Final Exam Information

Rough breakdown of topic coverage:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-80%</td>
<td>Material covered on Exams #1, #2, and #3</td>
</tr>
<tr>
<td>10-20%</td>
<td>L networks for impedance matching</td>
</tr>
<tr>
<td>10-20%</td>
<td>Feedback methods and analysis</td>
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</table>

The structure of the final exam will be guided by the ELEC 351 Course Outcomes, which are core competencies that can be measured by assessment instruments such as exam questions and design tasks. Specifically, a student who successfully completes the course should be able to:

1. Apply an appropriate small-signal model to analyze properties such as gain and input/output impedance of a BJT or MOSFET amplifier.

2. Explain some of the performance advantages of cascode amplifiers.

3. Analyze and design basic current mirror circuits.

4. Analyze the differential-mode and common-mode behaviors of BJT and MOSFET-based differential amplifiers.

5. Analyze the frequency response of a BJT or MOSFET amplifier.

6. Design a basic L network for impedance matching.

7. Analyze some of the effects of negative feedback on the performance of amplifier circuits.

The exam will take place 3:30-6:30 pm on Thursday, May 2 in Breakiron 166. The exam will be designed to take approximately 1.5 hours to complete, but you may use the full three hours if necessary.

You will be allowed to consult up to four 8.5 × 11-inch two-sided help sheets during the exam. There are no restrictions on the material that may be included on the help sheets. Please note that all help sheets will be collected at the end of the exam but will be returned to you later if you wish to have them back.

The final exam grade cannot be dropped.

The review topics for the final exam are summarized beginning on the following page.
Review Topics for Final Exam

The following is a list of topics that could appear in one form or another on the exam. Not all of these topics will be covered, and it is possible that an exam problem could cover a detail not specifically listed here. However, this list has been made as comprehensive as possible. You should be familiar with the topics on the previous review sheets in addition to those listed below.

Although every effort has been made to ensure that there are no errors in this review sheet, some might nevertheless appear. The textbook is the final authority in all factual matters, unless errors have been specifically identified there. You are ultimately responsible for obtaining accurate information when preparing for your exam.

L-shaped networks for impedance matching
- underlying concept: series-to-parallel transformations of resistance and reactance
  - \( R_p = R_s(Q^2+1) \) or \( Q = \sqrt{\frac{R_p}{R_s}} - 1 \),
  - where \( R_p \) = equiv. parallel resistance and \( R_s \) = equiv. series resistance
- for series combinations (\( R_s \) in series with \( X_s \)), \( Q = \frac{|X_s|}{R_s} \)
- for parallel combinations (\( R_p \) in parallel with \( X_p \)), \( Q = \frac{R_p}{|X_p|} \)
- \( X_p \) should be placed in parallel with larger resistance; \( X_s \) should be placed in series with smaller resistance
  - if \( R_{\text{sig}} > R_L \), place \( X_p \) in parallel with source and \( X_s \) in series with load
  - if \( R_{\text{sig}} < R_L \), place \( X_s \) in series with source and \( X_p \) in parallel with load
  - in either case, can have series-L/shunt-C or series-C/shunt-L
- if \( Q \) is large, \( \omega_o^2 \approx \frac{1}{LC} \) and \( |X_p| \approx |X_s| \), where \( \omega_o \) is the design radian frequency of interest
- matching bandwidth is inversely proportional to \( Q \)
- matching bandwidth can be increased by using multiple L network stages
- individual inductors and capacitors have component \( Q \); \( Q \) of inductors is usually much lower than that of capacitors and can be the limiting factor in network \( Q \)

Feedback in amplifier circuits
- parts of feedback loop
  - main amplifying block (gain = \( A \))
  - feedback network (feedback factor = \( \beta \)) – not to be confused with \( \beta \) for BJTs
  - summing junction
  - output sampling
- identification of signals (voltages or currents) in amplifier with feedback
  - source signal \( x_s \) (supplied externally)
  - input to main amplifying block \( x_i \)
  - output signal \( x_o \) (supplied to load)
  - feedback signal \( x_f \)
- open-loop gain = \( A \) (gain of main amplifying block)
- closed-loop gain \( A_f = \frac{A}{1 + A\beta} \)

- if open-loop gain is large enough so that \( A\beta >> 1 \), then \( A_f \approx \frac{1}{\beta} \)

- general characteristics of feedback circuits
  - the three signals at the summing junction (\( x_s \), \( x_f \), and \( x_i \)) must be either all voltages or all currents
  - type of output signal can be different from the three signals at the input (i.e., output signal can be a voltage even though input is a current, and vice versa)
  - feedback network can consist of active or passive components. We are considering only passive networks.
  - feedback signal \( x_f \) could be either subtracted from (negative feedback) or added to (positive feedback) the source signal \( x_s \). We are considering only neg. feedback.

- Main disadvantage of negative feedback is decrease in gain. Some benefits:
  - improved amplifier linearity
  - simplified gain control
  - gain independent of temperature, bias variations, and other environmental factors
  - wider bandwidth (lower \( f_L \) and higher \( f_H \) by the factor \( 1 + A\beta \), to a very good approximation)
  - improved input/output resistance characteristics (by the factor \( 1 + A\beta \))
  - suppression of power supply noise/hum/ripple/interference in power amplifier (gain = \( A_1 \)) with the addition of a preamplifier (gain = \( A_2 \)) in the feedback loop:
    \[
    V_o = V_{ox} + V_{on} = \frac{A_1A_2}{1 + A_1A_2\beta} V_s + \frac{A_1}{1 + A_1A_2\beta} V_n,
    \]
    where \( V_s = \) input signal; \( V_n = \) noise/hum/ripple/interference introduced to main power amplifier, usually because of an inadequately filtered power supply; \( V_{os} = \) output signal; \( V_{on} = \) output noise/hum/ripple/interference.
    \[
    \text{SNR}_o = A_2 \text{SNR}_i; \text{ that is, signal-to-noise ratio improves by preamp gain } A_2
    \]

Relevant course material:

HW: #7
Labs: #11, #12
Textbook: Sections 10.1-10.2

Web Links: (none)
Mathcad: (none)
Matlab: (none)