Closed book, calculators required; Friday, May 5; 11AM-1 PM

ECE 304: Final Exam Spring '06 Answers

NOTE: IN ALL CASES

1. Solve the problem on scratch paper. Then, once you understand your answer, compose your answer sheet as follows:
2. Put your answer first, and
3. Follow your answer with an outline of your solution. Each major step in the outline should
   3.1. Begin with a heading that describes the objective of that step, and should
   3.2. Have a body where actual work is done, not just hand waving, and should
   3.3. Conclude with a quantitative statement of the major result for that step (a number or formula or both).

A mish-mash of calculations is not an outline! No marks without an outline.

For all problems take the thermal voltage as $\mathbf{V_{TH}= 25.864\ mV}$.

Problem 1: Feedback network design

A signal current source with an output resistance R_N = 10 kΩ is to be used to drive a load R_L = 50 Ω. A current gain of 10 A/A is required. This goal is achieved using a negative feedback amplifier. We have available a T-section of resistors for a feedback network and a voltage amplifier with a gain of $A_{\upsilon 0} = 10^5$ V/V, input resistance R_I = 1kΩ and output resistance of R_O = 10 Ω.

1. Sketch the case of *ideal* feedback first and find the ideal β_{FB}. Ideal means a single controlled current or voltage source and *no* feedback resistors.
2. Set up a two-port for the real-world feedback network using a T-section of resistors.
3. Select the T-section resistor values for the maximum loaded open-loop current gain. In maximizing the loaded gain, assume β_{FB} maintains its ideal value from Part 1.
4. Sketch your final design with all components labeled.

Show your work in your outline.

Answers: Ideal β_{FB} = 0.1A/A, resistor values: $R_A = 9R_C$ =700.7 Ω, R_C = vertical resistor, R_A = left horizontal resistor, R_B = 0 Ω.

Problem 2: Feedback compensation

A compensated open-loop amplifier has a gain expression given by

EQ. 1

$$A_\upsilon(f) = \frac{A_{\upsilon 0}}{\left(1+ j\ \alpha \frac{f}{f_1}\right)\left(1+ j\frac{f}{\alpha f_2}\right)\left(1+ j\frac{f}{f_3}\right)}$$

where $A_{\upsilon 0} = 10^5$ V/V, $f_1 = 10^5$ Hz, $f_2 = 5 \times 10^6$Hz and $f_3 = 10^7$ Hz. The value of α is decided by the size of a compensation capacitor that shifts two of the pole frequencies (pole f_1/α moves down and pole αf_2 moves up in frequency as α increases). The amplifier is used in a feedback voltage amplifier with β_{FB} = 10 mV/V.

1. Find the value of α for a closed-loop Butterworth two-pole step response.
2. Sketch the Bode phase and magnitude plots of your final design for the open loop and closed loop amplifiers, and label all breakpoints with (frequency, value) coordinates.
3. Mark the open-loop phase flip frequency f_{180} and the $1/\beta_{FB}$ magnitude frequency $f_{1/\beta.}$ Show how you got them in your outline
4. Determine the gain and phase margin of the feedback amplifier.

Answers: α=20, gain margin 26 dB, phase margin 58.5°

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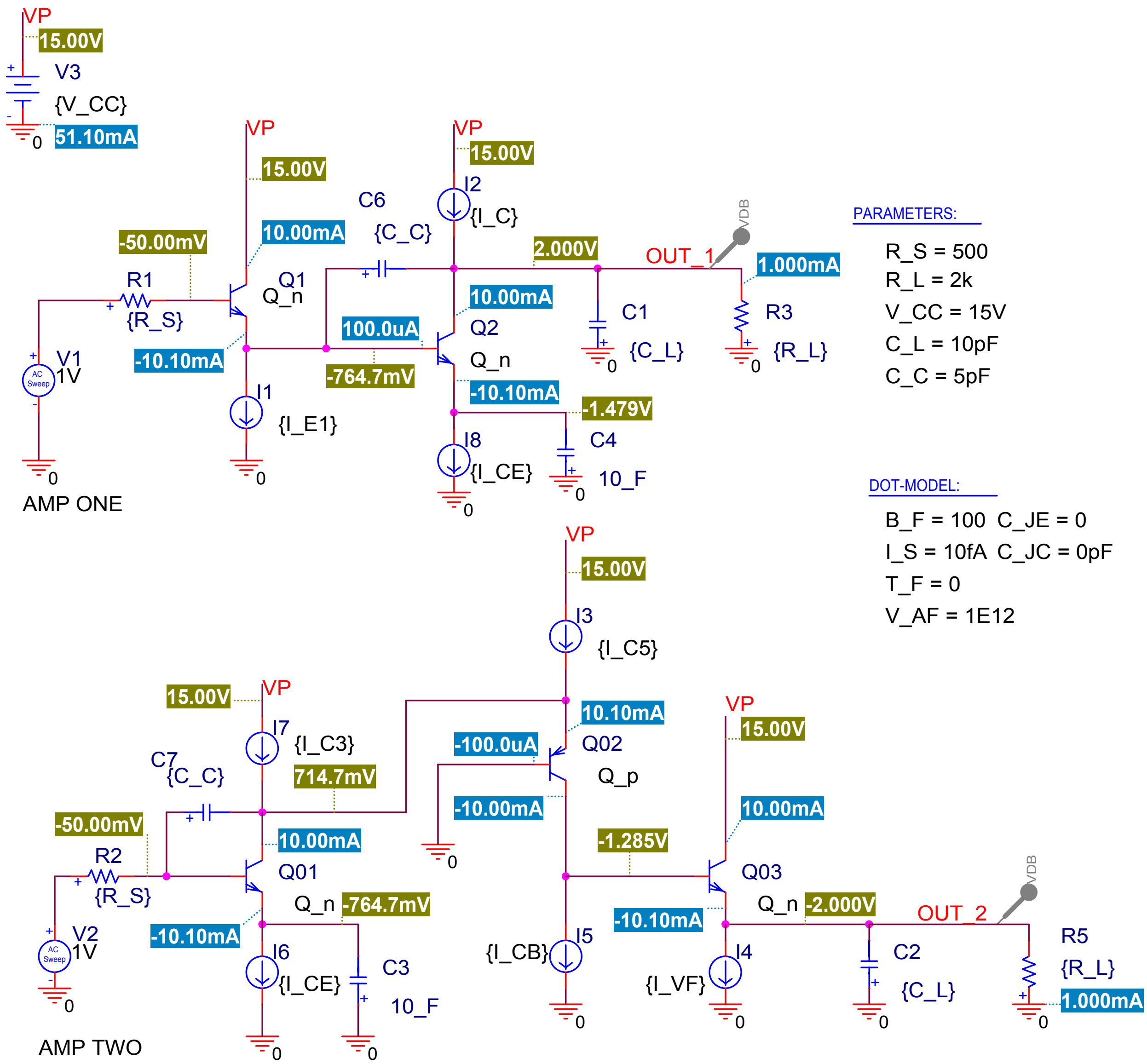
Problem 3: Corner frequency comparison



.model Q_n NPN (IS={I_S} BF={B_F}Cje={C_JE} Cjc={C_JC} Tf={T_F} Vaf={V_AF})

.model Q_p PNP (IS={I_S} BF={B_F}Cje={C_JE} Cjc={C_JC} Tf={T_F} Vaf={V_AF})

FIGURE 1

Two amplifiers for comparison; AMP ONE (top) and AMP TWO (bottom)

The transistors in Figure 1 have no internal capacitances, and do not exhibit Early effect ($V_{AF} = 10^{12}$ V).

1. Determine a formula for the upper 3dB frequencies f_{3dB} of both amplifiers.
2. Evaluate your formulas.
3. Explain the effect (if any) of each stage in each amplifier upon the bandwidth.
4. Explain the effect (if any) of each stage in each amplifier upon the small-signal midband gain.
5. By simple inspection without calculation, when used in a feedback amplifier, which amplifier exhibits the largest overshoot in step response? Explain.

Answers: f_{3dB}(Amp 1) = 2.73 MHz, f_{3dB}(Amp 2) = 7.63 MHz, Amp 2 shows most overshoot because C_C doesn't cause pole splitting (cascode), while Amp 1 does show pole splitting.

