Washington State University  
School of EECS  
Electrical Engineering Course Assessment Report

Course Number  EE 489  
Course Title  Control Theory  
Semester Offered Spring 2007  
Instructor  Hanshaw  
10th Day Enrollment 30  Number Completing Successfully (C grade or better)  24

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 final design project</td>
</tr>
<tr>
<td>(B) Ability to design and conduct experiments as well as analyze and interpret data.</td>
<td>2-4</td>
<td>Final design project</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 final design project, however, was the primary measure of this outcome. In the final design project, students designed and implemented a compensator for a fluid level control system.</td>
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<tr>
<td>(E) Ability to identify, formulate, and solve engineering problems.</td>
<td>1-8</td>
<td>The final design project was the primary measure for this outcome. The final design project required students to model a physical system and design and implement a compensator for the system.</td>
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<tr>
<td>(G) Ability to communicate effectively in written and oral formats.</td>
<td>1-8</td>
<td>Final project required a formal written project report and a short (5-10 minute) informal presentation.</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 final project 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>
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</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 and implementation of a fluid level control system. Course assessments from previous semesters have indicated that students may benefit from more “hands-on” exposure to control systems design, including an experimental or laboratory component to provide students with exposure to control system topics in a practical setting. This is the second semester that a practical implementation aspect has been incorporated in the final project. This semester, a fluid dynamic system was constructed, in which the height of a column of fluid could be adjusted by varying the DC voltage applied to a pump. The final project for the class was to design a compensator to control the fluid level in this system to meet a set of design requirements. Design requirements included specifications on system type, rise time, and peak overshoot. Students were required to implement their compensator, test it on the physical system, and comment on differences between experimental and theoretical results.

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 82% and the homework assignment average among students completing the course was 82%. The final exam required slightly more synthesis of the overall course material; the average score of the final exam was acceptable at approximately 78%.

One problem area was that some students had difficulty applying concepts learned in prerequisite courses. This became especially apparent during the first portion of the final project, in which students were required to estimate the (linearized) transfer function of a first order nonlinear system from measured step response data. Although students have seen the topic of linearization in previous classes (e.g. EE 352) and should have been comfortable with the step response of first order systems, most students were not comfortable enough with these topics to be able to design an experiment and perform the data analysis necessary to identify linearized first order system parameters from experimental data. On the positive side, the final project seemed to help students relate the rather abstract concept of linearization to the operation of 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 fluid dynamic system in which a fluid level could be adjusted by varying the DC voltage applied to a pump. The plant governing equations provided to the students result in a plant model which is a first order nonlinear differential equation. The students must linearize the governing equation and conduct an experiment to determine unknown parameters in the linearized governing equation.

Although students were familiar with step responses of first order systems and were able to identify a step response as an appropriate method of determining the desired model parameters, they tended to struggle with a number of details associated with acquiring and analyzing an appropriate data set. Many of their problems were relative to the concept of linearizing the original nonlinear differential equation. Students were able to perform the mathematics relative to linearization, but the mathematics did not seem to provide any insight into their desired experimental conditions. For example, the linearization is performed around a nominal operating point, or bias point. Most students did not preserve this concept when conducting an experiment to identify the unknown model parameters. 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.

Students were also required to design a compensator for the system, test the overall system’s performance, and compare this performance to expectations based on analyses. Students did well during this phase of testing; it was apparent that the students’ ability to design and conduct an experiment and analyze the resulting data had improved during the course of the semester.

(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 fluid level control system. The students are provided with a plant consisting of a Plexiglas tube in which a desired fluid level can be maintained by application of an appropriate DC voltage level to a pump. The students are required to design a compensator which will accept a measured fluid level and adjust the voltage to the pump to provide a desired fluid level. Disturbances can be applied to the system by changing the position of a drain valve at the bottom of the Plexiglas tube.

In general, the students did well on the design project. The overall average score for the interim report was approximately 84% and the average score on the final report was 87%. These scores are a significant improvement over last semester’s project scores. This improvement may be due to two reasons:
1. The system this semester (water level control) seemed to be somewhat more intuitive to students than the motor speed control system used last semester. It seemed that it was easier for students to “see” the water level move than to “see” a flywheel change its rotational velocity.

2. Procrastination did not seem to be as much of an issue as it was in the Fall 2006 semester.

Lack of familiarity with the overall design process and a lack of synthesis of material from previous courses and various parts of the current course remained a problem this semester, though the problem was not as pervasive as in the Fall 2006 semester. Students seemed more willing this semester to approach the design problem as being inherently iterative.

Compensator implementation was not nearly as problematic this semester as in the Fall 2006 semester. In the Fall 2006 semester, only six out of twenty seven students completing the course implemented a circuit which met all system requirements. This semester, eleven out of twenty four students implemented circuits which met all system requirements. Most other students were able to demonstrate a circuit which was tracking the reference input and rejecting disturbances to some extent, though possibly not to the extent expected by their analyses. Some students still displayed inadequate problem-solving skills when confronted with hardware related issues, but this problem did not appear to be nearly as pervasive as in the Fall 2006 semester. Since compensator implementation is still a rather tentative addition to the course, the inability to construct a functioning circuit did not significantly penalize the students’ overall grade for the course.

(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 fluid dynamic system in which the fluid level could be adjusted by varying the voltage applied to a pump. Students were required to identify an appropriate model for the plant, design and conduct experiments necessary to identify unknown model parameters, and design and implement 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 interim project report consisted of a short written paper describing their principle results and conclusions. Most students could identify the important results, draw meaningful conclusions, and summarize these results well.
The final project required an in-depth write up of their results; the quality of these reports was generally good. Most students displayed adequate to excellent written communication skills, but a few 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; the report submission date coincided with the due date for final reports in a senior design class.

The final design project submission also required students to informally present and demonstrate operation of their circuit to the instructor. Most students demonstrated adequate communication skills, at least in this informal setting.

(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 very well on exams and homework assignments. The average score on the midterm exams was approximately 82% and the homework assignment average was also 82%. The final exam required slightly more synthesis of the overall course material; the average score of the final exam was acceptable at approximately 78%. The final project report average was excellent, at approximately 78%. 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 linearization and first order linear system responses, 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: _____________________