ECE 3510 Final Exam Study Guide

Zoom Review, _____ Thur, 4/27   Final is Thur, 4/28/23, starting at 10:30am

The first part will be **closed book, closed notes, no-calculator,** not even your exam note sheets.

When you hand in the first part you will get the second part, which will be **open note sheets only, with calculator**.

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
5. Boundedness and convergence of signals

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

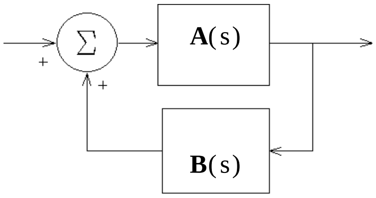
   Converges to 0 if all poles LHP. Converges to a non-zero value if a single pole is at zero

6. $H(s)$ of circuits

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

7. Block Diagrams & their transfer functions

   Standard feedback loop transfer function



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

8. BIBO Stability (Systems)

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

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

10. Steady-state (DC gain = $\mathbf{H}(0)$) & transient step responses

11. Effects of pole locations on step response, see Fig 3.15, p.51.

12. Sinusoidal responses, effects of poles & zeros, etc.

    Steady-state AC analysis to get $\mathbf{Y}(j\omega)$ & $y_{ss}(t)$

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

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

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15. Effect of initial conditions

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

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

   a. The total response is the sum of two independent components.
   b. These values together fully describe the *state* of the 2nd-order system at time $t = 0^-$ (the initial state): $y(0^-)$ $\quad \frac{d}{dt}y(0^-)$ $\quad x(0^-)$ $\quad \frac{d}{dt}x(0^-)$
   c. Similar denominator for both parts = Share poles = Similar responses
   d. Response to Initial conditions always go to zero if system is BIBO.
   e. Pole-zero cancellations in right-half plane can cause major problems with internal states of the system.

May give $\mathbf{H}(s)$, a's & b's $x(0)$s and $y(0)$s. and ask for effect of initial conditions

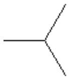
16. Electrical analogies of mechanical systems, particularly translational and rotational systems.
   Review the handout and homeworks 8 & 9.

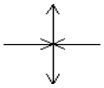
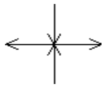
17. Control system characteristics and the objectives of a "good" control system. See p. 78
   Stable
   Tracking
      fast   smooth   minimum error (often measured in steady state)
   Reject disturbances
   Insensitive to plant variations
   Tolerant of noise
   Be able to relate these to poles and zeros on the real and Imaginary axis (where possible)

18. Elimination of steady-state error, p. 81.
   DC
   1 System stable
   2 $\mathbf{C}(s)$ or $\mathbf{P}(s)$ has pole @ 0
   3 $\mathbf{C}(s)$ or $\mathbf{P}(s)$ No zero @ 0

19. Rejection of constant disturbances, p. 82.
   DC
   1 System stable
   2 $\mathbf{C}(s)$ has pole @ 0
   3 or $\mathbf{P}(s)$ 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: $k = \frac{1}{|G(s)|}$

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. 105.
4. Compensators

   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

Choose points on the s-plane to achieve given required characteristics based on the 2nd-order assumption (RL Crib)
Know that the 2nd-order assumption may be inaccurate if other CL poles and/or zeros aren't 5x farther from Imaginary axis and are not canceling one another.

d) Unconventional root-locus

21. PID tuning Memorize some basic ideas, like why you would need to do it.
22. Ladder logic
23. **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

Material new to the Final:

Bode to transfer function

GM, PM & DM

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

1. Feedback in Linear Amplifiers

   Gain reduction and stabilization. Trade for other improvements. $A_f = \dfrac{A_o}{1 + A_o \cdot B}$

   Bandwidth Extension
   - Op-amp compensation and resulting bandwidth

   Input and Output Impedances For voltage amp with voltage feedback: Z_{in} Depends on how feedback is implemented

   Z_{out} Decrease, usually by $\left(1 + A_o \cdot B\right)$

   Reduce distortion, especially distortion caused by nonlinear gains

   Reduce amplifier noise. The later the noise is introduced in the amplifier, the greater the reduction.

2. Discrete signals $x(k)$

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

4. Finite-length signals have all poles at zero

   Relationship of signals to pole locations, Fig 6.9. Time constant: $\tau = -\dfrac{1}{\ln(|p|)}$ Settling time: $T_s = 4 \cdot \tau$
   lines of constant damping

   Speed of decay Damping factor $\zeta = \dfrac{-\ln(|p|)}{\sqrt{\ln(|p|)^2 - \theta_p^{\,2}}}$

6. Properties of the z-transform
   - linear
   - Right-shift = delay = multiply by $z^{-1} = \dfrac{1}{z}$
   - Left-shift = advance = multiply by z
   - Initial value = $x(0) = \mathbf{X}(\infty)$
   - Final value (DC) = $x(\infty) = (z - 1) \cdot \mathbf{X}(z) \Big|_{z := 1}$

7. Inverse z-transforms (partial fractions & long division) Divide by z first: $\dfrac{\mathbf{X}(z)}{z}$

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

9. 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

10. Difference equations, be able to get $\mathbf{H}(z)$

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

    BIBO Stability, all poles inside unit circle.

11. Integration $\mathbf{H}(z) = \dfrac{z}{z - 1}$ Differentiation $\mathbf{H}(z) = \dfrac{z - 1}{z}$

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

    DC gain = $\mathbf{H}(1)$ sinusoidal: $\mathbf{H}\left(e^{j \cdot \Omega_o}\right) = |\mathbf{H}|\,\underline{/\theta_H}$ multiply magnitudes and add angles
    just like Laplace only $j\omega$ is replaced with $e^{j \cdot \Omega_o}$

13. Implementations (block diagrams), be able to go back and forth to $\mathbf{H}(z)$

    General Interconnected Systems

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