \frac{G}{2} + sCV_i + (V_i - V_{o2})G_F = 0 \]
Combining these yields

\[ A_{vl} = \frac{V_{o2}}{V_{vl}} = \frac{G}{sC + \left( \frac{G}{2} - G_F \right)} \]
and \( T(s) = A_{vl}A_{v2} = \frac{1}{sRC\left( sRC + 1 - \frac{R}{R_F} \right)} \)

\[ \angle T(j\omega_o) = 0 \rightarrow R_F = 2R \text{ and } |T(j\omega_o)| = 1 \rightarrow \omega_o = \frac{1}{RC} \]

4.) Problem 18.88 (18.63) of the text.

![Circuit Diagram]

\[ f_o = \frac{1}{2\pi(5k\Omega)(500pF)} = 63.7 \text{ kHz} \]
\[ |v_o| = \frac{3(0.7V)}{2 - 15k\Omega \left( 1 + \frac{10k\Omega}{6.2k\Omega} \right) - 10k\Omega} = 6.85 \text{ V} \]

5.) Problem 18.95 (18.70) of the text.

![Circuit Diagram]

\[ C_T = C_{GD} + \frac{1}{C_2} + \frac{1}{C_1 + C_3 + C_{GS}} = 4pF + \frac{1}{50pF} + \frac{1}{50pF + 0 + 10pF} = 31.27pF \]

\[ f_o = \frac{1}{2\pi\sqrt{LC_T}} = \frac{1}{2\pi\sqrt{(10^{-5}H)(31.27 \times 10^{-12} F)}} = 9.00 \text{ MHz} \]

\[ g_m r_o \geq \frac{C_1 + C_3 + C_{GS}}{C_2} \cdot \frac{50pF + 0 + 10pF}{50pF} = 1.20 \text{ which is easily met.} \]