

Topics for Final Exam
16.060: Principles of Automatic Control
December 9, 2003

The final is on Monday, December 15, from 1:30pm-4:30pm in Johnson. To help you prepare for the final, there will be a question and answer session on Thursday, December 11, from 2:30pm-4:30pm. Bring any questions you have about anything we've covered in the course—from lecture notes, problem sets, labs, quizzes, and assigned readings. There will be office hours as usual on Wednesday from 1pm-2pm and 3pm-4pm, and we will also have office hours on Sunday evening 7pm-9pm. As always, if you can't make it to office hours or you just need some extra help, contact one of the TAs.

Here is a list of the major topics we have studied in 16.060—use it as a guide to studying, if you find it helpful.

Control System Analysis

- Open-loop vs. closed-loop control
- What is a transfer function?
- The standard block diagram
- Motivations for feedback
- The concept of gain
- Block diagram reduction
 - Making a system unity feedback
- Disturbances and parameter variations
- Sensitivity functions
- How to get good tracking and good disturbance rejection
- Steady-state errors
- Calculating gain and type number
- The steady-state error table
- Poles and zeros in the s-plane
- Calculating the inverse Laplace transform to get the transient response
- Graphical determination of residues: real poles and complex conjugate poles
- Root locus gain
- Stability
- Formulas for transient response for a simple lag or a quadratic lag system
- Dominant modes
- Transient response performance measures (T_s , $P.O.$, T_p , T_r)
- Effects of zeros

- Effect of a zero on a dominant quadratic mode
- Effect of a zero close to a pole
- Relationship between open-loop poles and zeros, and closed-loop poles and zeros

State-Space Methods

- The concept of state variables
- State space model ($\dot{\vec{x}} = A\vec{x} + B\vec{u}$, $\vec{y} = C\vec{x} + D\vec{u}$)
- Getting the state-space model from a differential equation
- Getting the transfer function from a state-space model
- The state-transition matrix
 - How to calculate it
 - How to use it to get $\vec{x}(t)$ in terms of $\vec{x}(0)$
- The general solution to a state-space differential equation
- Determining stability of a system from its state-space model
- Controllability
 - what it means
 - how to determine whether a system has that property
- State-space controller design
 - pole assignment using full-state feedback

Time Domain System Design

- Root Locus
 - what is the significance of a root locus plot?
 - angle and magnitude conditions
 - 10 rules for drawing root loci
 - asymptotes: number, direction, and point of intersection
 - angles of departure from complex poles
 - K_{crit}
- Root locus for negative gain
- Controller design using root locus
 - phase-lead
 - phase-lag
 - PD

Frequency Domain System Design

- Steady-state response to sinusoidal inputs
- Polar plots
- Nyquist plots
 - The D contour
 - Nyquist stability criterion: $N = Z - P$
 - Gain and phase margins
- Determining closed-loop behavior from open-loop frequency response
 - The second order paradigm
 - Open-loop encirclements of -1 \rightarrow closed-loop stability ($N = Z - P$)
 - Open-loop phase margin \rightarrow closed-loop damping ratio (VDV Fig. 8.7)
 - Open-loop magnitude and phase \rightarrow closed-loop magnitude and phase (Nichols chart)
- Bode diagrams
 - dB
 - gain factor, integrators, simple lags, quadratic lags
 - drawing Bode diagrams for right half-plane poles and zeros
 - gain and phase margin on the Bode diagram