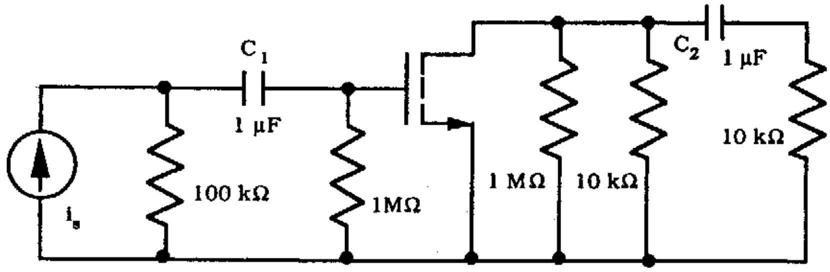
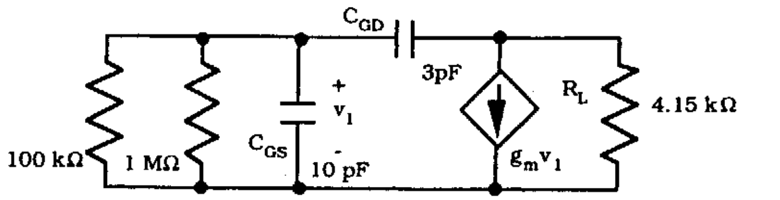
Homework Assignment No. 14 Solutions

18.30



$$\omega_1 = \frac{1}{10^{-6}(100\text{k}\Omega + 1\text{M}\Omega)} = 0.909\frac{\text{rad}}{\text{s}} \quad | \quad \omega_2 = \frac{1}{10^{-6}\left(10\text{k}\Omega + 25\text{k}\Omega \| 10\text{k}\Omega \| 1\text{M}\Omega\right)} = 58.5\frac{\text{rad}}{\text{s}}$$

Separate widely spaced poles $\rightarrow f_L^A = f_2 = \frac{58.5}{2\pi} = 9.31$ Hz



25kΩ||1MΩ||10kΩ||10kΩ

$$\omega_H^A = \frac{1}{r_{\pi o}C_T} = \frac{1}{(100\text{k}\Omega \| 1\text{M}\Omega)\left[10\text{pF} + 3\text{pF}\left(1 + 2\text{mS}(4.15\text{k}\Omega) + \frac{4.15\text{k}\Omega}{100\text{k}\Omega \| 1\text{M}\Omega}\right)\right]}$$

$$f_H^A = \frac{1}{2\pi}\frac{1}{(90.9\text{k}\Omega)(38.0\text{pF})} = 46.1 \text{ kHz}$$

$$\mathbf{v}_{gs} = \mathbf{i}_s(100\text{k}\Omega \| 1\text{M}\Omega) = (90.9\text{k}\Omega)\mathbf{i}_s \quad | \quad \mathbf{v}_o = -\left(2\text{x}10^{-3}\right)\mathbf{v}_{gs}(25\text{k}\Omega \| 10\text{k}\Omega \| 10\text{k}\Omega \| 1\text{M}\Omega)$$

$$A = \frac{\mathbf{v}_o}{\mathbf{i}_s} = -(2\text{mS})(4.15\text{k}\Omega)(90.9\text{k}\Omega) = -7.55\text{x}10^5\Omega \quad | \quad y_{12}^F = -10^{-5}\text{S}$$

$$1 + A\beta = 1 + \left(-7.55\text{x}10^5\Omega\right)\left(-10^{-6}\text{S}\right) = 1.76$$

$$f_L = \frac{9.31}{1.76} = 5.29 \text{ Hz} \qquad f_H = 46.1\text{kHz}(1.76) = 81.0 \text{ kHz}$$

18.32

$$\text{(a)}\quad A(s) = \frac{\dfrac{2\text{x}10^{14}\pi^2}{(2\pi\,\text{x}10^3)(2\pi\,\text{x}10^5)}}{\left(1 + \dfrac{s}{2\pi\,\text{x}10^3}\right)\left(1 + \dfrac{s}{2\pi\,\text{x}10^5}\right)} = \frac{5\text{x}10^5}{\left(1 + \dfrac{s}{2\pi\,\text{x}10^3}\right)\left(1 + \dfrac{s}{2\pi\,\text{x}10^5}\right)}$$

A(s) represents a low - pass amplifier with two widely - spaced poles

Open – loop: $A_o = 5\text{x}10^5 = 114\text{dB} \quad | \quad f_L = 0 \quad | \quad f_H \approx f_1 = 1000 \text{ Hz}$

(b)A common mistake would be the following:

Closed – loop: $f_H = 1000\text{Hz}\left[1 + 5\text{x}10^5(0.01)\right] = 5\text{MHz}$

Oops! - This exceeds $f_2 = 100$ kHz! This is a two - pole amplifier.

Prob. 18.32 – Cont'd

$$A_V(s) = \frac{\dfrac{2x10^{14}\pi^2}{(s+2\pi\,x10^3)(s+2\pi\,x10^5)}}{1+\dfrac{2x10^{14}\pi^2}{(s+2\pi\,x10^3)(s+2\pi\,x10^5)}(0.01)} = \frac{2x10^{14}\pi^2}{s^2+1.01(2\pi\,x10^5)s+2x10^{12}\pi^2}$$

Using dominant - root factorization: $f_1 = 101$ kHz, $f_2 = 4.95$ MHz

So the closed - loop values are $f_H = 101$ kHz and $f_L = 0$.

18.35

$$T = \frac{v_o}{v_x} = g_{m2}(r_{o2}\|r_{o4})\frac{(\beta_o+1)R}{(r_{o2}\|r_{o4})+r_{\pi 3}+(\beta_o+1)R} \quad | \quad g_{m1} = 40(10^{-4}) = 4.00\text{mS}$$

$$r_{o2} = \frac{50+1.4}{10^{-4}} = 514\text{k}\Omega \quad | \quad r_{o4} = \frac{50+11.3}{10^{-4}} = 613\text{k}\Omega \quad | \quad r_{\pi 3} = \frac{100(0.025)}{(12V/10\text{k}\Omega)} = 2.08\text{k}\Omega$$

$$T = (4x10^{-3})(280\text{k}\Omega)\frac{(101)10\text{k}\Omega}{280\text{k}\Omega+2.08\text{k}\Omega+101(10\text{k}\Omega)} = 876 \quad (58.9\text{ dB})$$

18.49

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

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

18.61

$$A_{V1} = \frac{\mathbf{V_{o1}}}{\mathbf{V_{o2}}} = -\frac{1}{sRC} \qquad \mathbf{V_{o2}} = \left(1+\frac{2R}{2R}\right)\mathbf{V_+} = 2\mathbf{V_+}$$

$(\mathbf{V_+} - \mathbf{V_{o1}})\dfrac{G}{2} + sC\mathbf{V_+} + (\mathbf{V_+} - \mathbf{V_{o2}})G_F = 0$ Combining these yields

$$A_{V2} = \frac{\mathbf{V_{o2}}}{\mathbf{V_{o1}}} = \frac{G}{sC+\left(\dfrac{G}{2}-G_F\right)} \quad \text{and} \quad T(s) = A_{V1}A_{V2} = \frac{1}{sRC\left(sRC+\dfrac{1}{2}-\dfrac{R}{R_F}\right)}$$

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