University of Pennsylvania
Department of Electrical and Systems Engineering
ESE 319 Microelectronic Circuits

Final Exam
December 16, 2010

This exam is a closed book exam. Students are allowed to use a calculator (not a smart Phone or PDA with Internet Access) and a single page reference sheet (two sided). Please show all work, justify all approximations and give the units for all calculated parameters.

1. Consider the four-stage amplifier circuit in Fig. P1. Stage 1 involves of transistors Q1, Q2; stage 2 involves Q3, Q4; stage 3 involves Q5 and stage 4 involves Q6. Assume all six transistors are forward-active with $|V_{BE}| = 0.7$ V, V_A = large and β = large. Furthermore let transistors Q1 - Q4 be matched and all current sources are ideal.

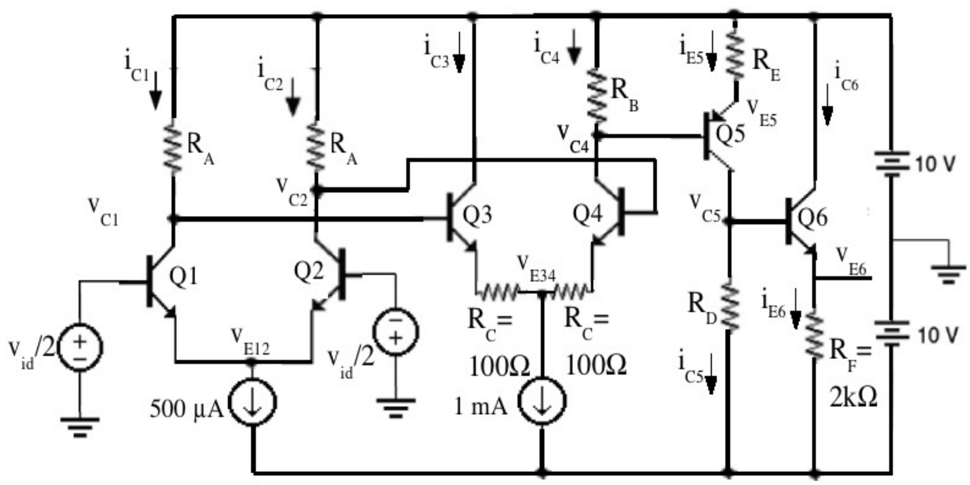


Fig. P1 Four-Stage Amplifier for Problem 1

(a). Determine values for dc currents I_{C1}, I_{C2}, I_{C3} and I_{C4} and dc voltages V_{E12}. (5 pts)

(b). Let the dc voltages be specified: $V_{C1} = V_{C2} = 7$ V and $V_{C4} = 8$ V. Determine the values for resistors R_A and R_B. Further determine the value for voltage V_{E5} and V_{E34}. (10 pts)

(c). Let $V_{C5} = 1$ V and $I_{C5} = 2$ mA. Determine values for resistors R_D and R_E. Further determine the value for voltage V_{E6}. (10 pts)

(d). Determine the values for currents I_{E6} and I_{C6}. (5 pts)

(e). Let the amplifier be driven by an ac differential input $\pm v_{id}/2$ and the dc currents be those in parts a through d above. Determine the values for the small-signal transconductance parameters for all six transistors, i.e. g_{m1}, g_{m2}, g_{m3}, g_{m4}, g_{m5} and g_{m6}. (10 pts)

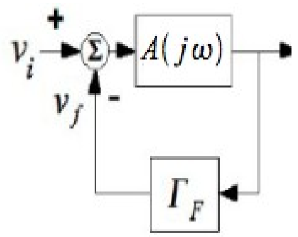
(f) Determine the mid-band gains for each of the four stages, i.e. $A_1 = \frac{v_{o1d}}{v_{id}}$; $A_2 = \frac{v_{c4}}{v_{o1d}}$; $A_3 = \frac{v_{c5}}{v_{c4}}$

and $A_4 = \frac{v_{e6}}{v_{c5}}$, where $v_{o1d} = v_{c2} - v_{c1}$. (10 pts)

(g) Let the output be $v_o = v_{e6}$, determine the overall voltage gain $A = \frac{v_o}{v_{id}}$. (10 pts)

(h) It is required to increase the overall gain A by 6 dB (actually 6.02 dB), while keeping the dc voltages V_{C1}, V_{C2}, V_{C4}, V_{C5} and V_{E6} the same as given in parts b and c, modify the value(s) of the appropriate resistor(s) to implement this requirement. (10 pts)

2. Consider the feedback amplifier where the gain and phase of the open-loop $A(s) = \frac{A_0 p_1 p_2 p_3}{(s+p_1)(s+p_2)(s+p_3)} = \frac{2 x 10^{24}}{(s+10^5)(s+3 x 10^6)(s+10^8)}$ are plotted in Fig. P2.



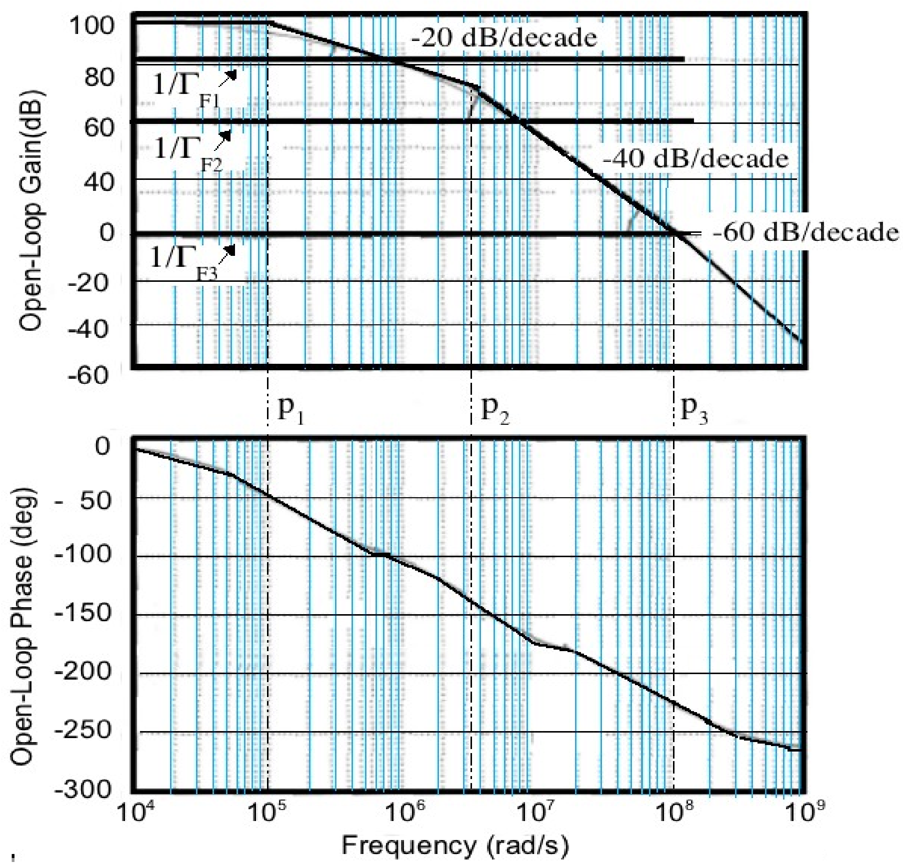


Fig. P2 Bode Plots for Problem 2

a. For feedback Γ_{F1} estimate the unity-gain crossover frequency ω_1, the 180° phase crossover frequency ω_{180} and the phase-margin PM_1. Is the closed-loop amplifier with $\Gamma_F = \Gamma_{F1}$ stable? (10 pts)

b. For feedback Γ_{F2} estimate the unity-gain crossover frequency ω_1, the 180° phase crossover frequency ω_{180} and the phase-margin PM_2. Is the closed-loop amplifier with $\Gamma_F = \Gamma_{F2}$ stable? (10 pts)

c. For feedback Γ_{F3} estimate the unity-gain crossover frequency ω_1, the 180° phase crossover frequency ω_{180} and the phase-margin PM_3. Is the closed-loop amplifier with $\Gamma_F = \Gamma_{F3}$ stable? (10 pts)