AME552: Nonlinear Control Systems

Instructor: H. Flashner
Office: Olin Hall 430D
Office Hours: Tu 10 -12
Phone: (213) 740-0489
e-mail: kflashne@usc.edu

Grading: The final grade will be calculated according to the following formula:

- Homework+Projects: 20%
- Midterm Examination (February 26): 30%
- Final Examination: (May 2, 4:30-6:30) 50%

Homework will be assigned every week on Thursday and must be submitted the following Thursday with no exceptions!


Reference Books:

Course Outline

1. Introduction
   (a) State-space representation of nonlinear systems
   (b) Basic characteristics of nonlinear systems.

2. Second Order Systems (Phase plane analysis)
   (a) Classification of equilibrium points.
   (b) Systems with multiple equilibria
   (c) Analysis of piecewise linear control systems
      i. Feedback systems in standard form
      ii. Classification of nonlinearities
   (d) Applications
      i. Servomechanism with variable gain
      ii. Servomechanism with Coulomb friction
      iii. Servomechanism with deadzone and with delay
      iv. Pulse control of spacecraft
      v. Digital autopilot control of the Shuttle.

3. Describing function analysis
   (a) The principle of harmonic balance.
      i. Describing functions for various nonlinearities.
   (b) Stability of limit cycles by describing function method.
   (c) Limit cycle analysis of control systems.

4. Lyapunov Stability Theory
   (a) Mathematical preliminaries
      i. Linear vector spaces
         A. Norms and inner products
         B. Normed and inner product spaces
      ii. Nonlinear differential equations
         A. Existence and uniqueness
   (b) Lyapunov's direct method
      i. Definite functions
      ii. Stability and instability theorems
   (c) La Salle theorems
   (d) Stability of linear systems
i. Lyapunov equation for time-invariant systems.
ii. Stability conditions for time-varying systems.

(e) Lyapunov’s linearization (indirect) method
(f) Region of attraction
(g) Adaptive control
(h) Frequency Domain Analysis of Feedback Systems
   i. Absolute stability (Lure) problem
   ii. Kalman-Yakubovitch lemma.
   iii. Circle criterion.
   iv. Popov’s theorem.

5. Nonlinear Control Design Methods
   (a) Sliding Mode Control
   (b) Robust Control of Nonlinear Systems
   (c) Backstepping

6. Feedback Linearization
   (a) Lie derivatives and Lie brackets
   (b) Input-state linearization of SISO systems
   (c) Input-output linearization of SISO systems

7. Input-Output Stability
   (a) Function spaces
   (b) Input-output stability definitions.
   (c) Small-gain theorem
   (d) Circle criterion

8. Passivity
   (a) Power and passive systems
   (b) Definitions of passivity
      i. Passivity of linear systems
   (c) Stability of feedback systems
   (d) Popov Criterion