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

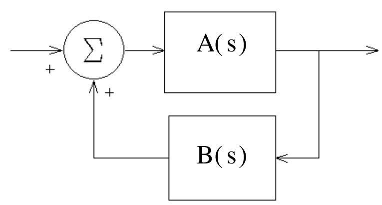
5. Boundedness and convergence of signals
   Bounded if all poles in LHP, no double poles on $j\omega$-axis
   Converges to 0 if all poles LHP. Converges to a non-zero value if a single pole is at zero

6. $H(s)$ of circuits
   $Z(s)$ 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

7. Block Diagrams & their transfer functions

8. BIBO Stability (Systems)
   BIBO if all poles in LHP, no poles on $j\omega$-axis

Standard feedback loop transfer function



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

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

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.
    Steady-state AC analysis to get $Y(j\omega)$ & $y_{ss}(t)$
    (Sinusoidal steady-state transfer function = $H(j\omega)$)

    Review complex math relations
    - Conversions
    - Add & Subtract
    - Multiply and divide

13. Transient sinusoidal response
    You should be ready to do partial fraction expansion to the first (transient) term from: $H(s)$ x $A\cdot\frac{s}{s^2+\omega^2}$ or $B\cdot\frac{\omega}{s^2+\omega^2}$
    $A\cdot\cos(\omega t)$ $B\cdot\sin(\omega t)$

14. 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. 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)

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

    1 System stable

    2 $C(s)$ or $P(s)$ has pole @ 0

    3 $C(s)$ or $P(s)$ No zero @ 0

19. 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

20. 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"

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 ∞. $(n - m)$

       These remaining branches approach asymptotes as they go to ∞.

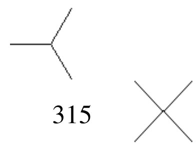
    4. The origin of the asymptotes is the centroid.

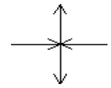
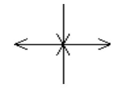
    $$\text{centroid} = \sigma = \frac{\sum_{\text{all}} \text{OLpoles} - \sum_{\text{all}} \text{OLzeros}}{n - m}$$

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

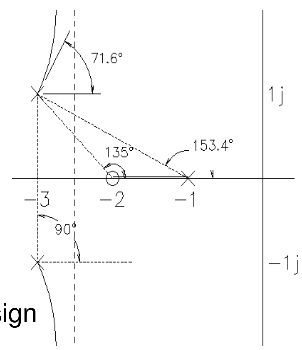
2. Gain at any point on the root locus: $k = \dfrac{1}{|G(s)|}$

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

4. Departure angles from complex poles:

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



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 feeback 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 $\quad s^2 + 2\cdot\zeta\cdot\omega_n\cdot s + \omega_n^2 \quad = \quad (s+a)^2 + b^2 \quad = \quad s^2 + 2\cdot a\cdot s + a^2 + b^2$

natural frequency $\quad \omega_n = \sqrt{a^2 + b^2} \qquad$ damping factor $\quad \zeta = \dfrac{a}{\omega_n} \qquad$ max at approx ω_n , $\quad \dfrac{1}{2\cdot\zeta} \qquad 20\cdot\log\left(\dfrac{1}{2\cdot\zeta}\right)$ 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 ($s = 0 = \omega$)) from the transfer function)

Find the final value ($\omega = \infty$) 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 $\omega < 0$ 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 $x(k)$

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

Finite-length signals have all poles at zero

f(k)	F(z)
$\delta(k)$	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, p159.
   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: $\frac{X(z)}{z}$

	F(z)	f(k)
	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. 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