ECE 3510 Final Exam Study Guide

The Final will be open book, open notes exam with calculators.

The exam will cover
1. Signals and blocks in a feedback loop
2. Laplace transforms, be prepared to look up and adapt a table entries
   Initial and final values
3. Inverse Laplace transforms (partial fractions)
4. Relationship of signals to pole locations  Figs 2.1 & 2.2 on page 7
5. Boundedness and convergence of signals
   Bounded if all poles in LHP, no double poles on jω-axis
   Converges to 0 if all poles LHP. Converges to a non-zero value if a single pole is at zero
6. $H(s)$ of circuits
   \[ Z(s) \quad R \quad Ls \quad \frac{1}{Cs} \]
   Be able to find $\frac{V_{\text{out}}(s)}{V_{\text{in}}(s)}$ or any other output over input.
   Review voltage dividers and current dividers
7. Block Diagrams & their transfer functions
8. BIBO Stability (Systems)
   BIBO if all poles in LHP, no poles on jω-axis
9. Impulse & step responses
   $h(t) = \frac{1}{s} H(s)$
10. Steady-state (DC gain = $H(0)$) & transient step responses
11. Effects of pole locations on step response, see Fig 3.12, p.36.
12. Sinusoidal responses, effects of poles & zeros, etc.
    Review complex math relations
    Steady-state AC analysis to get $Y(\omega)$ & $y_{ss}(t)$
    (Sinusoidal steady-state transfer function = $H(\omega)$)
13. Transient sinusoidal response
    You should be ready to do partial fraction expansion to the first (transient) term from:
    \[ H(s) \times \frac{A}{s^2 + \omega^2} \quad \text{or} \quad \frac{B}{s^2 + \omega^2} \]  
    $A \times \cos(\omega t)$ \quad $B \times \sin(\omega t)$
14. Effect of initial conditions
    \[ Y(s) = \frac{b \cdot y(0) + \frac{d}{dt} y(0) + a \cdot y(0) - b \cdot x(0) - b \cdot \frac{d}{dt} x(0) - b \cdot x(0)}{s^2 + a \cdot s + a_0} \]
    May ask question like points on p. 43
    May give $H(s), \ a's & b's x(0)s$ and $y(0)s$, and ask for effect of initial conditions
15. The advantages of state space over classical frequency-domain techniques.
   - Multiple input / multiple output systems
   - Can model nonlinear systems
   - Can model time varying systems
   - Can be used to design optimal control systems
   - Can determine controllability and observability

16. Electrical analogies of mechanical systems, particularly translational and rotational systems.
   - Review the handout and homeworks 8 & 9.

17. Control system characteristics and the objectives of a "good" control system. See pgs. 57 - 58
   - Stable
   - Tracking
     - fast
     - smooth
     - minimum error (often measured in steady state)
   - Reject disturbances
   - Insensitive to plant variations
   - Tolerant of noise
   - Be able to relate these to poles and zeros on the real and imaginary axis (where possible)


   1. System stable
   2. DC
   3. C(s) or P(s) has pole @ 0


   1. System stable
   2. DC
   3. C(s) has pole @ 0
   4. or P(s) has zero @ 0

   But bad for above


   \[
   D(s) = s^3 + 20s^2 + 59s + 32
   \]

   | \(s^3\) | 1 | 59 | 0
   | \(s^2\) | 20 | 32 |
   | \(s^1\) | \(\frac{20 \cdot 59 - 1 \cdot 32}{20} = 57.4\) | \(\frac{20 \cdot 0 - 1 \cdot 0}{20} = 0\) |
   | \(s^0\) | \(\frac{57.4 \cdot 32 - 20 \cdot 0}{57.4} = 32\) | \(\frac{57.4 \cdot 0 - 20 \cdot 0}{57.4} = 0\)

   Be able to do this with variable such as "k"

21. Root - Locus method
   a) Main rules
      1. Root-locus plots are symmetric about the real axis.
      2. On the real axis, spaces left of an odd number of O-L poles and zeros are always part of the locus.
         (Essentially, every other space on the real axis (counting leftward) is part of the plot.)
      3. Each O-L pole originates (\(k = 0\)) one branch. \((n)\)
         Each O-L zero terminates (\(k = \infty\)) one branch. \((m)\)
         All remaining branches go to \(\infty\). \((n - m)\)
         These remaining branches approach asymptotes as they go to \(\infty\).
         \[\sum \text{OL poles} - \sum \text{OL zeros}\]
         \[
         \text{centroid } = \sigma = \frac{\sum \text{OL poles} - \sum \text{OL zeros}}{n - m}
         \]
         \((\# \text{ poles} - \# \text{ zeros})\)

ECE 3510    Final Exam Study Guide   p2
5. The angles of the asymptotes

<table>
<thead>
<tr>
<th>n - m</th>
<th>angles (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>90   270</td>
</tr>
<tr>
<td>3</td>
<td>60   180 300</td>
</tr>
<tr>
<td>4</td>
<td>45   135 225 315</td>
</tr>
</tbody>
</table>

6. The angles of departure (and arrival) of the locus are almost always: OR:

b) Additional Root locus rules. Review the handout.

1. The breakaway points are also solutions to:
   \[ \sum_{i} \frac{1}{s + p_i} = \sum_{i} \frac{1}{s + z_i} \]

2. Gain at any point on the root locus:
   \[ k = \left| \frac{1}{G(s)} \right| \]

3. Phase angle of \( G(s) \) at any point on the root locus:
   \[ \arg(G(s)) = \arg(N(s)) - \arg(D(s)) = \pm 180^\circ \pm 360^\circ \ldots \]
   Or: \[ \arg \left( \frac{1}{G(s)} \right) = \arg(D(s)) - \arg(N(s)) = \pm 180^\circ \pm 360^\circ \ldots \]

4. Departure angles from complex poles:
   \[ 180 - 90 - 153.4 + 135 = 71.6 \text{ deg} \]

   \[ \begin{align*}
   &\text{180} &\text{-} &\text{90} &\text{-} &\text{153.4} &\text{+} &\text{135} &\text{=} &\text{71.6} &\text{deg} \\
   &\text{1j} & & & & & & & & &
   \end{align*} \]

c) Root Locus general, Interpretation and design

1. Concepts of what a root locus plot is and what it tells you. Movement of poles
2. Good vs bad, fast response vs slow, OK damping vs bad.
3. Effects of adding a compensator
   Know pole & zero locations of P, PD, PI, & PID Compensators as well as Lag and Lead
4. Important conclusions from root locus, section 4.4.5, p. 84.
5. Simple root-locus design, the placement of additional poles and zeros in order to affect the root locus.

22. Be able to find a transfer function for a system with multiple multiple feedback paths, like you did in the PID lab and again in lab 8.

23. Bode Plots

   Be able to draw both magnitude and phase plots.
   I may ask you to start with a circuit
   Basic rules
   Complex poles an zeros
   \[ s^2 + 2\zeta\omega_n s + \omega_n^2 = (s + a)^2 + b^2 = s^2 + 2a s + a^2 + b^2 \]
   natural frequency \( \omega_n = \sqrt{\frac{a^2 + b^2}{2\zeta}} \)
   damping factor \( \zeta = \frac{a}{\omega_n} \) max at approx \( \omega_n \), \[ \frac{1}{2\zeta} \]
   \[ 20 \log \left( \frac{1}{2\zeta} \right) \text{ dB} \]
   Bode to transfer function (like problem 5.2b)

GM, PM & DM
24. Nyquist plots

You may be asked to draw a simple one. At minimum you should:
Be able to find the start point (DC gain (s = 0 = ω)) from the transfer function
Find the final value (ω = ∞) and the approach angle to the final value.

Concepts of what a Nyquist plot is and what it tells you.
Be able to count encirclements, with or without the ω < 0 part of the plot.

GM & PM

25. Phase-lead compensator, section 5.3.9 & lab 10

Material new to the Final: Discrete-time Signals & Systems

1. Discrete signals

2. z-transform

3. Relationship of signals to pole locations, Fig 6.9, p159.

4. Properties of the z-transform

Linear
Right-shift = delay = multiply by z^{-1} = \frac{1}{z}
Left-shift = advance = multiply by z
Initial value = x(0) = X(\infty)
Final value (DC) = x(\infty) = (z-1) \cdot X(z) \mid z=1

5. Inverse z-transforms (partial fractions & long division)

Divide by z first:
\frac{X(z)}{z}

Poles on real axis (not at zero):
\frac{B \cdot z}{z-p} \quad B \cdot p^k

Complex poles:
\frac{B \cdot z}{(z-p)^2} + \frac{B \cdot z}{(z-p)}

6. Boundedness and convergence of signals, relate to continuous-time signals

Bounded if all poles in inside unit circle, no double poles on unit circle

Converges to 0 if all poles inside unit circle. Converges to a non-zero value if a single pole is at 1

7. Difference equations, be able to get H(z)

8. Discrete-time systems, FIR (all poles at zero), IIR (some poles not at zero)

9. BIBO Stability, all poles inside unit circle.

10. Step & Sinusoidal responses, effects of poles & zeros, etc.

DC gain = H(1) \quad \text{sinusoidal: } H(e^{j \omega}) = \frac{|H|}{0} \quad \text{multiply magnitudes and add angles}

11. Initial Conditions, p. 179

12. Implementations, p181 - 183, be able to go back and forth to H(z)

13. Same Feedback system as in continuous-time and Root locus works the same but is interpreted very differently.

All Homeworks

All Labs