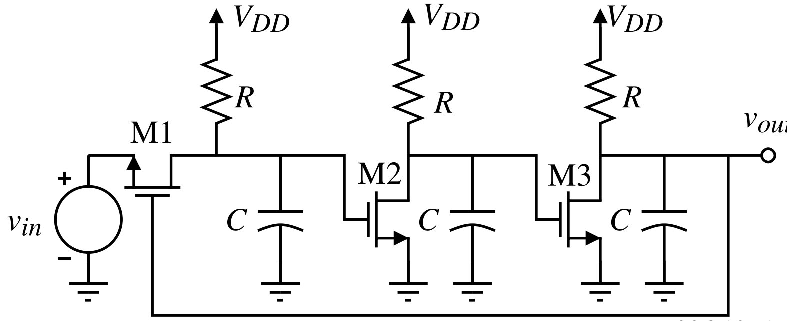
Homework Assignment No. 14 - Solutions

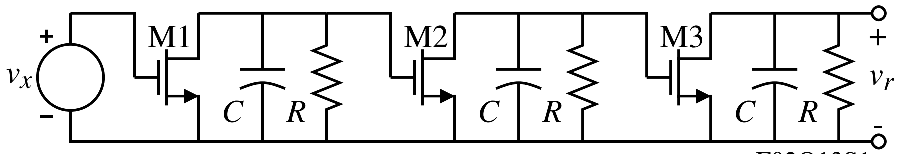
1.) Find the loop gain of the amplifier shown. Assume that g_m = 1mS and $r_{ds} = \infty$ for all MOSFETs and that R = 10kΩ and C = 100nF.

Solution



F02Q13P1B

Use the model shown to find the loop gain.



F02Q13S1

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

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

Therefore,

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

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

$(a)\ T = A\beta = \dfrac{2x10^{14}\pi^2}{(s+2x10^3\pi)(s+2x10^5\pi)}\left(\dfrac{1}{5}\right)$ | Yes, it is a second-order system and will have some phase margin, although Φ_M may be vanishingly small.

(b) For $\omega >> 2\pi\, x\, 10^5$, $|T(j\omega)| \approx \dfrac{4x10^{13}\pi^2}{\omega^2}$ and $|T(j\omega)| = 1$ for $\omega = 1.987x10^7 \dfrac{rad}{s}$

$\angle T(j1.987x10^7) = -\tan^{-1}\dfrac{1.987x10^7}{2000\pi} - \tan^{-1}\dfrac{1.987x10^7}{2x10^5\pi} = 178.2^o \rightarrow \Phi_M = 1.83^o$ | A very small phase margin.

3.) Problem 18.86 (18.61) of the text.

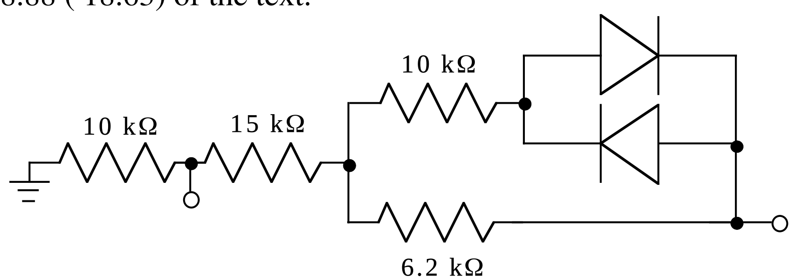
$$A_{v1} = \frac{V_{o1}}{V_{o2}} = -\frac{1}{sRC} \qquad V_{o2} = \left(1+\frac{2R}{2R}\right)V_+ = 2V_+$$

$$\left(V_+ - V_{o1}\right)\frac{G}{2} + sCV_+ + \left(V_+ - V_{o2}\right)G_F = 0 \quad \text{Combining these yields}$$

$$A_{v2} = \frac{V_{o2}}{V_{o1}} = \frac{G}{sC + \left(\frac{G}{2} - G_F\right)} \quad \text{and} \quad T(s) = A_{v1}A_{v2} = \frac{1}{sRC\left(sRC + \frac{1}{2} - \frac{R}{R_F}\right)}$$

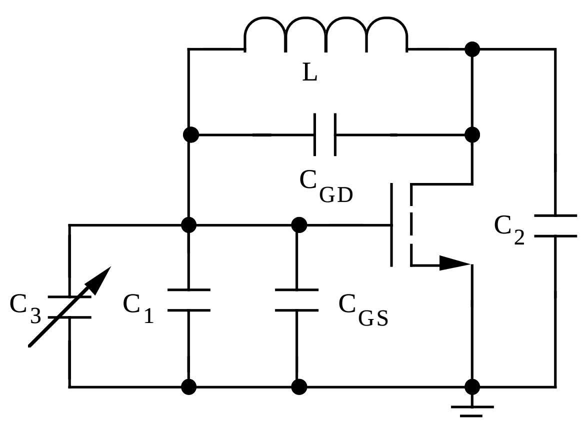
$$\angle T(j\omega_o) = 0 \rightarrow R_F = 2R \quad \text{and} \quad \left|T(j\omega_o)\right| = 1 \rightarrow \omega_o = \frac{1}{RC}$$

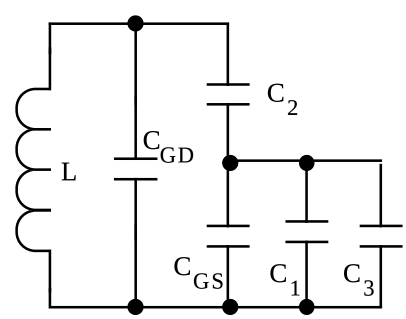
4.) Problem 18.88 (18.63) of the text.



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

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





$$C_{TC} = C_{GD} + \frac{1}{\frac{1}{C_2} + \frac{1}{C_1 + C_3 + C_{GS}}} = 4pF + \frac{1}{\frac{1}{50pF} + \frac{1}{50pF + 0 + 10pF}} = 31.27pF$$

$$f_o = \frac{1}{2\pi\sqrt{LC_{TC}}} = \frac{1}{2\pi\sqrt{\left(10^{-5}H\right)\left(31.27x10^{-12}F\right)}} = 9.00MHz$$

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