Beginning-of-Course Assessment Memo

ECE 4850 – Linear Control Systems (Fall 2011)

Course Description:
This course is to explore the modeling of linear dynamic systems via differential equations and transfer functions utilizing state-space and input-output representations; analysis of control systems in the time and frequency domains and using transfer function and state-space methods; study of the classical stability tests, such as the Routh-Hurwitz and Nyquist criterions, and design methods using root-locus plots and Bode plots; and the development of control techniques based on PID, lead and lag networks, using linear state or output feedback (3 credits). (Elective for Electrical and Computer Engineering)

Prerequisites:
ECE 3750 – Signals and Systems (I), or equivalent.

Objectives:
Study the principles of system modeling, system analysis and feedback control, and use them to design and evaluate feedback control systems with desired performance; specifically, to acquire the related knowledge and techniques to meet the following course objectives:

1. *Control system modeling*: modeling of electric, mechanical and electromechanical systems, using differential equations, transfer functions, block diagrams, and state variables;
2. *Control system analysis*: analysis of properties of control systems, such as sensitivity, stability, controllability, tracking, in time and frequency domains; and
3. *Control system design*: design of feedback controllers, such as PID, lead and lag compensators, pole placement designs, to meet desired system performance specifications.

Course Objectives and Program Outcomes Map:
Objective 1: program outcomes 1.a (in depth); 1.b, 1.d (familiarity); 3.d (exposure)
Objective 2: program outcomes 2.b, 2.f (in depth); 1.b, 1.d, 2.c (familiarity); 3.a, 3.d (exposure)
Objective 3: program outcomes 2.d, 2.f (in depth); 1.b, 1.d (familiarity); 3.a, 3.d (exposure).

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 design (4 lectures).

Instructor:
Dr. Gang Tao, Thornton Hall, Room E311, 924-4586, gt9s@virginia.edu.

Lecture Hours:
11:00 - 12:15, Tuesdays and Thursdays, Room MEC 216.

Assessment Scheme:
There are totally 10 homeworks, 1 project and 2 tests for this course.

> **1.a**: Application of calculus, differential equations, physical laws, complex variable theory in modeling of control systems (assignments in 4 homeworks, 2 tests, 1 project)
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> **1.b**: Procedure of technical developments in homeworks, tests and project
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> **1.d**: Standard of technical presentation in homeworks, tests and project
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> **2.b**: Use of matrix differential equations, Fourier transform, Laplace transform, matrix theory, and complex variable theory (assignments in 8 homeworks, two tests and 1 project)
>
> **2.c**: Use of Matlab in control system analysis throughout homeworks
>
> **2.d**: Study of system stability, sensitivity, transient and tracking performance, and design of control systems with desired performance specifications (assignments in 7 homeworks, two tests and 1 project)
>
> **2.f**: Study of control system knowledge through homeworks, tests and project
>
> **3.a**: Understanding of the need of learning more advanced topics in control systems, such as issues with nonlinearity and uncertainty
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> **3.d**: Practice of the UVa honor code in completing homeworks, tests and project.

Program Outcomes:
Program outcomes are the effectiveness measures of a course, which are grouped into three categories: 1. fundamentals, 2. specialists, and 3. citizenship.

> Outcome 1.a: knowledge of mathematics (including differential equations), science, and engineering fundamentals.
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> Outcome 1.b: ability to identify, formulate, and solve engineering problems.
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> Outcome 1.d: ability to effectively communicate technical material.
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> Outcome 2.b: knowledge of advanced topics in mathematics including vector calculus, transform calculus, complex variables and probability and statistics.
>
> Outcome 2.c: design of systems containing both hardware and software elements. Outcome 2.d: ability to specify, design, analyze and test an electrical/electronic system to meet a set of desired goals, within the context of a broader system application.
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> Outcome 2.f: specialized knowledge in one or more of the topical areas of electrical engineering: controls, communications, electrophysics, digital systems, or microelectronics.
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> Outcome 3.a: recognization of the need for and being capable of engaging in lifelong learning.
>
> Outcome 3.d: understanding of the ethical and professional responsibilities of an engineering practitioner or researcher.

ECE 4850 – **Linear Control Systems** (Fall 2011; 3 credits)

Schedule of Office Hours, Homeworks, and Tests

Instructor's office hours: 3:30 - 4:45, Monday; 9:30 - 10:45, Tuesday

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

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

Homework 1 (Topic 1): 1.1(c), (d), 1.5, 2.9(a), 2.15(b), (c), 2.20.
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, 3.26, 3.28 (hint: using the region $\omega_1 \leq \omega_n \leq \omega_2$, $\theta_1 \leq \theta \leq \theta_2$ containing the given circle), 3.35.
Due on **September 20, Tuesday**.

Homework 4 (Topic 4): 3.42 (hint: $KG(s)$ is an open loop transfer function), 3.43, 3.45.
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.
Due on **November 22, Tuesday**.

Homework 10 (Topic 10): 7.17(b), 7.20, 7.21, 7.30(a), 7.48(a), (b), (c).
Due on **December 6, Tuesday**.

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