Washington State University
School of EECS
Electrical Engineering Course Assessment Report

Course Number  EE 489
Course Title  Control Theory
Semester Offered Fall 2007
Instructor  Hanshaw
10th Day Enrollment 19 Number Completing Successfully (C grade or better)  15

I. Assessment Outcomes from the Course Syllabus

☐ (A) Ability to apply knowledge of mathematics, science and engineering.
☐ (B) Ability to design and conduct experiments as well as analyze and interpret data.
☐ (C) Ability to design a system, component, or process to meet desired needs.
☐ (D) Ability to function on multidisciplinary teams.
☒ (E) Ability to identify, formulate, and solve engineering problems.
☐ (F) An understanding of professional and ethical responsibility.
☒ (G) Ability to communicate effectively in written and oral formats.
☐ (H) A broad education necessary to understand the impact of engineering solutions in global, economic, and societal context.
☐ (I) Recognize the need for, and have the ability to engage in life long learning.
☐ (J) Have a broad education and knowledge of contemporary issues.
☒ (K) Ability to use techniques, skills and modern engineering tools necessary for engineering practices.

II. List of Course Topics from the Course Syllabus

1. The general concept of control system design
2. Mathematical techniques for the control engineer
3. Transfer function, block diagram, and signal flow graph
4. State variable analysis, controllability, observability
5. Control system stability
6. Root locus techniques
7. Time domain analysis and design
8. Frequency domain analysis and design
### III. Course Assessment Summary Table: one row of the table should be devoted to each of the checked outcomes in part I.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Topics</th>
<th>Specific Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Ability to apply knowledge of mathematics, science and engineering.</td>
<td>2-8</td>
<td>Homework assignments, exams, and <strong>final design project</strong></td>
</tr>
<tr>
<td>(B) Ability to design and conduct experiments as well as analyze and interpret data.</td>
<td>2-4</td>
<td><strong>Final design project</strong></td>
</tr>
<tr>
<td>(C) Ability to design a system, component, or process to meet desired needs.</td>
<td>5-8</td>
<td>Homework assignments and exams contain some exposure to system design. The <strong>final design project</strong>, however, was the primary measure of this outcome. In the final design project, students designed and implemented a compensator for a translational spring-mass-damper system.</td>
</tr>
<tr>
<td>(E) Ability to identify, formulate, and solve engineering problems.</td>
<td>1-8</td>
<td>The <strong>final design project</strong> was the primary measure for this outcome. The final design project required students to model a physical system and design a compensator for the system.</td>
</tr>
<tr>
<td>(G) Ability to communicate effectively in written and oral formats.</td>
<td>1-8</td>
<td><strong>Final project</strong> required a formal written project report.</td>
</tr>
<tr>
<td>(K) Ability to use techniques, skills and modern engineering tools necessary for engineering practices.</td>
<td>2-8</td>
<td>Most homework assignments and especially the <strong>final project</strong> required the use of MATLAB to assist in system design and simulate system responses. Most students used Simulink in the final project to simulate nonlinear system responses.</td>
</tr>
</tbody>
</table>
IV. Using the table as a guide, for each outcome summarize your evaluation of the students’ achievement of that outcome; cite student performance on the identified measures as evidence to support your conclusions.

Background:
Examinations and homework assignments performed throughout the semester primarily functioned as vehicles to introduce specific course topics and to provide mid-course corrections for misconceptions about specific course topics. The final class project required synthesis of overall course topics in the context of system modeling and compensator design.

The project this semester consisted of design of a position control system for a translational spring-mass-damper. Previous experience with this class has indicated that students benefit from exposure to a physical system and the use of experimental data for development and correlation of the plant model. This semester, a spring-mass-damper system was constructed, in which the height of a mass could be adjusted by varying the DC voltage applied to a motor. The position of the mass was measured by an acoustic proximity sensor. The final project for the class was to design a compensator to control the position of the mass to meet a set of design requirements. Design requirements included specifications on system type, settling time, and peak overshoot. Students were required to use experimental input-output data from the plant in order to develop a model of the plant. Unlike the past two semesters, students were not required to implement the compensators they designed; this option was available to the students, but no students elected to perform the implementation.

Results:
The previously listed course criteria and the way in which they are addressed in the final project are discussed below.

(A) An ability to apply knowledge of mathematics, science and engineering:

Examinations, homework assignments, and the class project all addressed this ABET criterion. Overall, the majority of students displayed an adequate ability to apply concepts learned during the course. This was reflected by the high overall homework and examination averages. The average of the three midterm examinations was approximately 75% and the homework assignment average among students completing the course was approximately 70%. The average score of the final exam was acceptable at approximately 84%.

One problem area was that some students had difficulty applying concepts learned in pre-requisite courses. This became especially apparent during the first portion of the final project, in which students were required to estimate the transfer function of a third order system from measured input-output data. This process required them to apply concepts (Discrete Fourier Transforms, Bode Plots) that were covered in pre-requisite classes (e.g. EE 321, EE 341). An informal survey made early in the course indicated that all students felt reasonably comfortable with these subjects. However, virtually no students were able to create a reasonable transfer function without significant guidance from the instructor. On the positive side, the final project seemed to help student relate the above topics to data acquired from a physical system.
(B) Ability to design and conduct experiments as well as analyze and interpret data.

The final design project required students to identify a mathematical model for the plant to be controlled. The plant was a translational spring-mass-damper system in which a mass's position could be adjusted by varying the DC voltage applied to a motor. The plant governing equations provided to the students result in a plant model which is a fourth order nonlinear differential equation. The students must linearize the governing equation and use experimental data provided by the instructor to estimate unknown parameters in the linearized governing equation.

The system provided this semester was felt to be too complex to require the students to design an appropriate experiment and acquire response data. Thus, experimental data for the transfer function identification was generated and provided to the students by the instructor. The input-output data provided to the students corresponded to pulse inputs to motor voltage. The data provided to the students were intentionally noisy; multiple trials were provided to allow students to interpret noise effects vs. actual system response effects. Students were advised to use discrete Fourier transform methods to determing gain, phase and coherence vs. frequency for the data. Bode plots of the gain and phase for frequency ranges with high coherence were then to be used to estimate the transfer function. Although students were supposedly familiar with the concept estimating a transfer function from Bode plots, they struggled with a number of details associated with analyzing a given data set. An interim project report was submitted by the students approximately two-thirds of the way through the semester, to ensure that students had appropriate feedback on their plant models prior to designing a compensator. Only one student submitted a reasonable transfer function in his interim project report; all other students submitted either nonsensical transfer functions or simply did not estimate a transfer function at all. (Disturbingly, the assumption seemed to be that the instructor would provide a transfer function if the students did not generate one.) This shortcoming was rectified after submission of the project interim report; virtually all students were able to use experimental data to identify an appropriate plant model by the time the final project report was submitted, though most students needed significant help from the instructor to do this.

(C) Ability to design a system, component, or process to meet desired needs.

Exams and homework assignments address this requirement, but in a somewhat abstract sense. The primary assessment for this ABET criteria was, therefore, the final class project. The project required students to design and implement a position control system. The students are provided with a plant consisting of a spring-mass-damper system in which a desired position of a mass can be maintained by application of an appropriate DC voltage to a motor. The students are required to design a compensator which will accept a mass position measured by an acoustic proximity sensor and adjust the voltage to the motor to provide a desired mass position.

In general, the students did reasonably well on the design project. The overall average score for the final report was 76%. These scores are lower than last semester's project scores. A secondary contributor for this may be that the plant to be controlled this
semester is significantly more complex than last semester’s plant; this was, however, offset by reducing the difficulty of some other aspects of the project report. The primary contributors to the lower scores are:

1. Procrastination. Students did not start their projects in a timely manner. Specifically, most students did not complete the estimation of the system transfer function at the required due date; this resulted in this task being performed later in the semester, when students should have been concentrating on compensator design.
2. Implementation of the students’ compensators was not required this semester. A circuit which could implement their compensator was, however, required. Most students did not provide a reasonable circuit, which resulted in a grade penalty.

(E) An ability to identify, formulate, and solve engineering problems

This ABET criteria was addressed primarily by the final design project. In the final design project, the students were provided with a plant consisting of a mechanical system in which the position of a mass could be adjusted by varying the voltage applied to a motor. Students were required to identify an appropriate model for the plant, determine unknown model parameters from provided input-output data, and design a compensator for the plant to meet a set of prescribed design requirements. This design project required students to synthesize material learned in different portions of the class and pre-requisite classes in order to develop an appropriate compensator design.

(G) Ability to communicate effectively in written and oral formats

The final project required an in-depth write up of their results; the quality of these reports was quite variable. Most students displayed adequate written communication skills, but a number of the reports tended to be poorly written, poorly organized, or both. In at least some of the latter cases, the problem was attributed by the students to lack of time available to spend on writing a coherent report. Penalization for poor reporting was minimal in this class.

(K) Ability to use techniques, skills and modern engineering tools necessary for engineering practices

Matlab was used to simulate system responses in most homework assignments. Both the interim project report and the final project required more in-depth use of Matlab to analyze engineering problems and perform system design. In general, students were enthusiastic about using Matlab for solving engineering problems. Their ability to critically review their numerical results was, however, somewhat inconsistent. Many
students showed a strong desire to take the accuracy of any computer-generated results for granted.

Students used Simulink to simulate the system’s performance in the presence of nonlinearities in the form of saturation at the controller output. Again, students were readily able to perform the necessary analyses, but were less able to critically review their numerical results.

V. Qualitative Assessment of Student Performance: using the arguments above and other data support the claim that students who completed this course with a grade of C or better have achieved each of the intended outcomes of this course.

Overall, the students did adequately on exams and homework assignments. The average score on the midterm exams was approximately 75%. The homework assignment average was lower than usual, at approximately 70%. The average score of the final exam was considerably higher than previous semesters, at approximately 84%. The final project report average was approximately 76%, which was consistent with previous semesters. This indicates adequate performance relative to the ABET criteria listed above.

VI. Concerns: state any concerns you may hold about this class – were the students adequately prepared coming into it? Are there topics or outcomes where (some) students were weak after completing the course? Other concerns? Were there any comments on students’ course evaluations that should be addressed in future instances of the course? This section is very important for improving our program: it provides critical input to the curriculum committee for identifying areas requiring attention.

Students were, in general, adequately prepared for the class before entering it. One problem area appeared to be synthesis of materials from various previous classes. (For example, students were familiar with individual topics such as Fourier transforms and Bode plots, but had not made a connection between these topics.) Overall, students appeared to have better skills relative to use of engineering analysis tools such as MatLab than in previous semesters.

Students need more exposure to design problems and especially the implementation phase of the design process in this class and other concurrent classes. Students still seem somewhat tentative in their approach to a design problem, though most of them appear to enjoy exposure to design-related problems. Students also seem to need more exposure to data analysis and experiment design; many students appear to have difficulty relating theoretical and practical aspects of a problem.

Signature: ___________________________ Date: ___________________________