ECE 3510 Final Exam Study Guide

The first part will be **closed book**, **no-calculator,** but may include information.

When you hand in the first part you will get the second part, which will be **open book, notes, & calculator**.

Download old exams from HW page on class web site.

The exam will cover

1. Review the questions you were asked on the homeworks.

2. Laplace transforms, be prepared to look up and adapt 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 $\dfrac{1}{Cs}$ Be able to find $\dfrac{V_{out}(s)}{V_{in}(s)}$ or any other output over input.
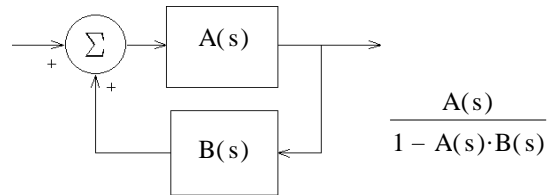   Review voltage dividers and current dividers

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

8. BIBO Stability (Systems)

   BIBO if all poles in LHP, no poles on $j\omega$-axis

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

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

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
    Conversions
    Steady-state AC analysis to get $Y(j\omega)$ & $y_{ss}(t)$ Add & Subtract
    (Sinusoidal steady-state transfer function $= H(j\omega)$)   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 $A\cdot\dfrac{s}{s^2+\omega^2}$ or $B\cdot\dfrac{\omega}{s^2+\omega^2}$

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

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.   Open-book part only.

17. Control system characteristics and the objectives of a "good" control system. See pgs. 59 - 60
   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.   1   System stable

                              DC   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.   1   System stable

                              DC   2 $C(s)$ has pole @ 0

                                         3   or $P(s)$ has zero @ 0   But bad for above

20. Routh-Hurwitz method. Remember, this is performed on the closed-loop transfer function.

   Be able to do this with variable such as "k"   Open-book part only.

21. Root - Locus method
   a) Main rules and concepts (Memorize)
      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 ∞. $(n - m)$

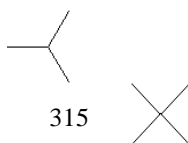   These remaining branches approach asymptotes as they go to ∞.

      4. The origin of the asymptotes is the centroid. $$\text{centroid} = \sigma = \frac{\sum\limits_{all} \text{OLpoles} - \sum\limits_{all} \text{OLzeros}}{n - m}$$
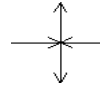   (# poles - # zeros)

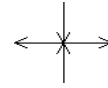   5. The angles of the asymptotes

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:

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

8. Complex angle of $G(s)$ at
any point on the root locus: $\arg(G(s)) = \arg(N(s)) - \arg(D(s)) = \pm 180^o, \pm 540^o, \ldots$

Or: $\arg\left(\dfrac{1}{G(s)}\right) = \arg(D(s)) - \arg(N(s)) = \pm 180^o, \pm 540^o, \ldots$

b) Additional Root locus rules. Review the handout.   Open-book part only.

1. The breakaway points are also solutions to: $\displaystyle\sum_{all} \dfrac{1}{(s+-p_i)} = \sum_{all} \dfrac{1}{(s+-z_i)}$

2. Departure angles from complex poles:

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. Important conclusions from root locus, section 4.4.5, p. 84.

4. Compensators, Bring your crib sheet.

   Know pole & zero locations of P, PI, lag, PD, lead & PID Compensators.

   PI and Lag, purpose and design, ties in with steady-state error

   PD and Lead, purpose and design ties in with root locus angle rules

   PID & lead-lag design order & why (good closed-book question)

   Compensator Circuits   Open-book part only.

d) Unconventional root-locus

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   Open-book part only.

   Bode to transfer function

   GM, PM & DM

24. Material from all labs   Good for closed-book questions

   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.

   Phase-locked loops   How does it work   The loop block diagram

Material new to the Final: Nyquist Plots & Discrete-time Signals & Systems   ~1/2 OF EXAM

1. 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.

    $$Z = N + P$$

    Be able to count encirclements, with or without the $\omega < 0$ part of the plot.

    Be able to handle poles at the origin.

    GM & PM

2. Discrete signals $x(k)$

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

    Finite-length signals have all poles at zero

4. Relationship of signals to pole locations, Fig 6.9, p159.
        lines of constant damping
        Speed of decay

5. Properties of the z-transform
        linear
        Right-shift = delay = multiply by $z^{-1} = \dfrac{1}{z}$

        Left-shift = advance = multiply by z

        Initial value = $x(0) = X(\infty)$

        Final value (DC) = $x(\infty) = (z-1){\cdot}X(z) \; \big|_{z\,:=\,1}$

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

Open-book or table given.

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

    Divide by z first: $\dfrac{X(z)}{z}$

    Open-book or table given.

$F(z)$	$f(k)$
A	$A{\cdot}\delta(k)$
Poles on real axis (not at zero): $\dfrac{B{\cdot}z}{(z-p)}$	$B{\cdot}p^k$
Complex poles: $\dfrac{B{\cdot}z}{(z-p)} + \dfrac{\overline{B}{\cdot}z}{(z-\overline{p})}$	$2{\cdot}|B|{\cdot}(|p|)^k{\cdot}\cos(\theta_p{\cdot}k + \theta_B)$

7. 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

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

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

10. BIBO Stability, all poles inside unit circle.

11. Step & Sinusoidal responses, effects of poles & zeros, etc.
    DC gain = $H(1)$ sinusoidal: $H\!\left(e^{j{\cdot}\Omega_o}\right) = |H|\,\underline{/\theta_H}$ multiply magnitudes and add angles

12. Initial Conditions, p. 179   Open-book part only.

13. Implementations, p180 - 183, be able to go back and forth to $H(z)$ Open-book part only.

                                          Blocks to transfer function my be in closed-book part

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