ECE 3510 Final Exam Study Guide   Review, 3:30 Fri, 4/26, Final: 10:30 Mon, 4/29/19
Last Problem Session: Wed. at normal class time   All in normal classroom

The exam will be **closed book,** but you may use the information passed out earlier.

Download old exams from HW page on class web site.

<u>The exam will cover</u>

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

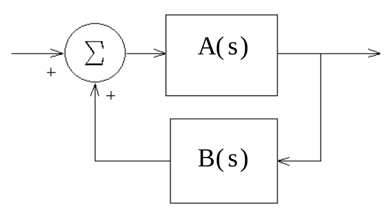
   Bounded if all poles in LHP, no double poles on $j\omega$-axis

   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 $\frac{1}{Cs}$ 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   Standard feedback loop transfer function



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

8. BIBO Stability (Systems)

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

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. 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.
    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. 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.)

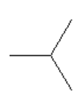
    3. Each O-L pole originates ($k = 0$) one branch. (n)

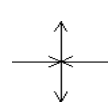
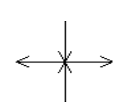
       Each O-L zero terminates ($k = \infty$) one branch. (m)

       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. centroid = $\sigma = \dfrac{\sum_{\text{all}} \text{OLpoles} - \sum_{\text{all}} \text{OLzeros}}{n - m}$
       (# 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: 

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

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

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

   Compensator Circuits

   PID tuning, memorize some basic ideas, like why you would need to do it.

d) Unconventional root-locus

21. Ladder logic

Material new to the Final: ~1/2 to 2/3 OF EXAM (simple Bode plot in exam 3)

1. Bode Plots

   Be able to draw both magnitude and phase plots

   Basic rules

   Complex poles an zeros $s^2 + 2\cdot\zeta\cdot\omega_n\cdot s + \omega_n^2 = (s+a)^2 + b^2 = s^2 + 2\cdot a\cdot s + a^2 + b^2$ Open-book part only.

   natural frequency $\omega_n = \sqrt{a^2 + b^2}$ damping factor $\zeta = \frac{a}{\omega_n}$ max at approx ω_n, $\frac{1}{2\cdot\zeta}$ $20\cdot\log\left(\frac{1}{2\cdot\zeta}\right)$ dB

   Bode to transfer function

   GM, PM & DM

   Estimate overshoot from phase margin and delay (HW NqBd) $\zeta \simeq \frac{PM}{100\cdot deg}$ (PM in degrees and may include delay effects)

2. ~~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.

   Be able to find GM & PM and basic magnitude and phase information from the plot

4. Discrete signals $x(k)$

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

   Finite-length signals have all poles at zero

6. Relationship of signals to pole locations, Fig 6.9, p159.
   lines of constant damping
   Speed of decay $\tau = \dfrac{1}{-\ln(|p|)}$

7. 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) = $x(\infty) = (z-1)\cdot X(z) \Big|_{z := 1}$

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

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

   Open-book or table given.

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

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:	$\dfrac{B\cdot z}{(z-p)}+\dfrac{\overline{B}\cdot z}{(z-\overline{p})}$	$2\cdot\lvert B\rvert\cdot(\lvert p\rvert)^k\cdot\cos(\theta_p\cdot k+\theta_B)$

9. Nyquist sampling criterion, at least twice the highest signal frequency

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

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

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

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

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

13. BIBO Stability, all poles inside unit circle.

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