AC 2008-1800: BUILDING ENGINEERING LITERATE NON-ENGINEERS

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Building Engineering Literate Non-Engineers

Abstract

All students at the United States Naval Academy, regardless of major, must take two electrical engineering courses. The course topics include circuit theory, motors, generators, three-phase power distribution systems, communication systems, digital logic, and computer networks. These courses are taught to more than 600 non-engineering students each year. A different course sequence is used for ABET accredited majors.

This paper presents the approach used by the Electrical and Computer Engineering Department at the Naval Academy to improve the technological literacy of non-engineering students. Electrical engineering fundamentals and applications are emphasized with the relevant mathematics introduced as needed. Applications of the fundamentals evolve to stress the relevance of a particular topic area. Key technical concepts are reinforced with practical laboratory exercises. The final practical exercise takes place aboard a Naval Academy patrol craft. The students explore the electrical systems on the ship and relate them to the fundamentals studied during the semester.

Course outcomes show that students across a range of majors can attain a level of knowledge that appreciably increases their engineering technological literacy. In addition, there is considerable improvement in their problem solving and critical thinking skills. The courses, including sample laboratory exercises, are reviewed. Student reaction to the courses as well as achieved results is presented along with suggestions for successful implementation at other institutions.

Introduction

Technological literacy, as defined in the report[1] by the National Academy of Engineering and the National Engineering Council, has three components: knowledge, ways of thinking and acting, and capabilities. The Electrical and Computer Engineering Department at the United States Naval Academy improves the engineering literacy of students with majors as diverse as English, Political Science, Economics, Mathematics and Chemistry by offering a two course overview of fundamental Electrical Engineering topics. The goal of this course sequence is not to train engineers, but to introduce students to the language and concepts of electrical engineering so that they are effective in their role as future Navy or Marine Corps Officers. An additional goal is an improvement in their problem solving and critical thinking skills. These goals correspond to some of the traits that characterize the knowledge and capabilities components of technological literacy.[1] As pointed out by Ollis and Pearson[2], it would be difficult to find any person that exhibited all the characteristics associated with all three components. These courses make no attempt to reach such a goal. The primary purpose of the courses is to prepare midshipmen to be successful leaders in an increasingly technologically based military. Hence the goals of the course for midshipmen development coincide with the characteristics of a technologically astute citizen.

The first part of this paper reviews the history and background of the institution and the courses. The second part is an overview of the courses with sample laboratory exercises. The discussion and conclusion present student responses, comment on assessment, and suggest ways to implement the course as a technology literacy course at other institutions.

History and Background

The United States Naval Academy (USNA) is a four year undergraduate institution. The four thousand students come from every state in the United States and some foreign countries. The class of 2007 was 16.7% women and 24.6% minorities. The faculty at the USNA is approximately 50% Navy and Marine Corps Officers and 50% civilian PhDs. Students begin their majors program sophomore year after a freshmen year that requires Calculus, Chemistry, U.S government, Naval History, Leadership and Human Behavior and Rhetoric and Literature.

Non-engineering students at the USNA have taken one or two courses in Electrical Engineering for over twenty years and Electrical Sciences courses for nearly 100 years. The Navy and Marine Corps have long recognized the importance of technologically literate officers. In addition to a broad education that emphasizes leadership, communication skills and an understanding of the geopolitical and cultural implications of command decisions, in the words of former USNA Superintendent Vice Admiral Rodney Rempt, "in an increasingly technical world, our officers must understand what makes their systems tick". The topics chosen cover fundamental electrical engineering concepts, but the applications have evolved to stress the relevance of those topics. The course sequence is presently two semesters long.

This two course sequence for non-engineers is coupled with one course each in Mechanical Engineering, Naval Architecture and Systems Engineering. The major topics consist of the principles of energy conversion, ship stability and operability, and theory of weapons systems, respectively.

The courses are taught by officers with at least a Masters degree in Electrical Engineering and civilians with PhDs in Electrical Engineering. A civilian and an officer are co-coordinators of the course. They are responsible for implementing the topic areas chosen by the Electrical and Computer Engineering Department Curriculum Committee via a syllabus, textbook choice and learning objectives. In cases where an appropriate textbook isn't available, the instructors write the required course material. In addition, laboratory or "practical exercises" have been developed by course instructors for every topic area. The 600 to 700 students who take the course are divided into classes of approximately 20 students. They share not only a common syllabus, but have the same exams and practical exercises.

Originally both courses met four days a week for three lecture hours with a two hour laboratory session on a 1-1-2-1 or 1-2-1-1 schedule. In its present form, the courses meet 3 days a week on a 1-2-2 schedule. The first meeting is a one hour lecture. The other two meetings are two hours long and consist of lecture and practical exercises. The course has evolved in its pedagogical approach so that instructors have the option of

immediately following a brief lecture with a practical exercise that reinforces the topic just introduced. This approach is facilitated by a renovation that created studio classrooms in 2001.[3] The studio concept places the lecture space and laboratory benches in the same room as shown in Figure 1. Each laboratory bench is outfitted with DC power supplies, multimeters, AC signal generators, an oscilloscope and a circuit board. In addition, three phase power is available at every lab bench.

Course Overview

The first course is an electrical circuit analysis and power course. Power is a vital subject for officers who will be assigned to Navy ships and submarines. The initial course topic is basic DC circuit theory. Students learn DC resistor based circuit concepts that include voltage and current divider and Thevenin's theorem. Instructors often use examples such as light bulbs and car batteries to help students relate the concepts to familiar items. The

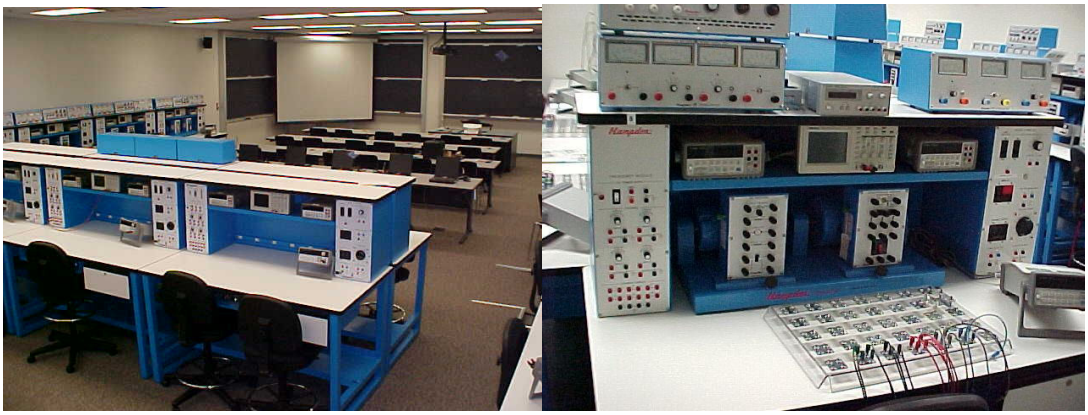

Figure 1: Studio Classroom Laboratory and Populated Laboratory Bench

transparent plastic circuit board in Figure 1 permits quick circuit assembly that an instructor can easily check. Components such as resistors are mounted for easy circuit assembly. The initial practical exercises are designed for immediate circuit assembly and test to verify and practice circuit analysis concepts. Instructors are encouraged to require individual work so that students gain confidence in their ability to understand and use electrical test equipment. Student feedback confirms that these short focused practical exercises enhance their understanding of basic circuit theory. After only 5 weeks of introductory circuit theory, DC motors are introduced. For many students this is the first time they are exposed to basic machine operation. The practical exercise reviews basic DC motor operation using a Hampden DC machine.

The next set of topics covers the other two basic circuit elements – a capacitor and an inductor. Students use an oscilloscope for the first time as they study the charging and discharging characteristics of capacitors. AC circuit analysis is the next topic. Although most students have been exposed to sinusoidal functions, the topic is reviewed to reinforce student understanding. Most students are unfamiliar with complex numbers so

the relevant mathematics is introduced so that students can approach AC circuit analysis with confidence. The mathematics is reviewed as all of the DC circuit analysis concepts are reapplied for AC circuits. The practical exercises reinforce the concepts as students use a signal generator for the first time.

The remainder of the course focuses on AC power. Topics covered include the AC power triangle and power factor correction. The practical exercise for power factor correction asks students to correct the power factor of the circuit shown in Figure 2 and requires circuit analysis skills and an understanding of circuit element characteristics and AC power requirements for a very practical application. This practical exercise is a positive experience for many students as their electrical engineering literacy is showcased. The final topic is three phase generators, three phase power and transformers. Practical exercises use the three phase power capability of the laboratory benches and a Hampden AC machine.

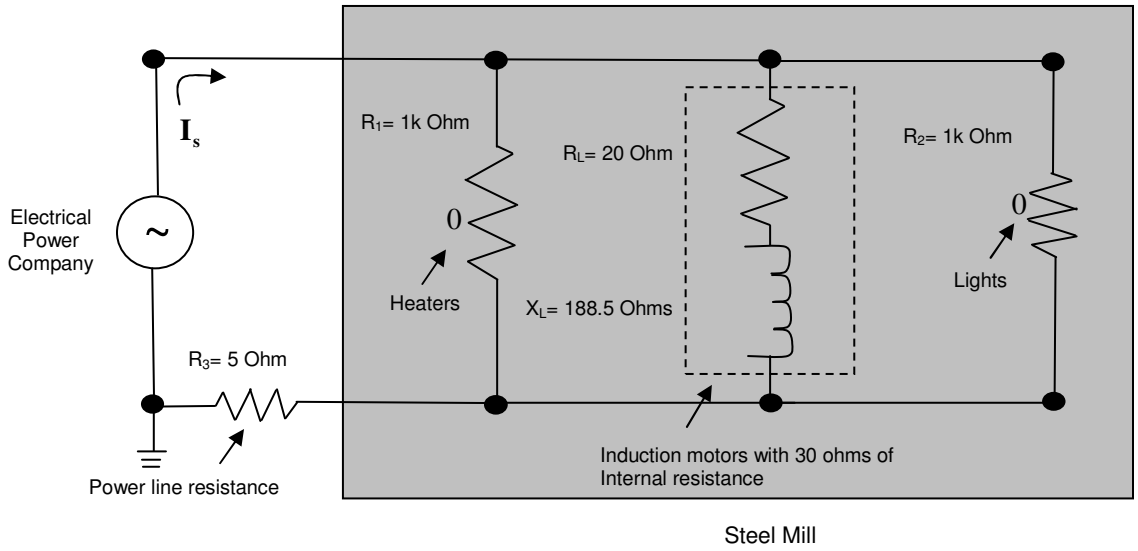

Figure 2: Power Factor Correction Practical Exercise Circuit

The culminating practical exercise occurs on board the USNA yard patrol crafts (YPs- Figure 3). The YPs have two diesel generators that power all ship systems. Students are expected to understand the basic schematic of the YP power system before going on board. Once on board the YPs, they track down the elements of the power system and observe actual diesel generator operations. The students also answer questions that range from how generators are put in parallel to how the anchor windlass motor works. This is a very satisfying experience for students that rarely know what a transformer is at the beginning of the semester.

Figure 3: USNA Yard Patrol Craft

This circuits and power course is a prerequisite for the second course on communication systems, digital logic and computer networks. Simple filter design and the concepts of gain, attenuation, noise and frequency spectrum prepare students to study Amplitude Modulation (AM) and Frequency Modulation (FM) based communication systems. The practical exercise circuit in Figure 4 uses a summing operational amplifier coupled to signal and noise sources and a speaker to reinforce the concept of signal-to-noise ratio. Student use their oscilloscope skills to examine how different levels of noise interfere with both a sinusoidal signal and an iPod generated audio signal. An introduction to superheterodyne receivers gives students experience moving signals around the frequency spectrum and reinforces the concept of bandwidth.

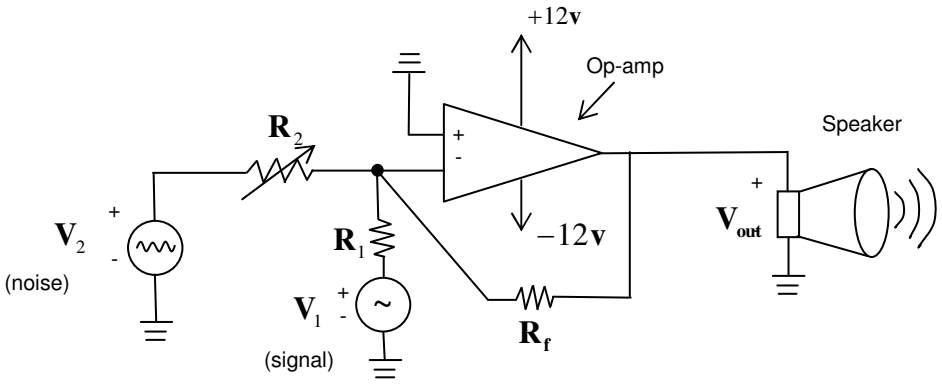

Figure 4: Signal-to-Noise Ratio Practical Exercise Circuit

The next part of the course includes digital logic and digital to analog converters. Students are introduced to digital transmission, pulse code modulation, frequency shift keying, and error detection, error coding, and multiplexing. Antennas basics and a satellite communication application complete this broad survey of communication system components and operation.

The final part of the course covers networking. Students learn about networking equipment, internet protocols, internet addressing, routing and wireless networking.

Discussion and Conclusions

The goal of both courses is not to create engineers, but to build students conversant in the language and basic concepts associated with the topic areas. In addition, practice solving numerous technical problems inevitably improves students' problem solving and critical thinking skills. The course results show that students across a range of majors can achieve a level of knowledge that appreciably increases their engineering technological literacy.

While it may appear that having a wide range of student aptitudes might present a pedagogical problem, this does not turn out to be true. At the USNA, all of the students have had at least 3 semesters of calculus and 2 semesters of physics so the difference in preparation is not that great. This is a key point in teaching non-engineers technical topics, a solid math and science foundation, hopefully started in K-12 that can be built upon in the early college years. A solid K-12 foundation would permit any institution implementing such a course to be successful. The math and science foundation all midshipmen receive allows us to teach engineering fundamentals and applications that in many cases, are the applied math and science problems that many technically unaware students actually crave. As in any class, students have a range of abilities. The courses focus on fundamental engineering concepts and although the students have had calculus, the courses are not calculus based. This allows weaker students to keep up. Competent instructors can challenge the stronger students and in a collaborative environment, strong students are encouraged to work with the weaker students. For example, some instructors deputize students who quickly complete practical exercises. The peer learning that results benefits both individuals.

The USNA is a unique institution, however the approach used can be translated to other institutions. Such a course would focus on fundamental engineering concepts and relevant applications. These two electrical engineering courses for non-engineers enjoy their success in part due to the relevance of the course material and the presented applications. The second course in particular has evolved in its applications. For example the course has always included communication and digital fundamentals, but the applications have grown to include more digital communication and networking topics.

The courses have not formally included such topics as the study of the benefits and risks of technology and how technology shapes human history although some individual instructors do link the course material to such topics to engage history and political science majors taking the course. This could become a formal part of such a course. The midshipmen are required to take courses in leadership, ethics and law where some of these topics are addressed.

The assessment process for both courses is evolving. The Electrical and Computer Engineering process for ABET accredited courses is currently being modified to better assess students outcomes for department courses intended to increase technological literacy but not produce practicing engineers.

Both courses are well received by the students. Students have commented that the course material is worthwhile and pertinent and that they feel better prepared and more confident to undertake their future profession in an increasingly technologically based military. When they encounter a technical issue such as what is causing a generator to fail, why a piece of communication gear isn't working or why a computer network isn't on line they will have the technical depth to understand the problem. They are also prepared to effectively lead enlisted mechanics and technicians and explain technical concerns to their superiors.

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