ECE 3510 Final Exam Study Guide

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

<u>The exam will cover</u>

1. Laplace transforms (simple forms only)

2. Inverse Laplace transforms (partial fractions)

3. Relationship of signals to pole locations

   Figs 2.1 & 2.2 on page 7

4. Boundedness and convergence of signals

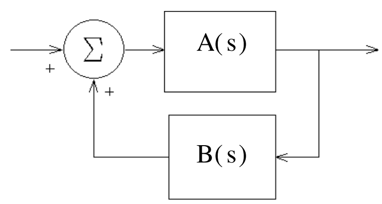
   Bounded if all poles in LHP, no double poles on jω-axis

   Converges to 0 if all poles LHP. Converges to a non-zero value if a single pole is at zero

5. H(s) of circuits

   $Z(s)$ R Ls $\frac{1}{Cs}$ Be able to find $\frac{V_{out}(s)}{V_{in}(s)}$ or any other output over input.
   Review voltage dividers and current dividers

6. Block Diagrams & their transfer functions. Standard feedback loop transfer function



$$\frac{A(s)}{1 - A(s) \cdot B(s)}$$

7. BIBO Stability (Systems)

   BIBO if all poles in LHP, no poles on jω-axis

8. Impulse & step responses $h(t)$ $\frac{1}{s} \cdot H(s)$

9. Steady-state (DC gain) & transient step responses

   $H(0)$

10. Effects of pole locations on step response, see Fig 3.12, p.36.

11. Steady-state sinusoidal response. You should be ready to do some complex arithmetic.

    $H(j\omega)$

12. Transient sinusoidal response. You should be ready to do partial fraction expansion to the first (transient) term.

    $H(s)$ x $A \cdot \frac{s}{s^2 + \omega^2}$ or $B \cdot \frac{\omega}{s^2 + \omega^2}$

    $A \cdot \cos(\omega t)$ $B \cdot \sin(\omega t)$

13. Effect of initial conditions

$$Y(s) = \frac{b_2 \cdot s^2 + b_1 \cdot s + b_0}{s^2 + a_1 \cdot s + a_0} \cdot X(s) + \frac{s \cdot y(0) + \frac{d}{dt} y(0) + a_1 \cdot y(0) - b_2 \cdot s \cdot x(0) - b_2 \cdot s \cdot \frac{d}{dt} x(0) - b_1 \cdot s \cdot x(0)}{s^2 + a_1 \cdot s + a_0}$$

    May ask question like points on p. 42

    May give H(s), a's & b's and y(0).. and ask for effect of initial conditions

14. 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

15. Electrical analogies of mechanical systems, particularly translational and rotational systems.

    Review the handout and homeworks 8 & 9.

16. 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

17. Elimination of steady-state error, p. 61.
    DC

    1 System stable
    2 $C(s)$ or $P(s)$ has pole @ 0
    3 No zero @ 0

18. Rejection of constant disturbances, p. 63.
    DC

    1 System stable
    2 $C(s)$ has pole @ 0
    3 or $P(s)$ has zero @ 0 But bad for above

19. Routh-Hurwitz method.

$$D(s) = s^3 + 20 \cdot s^2 + 59 \cdot s + 32$$

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"

20. 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)

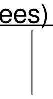
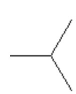
       All remaining branches go to ∞. $(n - m)$

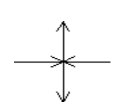
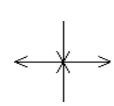
       These remaining branches approach asymptotes as they go to ∞.
    4. The origin of the asymptotes is the *centroid*.

$$\text{centroid} = \sigma = \frac{\sum_{\text{all}} \text{OLpoles} - \sum_{\text{all}} \text{OLzeros}}{n - m}$$

(# poles - # zeros)

    5. The angles of the asymptotes

n - m	angles (degrees)				
2	90	270			
3	60	180	300		
4	45	135	225	315	

    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: $\sum_{all} \frac{1}{(s + -p_i)} = \sum_{all} \frac{1}{(s + -z_i)}$

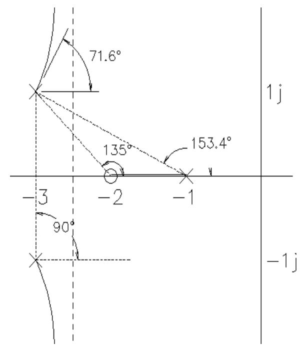
2. Gain at any point on the root locus: $k = \frac{1}{|G(s)|}$

3. Phase angle of G(s) at any point on the root locus: $\arg(G(s)) = \arg(N(s)) - \arg(D(s)) = \pm 180^o \quad \pm 360^o$ ...

   Or: $\arg\left(\frac{1}{G(s)}\right) = \arg(D(s)) - \arg(N(s)) = \pm 180^o \quad \pm 360^o$ ...

4. Departure angles from complex poles:

   $180 - 90 - 153.4 + 135 = 71.6 \quad \text{deg}$



Root Locus general

a) Concepts of what a root locus plot is and what it tells you. Movement of poles

b) Good vs bad, fast response vs slow, OK damping vs bad.

c) Effects of adding a compensator

d) Important conclusions from root locus, section 4.4.5, p. 82.

e) Simple root-locus design, the placement of additional poles and zeros in order to affect the root locus.

21. Phase-locked loops

    How does it work   The loop block diagram   Material from labs

22. 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 $s^2 + 2\cdot\zeta\cdot\omega_n\cdot s + \omega_n^2$

    $(s + a)^2 + b^2 = s^2 + 2\cdot a\cdot s + a^2 + b^2$ max at ω_n $\frac{1}{2\cdot\zeta}$

    Bode to transfer function (like problem 5.2b)

    GM & PM

23. Nyquist plots

    You may be asked to draw one, be able to find start, end, and end approach angle.
    Use a quicky Bode plot to estimate curve

    Concepts of what a Nyquist plot is and what it tells you. $Z = N + P$ Make sure you understand problem 5.11

    GM & PM

24. Phase-lead compensator

1. Discrete signals $x(k)$
2. z-transform $X(z) = \sum_{k=0}^{\infty} x(k)\cdot z^{-k}$

   Finite-length signals have all poles at zero

$\delta(k)$	1
$u(k)$	$\frac{z}{z-1}$
p^k	$\frac{z}{z-p}$
$\cos(\Omega_o\cdot k)$	$\frac{z\cdot(z-\cos(\Omega_o))}{z^2-2\cdot\cos(\Omega_o)\cdot z+1}$
$\sin(\Omega_o\cdot k)$	$\frac{z\cdot\sin(\Omega_o)}{z^2-2\cdot\cos(\Omega_o)\cdot z+1}$

3. Relationship of signals to pole locations, Fig 6.9, p155.
   lines of constant damping
   Speed of decay
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) = $x(\infty) = (z-1)\cdot X(z) \Big|_{z:=1}$
5. Inverse z-transforms (partial fractions & long division)
   Divide by z first: $\frac{X(z)}{z}$

	A	$A\cdot\delta(k)$
Poles on real axis (not at zero)	$\frac{B\cdot z}{(z-p)}$	$B\cdot p^k$
Complex poles	$\frac{B\cdot z}{(z-p)} + \frac{\overline{B}\cdot z}{(z-\overline{p})}$	$2\cdot\lvert B\rvert\cdot(\lvert p\rvert)^k\cdot\cos(\theta_p\cdot k+\theta_B)$

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 = $H(1)$ sinusoidal: $H\left(e^{j\cdot\Omega_o}\right) = \lvert H\rvert \angle\theta_H$ multiply magnitudes and add angles
11. Initial Conditions, p. 174
12. Implementations, p176 & 177, 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.
14. Sampled-data systems $t = k\cdot T$ $x_d(k) = x(kT)$ A/D converter $z = e^{s\cdot T}$ $s = \frac{\ln(z)}{T}$
    Compare s-plane to z-plane, Fig 7.3, p.190
15. Conversions of continuous-time transfer functions to discrete-time transfer functions
    $y(s) = \frac{1}{s}\cdot H(s)$ find $y(t)$ by partial frac. exp. (step response) $y_d(k) = y(kT)$ (discrete step response) find: $Y(z)$ $\frac{z}{z-1}\cdot H(z) = Y(z)$
    $H(z) = \frac{z-1}{z}\cdot Y(z)$
    Discrete system should have the same step response
16. Nyquist sampling criterion, at least twice the highest signal frequency

All Homeworks I' ll scan through for problems
All Labs
- Position & speed control
- DC motor characteristics
- PID PLL

Matlab
- Ball & Beam
- Inverted Pendulum

Flexible Beam