School of Engineering and Applied Science
Department of Electrical and Computer Engineering

ECE 6851 (MAE 6610) – Linear Automatic Control Systems (Fall 2011, 3 credits)

Objective:

Study the theory and techniques for design and analysis of linear feedback control systems.

Description:

This course is to explore modeling of linear dynamic systems (using input-output representations and state space representations described by differential equations and transfer functions), to analyze control systems in both time and frequency domains, to study properties of feedback control systems, to investigate system stability using the Routh-Hurwitz criterion, Nyquist criterion, root-locus and Bode plots, and to design PID, lead, lag and state feedback controllers to improve system performance.

Prerequisites:

ECE 3750 (Signals and Systems) or equivalent.

Instructor:

Dr. Gang Tao, Thornton Hall, Room E311, (434) 924-4586, gt9s@virginia.edu.

Lecture hours:

11:00 - 12:15, Tuesdays and Thursdays.

Textbook:

G. F. Franklin, J. D. Powell and A. Emami-Naeini, Feedback Control of Dynamic Systems, 6th ed., Pearson Prentice Hall, Upper Saddle River, NJ, 2009 (ISBN-13: 978-0-13-6019690-5)

Topics:

1. Mathematical models of control systems (2 lectures)
2. Transfer functions and block diagrams (2 lectures)
3. Time-domain responses (2 lectures)
4. The Routh-Hurwitz stability criterion (2 lectures)
5. Feedback control systems (2 lectures)
6. Root-locus techniques (5 lectures)
7. Bode plot techniques (2 lectures)
8. The Nyquist stability criterion (2 lectures)
9. Dynamic compensation in frequency-domain (3 lectures)
10. State space analysis and pole placement design (4 lectures).

References:

1. R. C. Dorf, *Modern Control Systems*, Addison Wesley, 9th ed., 2001.
2. B. C. Kuo, *Automatic Control Systems*, Prentice Hall, 7th ed., 1995.

(Their newer editions are also good choices).

Grading:

1. Homeworks: 20 %; 2. Test 1: 30 %; 3. Project: 20%; 4. Test 2: 30 %.

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Schedule of Office Hours, Homeworks, and Tests

Instructor's office hours: 10:30 - 11:45, Monday; 9:30 - 10:45, Tuesday

Solution policy: No old or new solution can be consulted before a homework, project or test is handed in.

Homework 1 (Topic 1): 1.1(c), (d), 1.5, 2.9(a), 2.20, 9.1.
(Hint for 9.1: with $x_1 = \theta$, $x_2 = \dot{\theta}$, do linearization at $\theta = \dot{\theta} = 0$.)

Reading assignment: Section 9.2.1 – Linearization

Due on **September 6, Tuesday**.

Homework 2 (Topic 2): 3.3(c), 3.7(d), (i), 2.9(b), 3.15 (the input is v_a), 3.20.

Due on **September 13, Tuesday**.

Homework 3 (Topic 3): 3.25, 3.28 (hint: using the region $\omega_1 \le \omega_n \le \omega_2$, $\theta_1 \le \theta \le \theta_2$ containing the given circle), 3.35, 3.38 (just use the given expression of $y(t)$ to work out parts (a) - (d); no need to derive it).

Reading assignment: Section 3.1.7 – Zero-input response

Due on **September 20, Tuesday**.

Homework 4 (Topic 4): 3.42 (hint: $KG(s)$ is the open-loop transfer function), 3.43, 3.45; and, in addition,

> investigate the relative stability concept: (a) design a scheme to test the root locations of an nth-order polynomial equation $a(s) = 0$ relative to the axis $s = -\delta$ with $\delta > 0$, and (b) illustrate your scheme by a third-order example.

Due on **September 27, Tuesday**.

Homework 5 (Topic 5): 4.2, 4.31 (hint: for (c), (e) and (g), only evaluate the steady-state value of $\theta(t)$ for $w(t) = w_0$ and $\theta_r(t) = 0$, and do not determine system type and error constant; for (a), (b), (d), (f), set $w(t) = 0$; for all parts, check system stability), 4.19, 4.24(a), (b), (c).

Due on **October 4, Tuesday**.

Test 1 (Topics 1 - 5): **October 5, Wednesday; 6:00 - 7:30pm** (in classroom, closed-book, two pages of notes allowed).

Homework 6 (Topic 6a): 5.4(c), 5.6(d), 5.7(a), 5.8(b), 5.41 (for 5.7(a), 5.8(b)).

Due on **October 18, Tuesday**.

Homework 7 (Topic 6b): 5.25, 5.26, 5.30 (hint: for (a), consider a positive K for positive feedback and use root locus technique in Matlab).

Due on **October 25, Tuesday**.

Homework 8 (Topics 7 and 8): 6.3(c), (d), (e), (h) (hint: obtain the Bode plots by Matlab), 6.17(b), 6.19 (b), (d) (hint: draw Nyquist plot by hand and verify it by Matlab). For 6.3(c) and (e), also figure out the gain margin and phase margin of each case at $K = 1$, for the closed-loop unity negative feedback system with open-loop transfer function $KL(s)$. Also, for each case, examine the closed-loop stability for $K = 1$.

You may use the "grid" command on the Bode plots to make it easy to figure out the numbers; note that the amplitude Bode plots from Matlab are given in db: $20\log|L(j\omega)|$, e.g., $20\log(1) = 0$, and you need to figure out the original $|L(j\omega)|$.

Due on **November 1, Tuesday**.

Project: **November 3 - 10, Thursday - Thursday** (take home, open-book).

Homework 9 (Topic 9): 6.49, 6.50, 6.60 (hint: use $VM = \min_\omega 1/|S(j\omega)| = 1/\max_\omega |S(j\omega)|$).

Reading assignement: Section 6.9.0 – Sensitivity

Due on **November 22, Tuesday**.

Homework 10 (Topic 10): 7.17(b), 7.20, 7.21, 7.48(a), (b), (c), 9.28 (hint for 9.28: put the closed-loop system in the controller canonical form to get the F matrix first.)

Reading assignment: Section 9.5.2 – Lyapunov stability

Due on **December 6, Tuesday**.

Test 2 (Topics 7 - 10): **December 8, Thursday** (in classroom, 11:00 - 12:30, open-book).