

Fall 2003

## CE/EE/ME 263: Multivariable Control

- Instructor:** Henri Gavin, 122 Hudson Hall, [henri.gavin@duke.edu](mailto:henri.gavin@duke.edu)  
**Class Time:** Tu, Th, 9:10–10:30  
**Classroom:** 222 Hudson Hall  
**Textbook:** Glad & Ljung, *Control Theory*, Taylor & Francis, 2000. ([10])  
**Website:** <http://www.duke.edu/~hpgavin/ce263/>  
**Academic Integrity:** <http://www.gradschool.duke.edu/Regulations/standards.htm>  
**Prerequisites:** 1) A course in classical control.  
2) A course in linear systems and state space models.  
**Computers:** Many assignments will require computations using MATLAB.  
Students are responsible for familiarizing themselves with MATLAB.  
**Grading:** Homework 40%; Midterm 20%; Participation 10%; Project 30%

### OUTLINE

1. Linear System Review: controllability and observability; transfer functions and their realizations; cascade, parallel, and feedback systems. [7]; [10]:21,27–31,43–63; [11] [16]; [19]; [20]; [24]:113–126; [28]:17–38,45–52;
2. Lyapunov Stability Theory: Lyapunov stable, semi-stable, asymptotically stable systems. [10]:21,321–330; [17]; [13]:97–113;
3. The Standard Problem: Two-input, two-output (TITO) formulation; Gramians and Lyapunov equations; dual and modern forms; poles. [10]:63–68; [24]:127–142; [28]:71–78;
4. The  $H_2$  Norm: Frobenius norm; free, forced, impulse response; integral squared response; frequency domain and Parseval. [10]:15–18,63,111; [9]:13–31; [24]:114–116,514–526; [28]:28–30,91–104;
5. Linear Quadratic Regulator (LQR) Synthesis: Hamilton-Jacobi equations; two-input, two-output (TITO) representation; weighting matrices; closed loop properties; Lagrange multipliers; state and control costs. [10]:15–18,63,111; [26]:36–41,184–222; [8]:9–42; [1]:7–28,35–55; [2]:275–277; [4]:45–92; [5]:179–195; [14]; [15]:201–233; [22]; [23]:366–372; [24]:349–362; [25]:10–15;
6. Analysis of the Riccati Equation: compare to Lyapunov eqn; the Hamiltonian matrix; stabilizing solutions; frequency domain properties of LQR; the Nyquist test; gain and phase margins. [8]:9–42; [5]:205–218; [23]:366–372; [28]:327–372;
7. Passivity, Positivity, Self-Dual realizations, and collocation.
8. Linear Quadratic Gaussian (LQG) Controller Synthesis: closed loop properties,  $H_2$  performance, observers and the Kalman filter, frequency domain performance specifications, reduced order LQG. [10]:239–276; [8]:99–102; [23]:379–393; [24]:349–362;
9.  $H_\infty$  Analysis and Synthesis:  $H_\infty$  norm for SISO and MIMO cases; nominal performance, robust stability, mixed sensitivity;  $H_2 / H_\infty$  with cross-weighting; loop-shaping. [10]:277–304; [8]:123–168; [23]:395–440; [24]:363–396;

## References

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