ECEN 326 Lab 11
Design of a Two-Stage Amplifier with Miller Compensation

Circuit Topology

Figure 1(a) shows the two-stage differential amplifier to be designed in this lab. C_L represents the load capacitor, whereas C_M is the Miller compensation capacitor. This amplifier will be compensated for unity-gain feedback configuration, shown in Fig. 1(b).

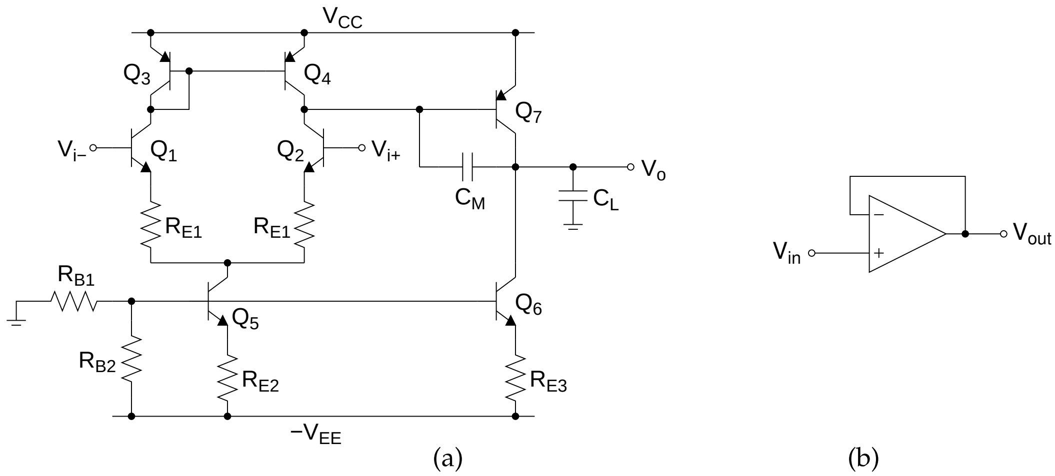

Figure 1: (a) Two-stage differential amplifier (b) Unity-gain feedback configuration

Defining $V_i = (V_{i+} - V_{i-})$, the amplifier's transfer function can be obtained as

$$\frac{V_o}{V_i}(s) \approx \frac{A_o}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)} \tag{1}$$

where

$$A_o \approx g'_{m2} R_{o1} g_{m7} R_{o2} \tag{2}$$

$$g'_{m2} \approx \frac{g_{m2}}{1+g_{m2}R_{E1}} \tag{3}$$

$$R_{o1} \approx r_{\pi 7} \parallel r_{o4} \parallel (r_{o2} + g_{m2} r_{o2} R_{E1}) \tag{4}$$

$$R_{o2} \approx r_{o7} \parallel (g_{m6} r_{o6} (R_{E3} \parallel r_{\pi 6}) + r_{o6}) \tag{5}$$

$$\omega_{p1} \approx \frac{1}{g_{m7} R_{o1} R_{o2} C_M} \tag{6}$$

$$\omega_{p2} \approx \frac{g_{m7}}{C_L} \tag{7}$$

Assuming $\omega_{p2} \gg \omega_{p1}$ and $\omega_{p2} > \omega_t$, the unity-gain frequency ω_t can be calculated as

$$\omega_t = A_o \omega_{p1} = \frac{g'_{m2}}{C_M} \tag{8}$$

The phase margin for unity-gain configuration is approximately equal to

$$\text{PM} \approx \tan^{-1}\left(\frac{\omega_{p2}}{\omega_t}\right) = \tan^{-1}\left(\frac{g_{m7}}{g'_{m2}}\frac{C_M}{C_L}\right) \tag{9}$$

Calculations and Simulations

Using 2N3904 and 2N3906 transistors, and assuming $\beta_{npn} = 140$, $\beta_{pnp} = 180$, $V_{A,npn} = 75\ V$, $V_{A,pnp} = 20\ V$, design the two-stage amplifier circuit with the following specifications:

$V_{CC} = V_{EE} = 5\ V$ $\quad C_L = 10\ nF$
$R_{E1} = 200\ \Omega$ $\quad A_o \geq 80\ dB$

1. Show all your calculations and final component values.
2. Find a set of C_M values which results in PM = 30°, 45° and 60° for unity-gain configuration.
3. Verify your results using a circuit simulator. Submit all necessary simulation plots showing that the specifications are satisfied. Also provide the circuit schematic with DC bias points annotated.
4. In unity-gain configuration, perform AC simulation to obtain the closed-loop gain for PM = 30°, 45° and 60°.
5. In unity-gain configuration, apply a 1-V step input and perform transient simulation to obtain the step response for PM = 30°, 45° and 60°.
6. Submit all simulation plots showing AC and step responses.

Measurements

1. Construct the amplifier you designed.
2. Measure I_{supply} and all DC quiescent voltages and currents.
3. Using the amplifier in unity-gain configuration, obtain the frequency and step responses for PM = 30°, 45° and 60°.

Report

1. Include calculations, schematics, simulation plots, and measurement plots.
2. Prepare a table showing calculated, simulated and measured results.
3. Compare the results and comment on the differences.

Demonstration

1. Construct the amplifier you designed on your breadboard and bring it to your lab session.
2. Your name and UIN must be written on the side of your breadboard.
3. Submit your report to your TA at the beginning of your lab session.
4. Measure I_{supply}.
5. Using the amplifier in unity-gain configuration, show the frequency and step responses for PM = 30°, 45° and 60°.