AC 2009-2170: DEVELOPING BIOMEDICAL INSTRUMENTATION LABORATORY EXERCISES FOR ENGINEERING TECHNOLOGY

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Developing Biomedical Instrumentation Laboratory Exercises for Engineering Technology

Abstract

With the rapid growth of the Biomedical Engineering field in recent years, many academic institutions have developed Biomedical Engineering and Biomedical Engineering Technology programs to address this growth trend. However, the number of Biomedical Engineering Technology programs that have been developed to address the need for qualified technologists in this filed have been few and far between[1]. The Electrical Engineering Technology (EET) program at Southern Polytechnic State University was recently approved to offer an option in Biomedical Engineering Technology (BMET). The primary objective for the development of the BMET option has been to produce graduates that will have the requisite skills for a successful career in the Biomedical Engineering/Technology field. Given the background to the development of this option, one of the key courses proposed for the option was a course in Biomedical Instrumentation. The traditional approach to teaching Biomedical Instrumentation has relied on a solid background in Engineering Circuit theory, advanced Mathematics and Engineering design. However, for Engineering Technology students, who, in most cases lack an advanced mathematical background, the need is for a more applied and hands-on approach. Unfortunately, the prohibitive cost of many of the kinds of equipment encountered in the Biomedical Engineering field makes it difficult to develop an effective laboratory component to a Biomedical Instrumentation course for Engineering Technology. In this paper a discussion of the approach utilized to develop a meaningful laboratory experience for ET students in the BMET option is presented.

I. Introduction

The Electrical Engineering Technology (EET) program at Southern Polytechnic State University was recently approved to offer an option in Biomedical Engineering Technology (BMET). This option was developed with the primary objective of producing graduates who will have the requisite skills for a successful career in the Biomedical Engineering/Technology field. One of the key courses proposed for the option was a course in Biomedical Instrumentation. Traditional approaches to teaching Biomedical Instrumentation has relied on a solid background in Engineering Circuit theory, advanced Mathematics and Engineering design. However, for Engineering Technology students, who in most cases lack an advanced mathematical background, the need is for a more applied and hands-on approach. This implies that students will need to be exposed to the different types of equipment to be encountered in the medical environment. Unfortunately, the cost of such equipment can be prohibitive and not practical for many college programs. For example, an MRI can cost upwards of a million dollars. Also, as a result of rapid advances in technology medical equipment tend to become obsolete rather quickly. In addition, some of the equipment can pose health and safety hazards that programs are

not equipped to deal with. For example, while the use of Magnetic Resonance Imaging (MRI) in medicine has considerably improved the accuracy of medical diagnosis, and these machines have become invaluable for medical diagnosis, they pose serious hazards for patients with metal implants or implanted pace-makers. Housing such a piece of equipment would entail constructing special structures to safely house them, and providing shielding, etc., for the equipment. This would entail more costs for programs. In fact, during the development of the new EET degree option in Biomedical Engineering Technology at Southern Polytechnic State University, it was decided to include a safety course as an essential requirement for the degree in order to address such concerns

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One approach that programs could follow for their Biomedical Instrumentation courses would be to rely on equipment donations from the medical community as they upgrade to newer models or types of equipment. This is still a prohibitively costly approach as it may require arranging for the transportation of some bulky pieces of equipment. Some of the donated equipment may not be usable without additional equipment and material which can be costly as well.

The result is that Biomedical Engineering and Biomedical Engineering Technology programs have to be creative in coming with ways to offer a Biomedical Instrumentation course that provides their students with the fundamental understanding of the principles of Biomedical Instrumentation with a sufficient hands-on component included.

II. The BMET Option in EET

The Electrical Engineering Technology (EET) program at Southern Polytechnic State University (SPSU) recently instituted an option in Biomedical Engineering Technology (BMET) [2 – 4]. The EET program is accredited by ABET, Inc[6]. The BMET option was designed with a view towards retaining the ABET accreditation of the EET program. The curriculum for the option is shown in Table 1.

The curriculum adds five new technical courses to a core of ECET, Mathematics, English, Science, and Social Science courses. The program is structured within the 130 credit-hour limit set by the Georgia Board of Regents. Eighteen (18) hours are allocated to Biomedical Engineering Technology specific courses created for the program (indicated by asterisks); Fifty-two (52) hours constitute a core of ECET technical courses; Sixty (60) hours are for the mathematics, science, English, and social science core. The Biomedical Engineering Technology courses are identified by asterisks. Weekly lecture hours, laboratory hours, and total credit hours are also provided.

The BMET option has been structured so as to retain the main core of the EET program. The EET curriculum was recently revised with input from the Industrial Advisory Board (IAB) [5] to allow the ECET students more flexibility in designing their curriculum. This has allowed for the proposed BMET option to be easily accommodated within the EET program.

III. The EET-BMET Option Approach to Biomedical Instrumentation

Recognizing that in order to provide a rounded education for our students, it was imperative that they be exposed to actual biomedical instruments used in the medical field, the curriculum includes a capstone course that can be satisfied by completing either a capstone project in an area

Table 1. ECET courses in the BSBMET degree program option.

COURSE NAME	SEMESTER NUMBER	WEEKLY LECTURE HRS	WEEKLY LAB HRS	CREDIT HOURS
Orientation	1	2	0	2
Fundamentals	1	2	3	3
Circuits I	2	3	3	4
Digital I	2	3	3	4
Circuits II	3	3	3	4
Electronics I	3	3	3	4
Introduction to Biomedical ET*	4	3	0	3
Digital II	4	3	3	4
Electronics II	4	3	3	4
Data Communications	5	3	3	4
Test Engineering	5	3	3	4
Applications of C++, JAVA and HTML	5	2	3	3
Health Care Safety*	5	3	0	3
High Frequency Systems	6	3	3	4
Embedded PCs	6	3	3	4
Biomedical Instrumentation*	7	3	3	4
BMET Elective (ECET)	7	3	3	4
BMET Elective*	8	3	3	4
BMET Capstone Project/Internship*	8	3	3	4

*Indicates Biomedical ET course

of Biomedical Engineering Technology or by undertaking a supervised industrial Internship during which the student will gain a broad experience of some area(s) of Biomedical Engineering Technology. Students will be required to write a report of their Internship experiences, and will also be provided with a grade by their industrial supervisor. The catalog description for the capstone course is as follows:

> ***Capstone (Project):*** *In this capstone course, the students implement the design and development of an approved bioengineering project. The project which will involve the design, fabrication, and formal demonstration of hardware and*

software functionality is completed during the course of the semester. A formal report and oral presentation are required

Capstone (Internship): *This course introduces the student to an on-site learning experience at an operating biomedical equipment section of a health care facility. Supervision of the intern is shared by the working environment supervisor and a faculty advisor. Internist performance is evaluated at weekly seminars. Topics include: problem solving, use of proper interpersonal skills, interpreting work authorizations, identifying logistical support requirements, servicing biomedical instruments, evaluating operating cost, and professional development.*

The Biomedical Instrumentation course could thus be structured to instruct students on the theoretical background to biomedical instruments and provide basic hands-on laboratory experiences on the principles and applications behind the theories. The catalog description for the Biomedical Instrumentation course is as follows:

Biomedical Instrumentation: *An introduction to biomedical instrumentation principles, design, measurement and analysis techniques. This course provides an overview of typical biomedical instruments used in the field. Topics include the acquisition and analysis of biomedical signals, a study of medical diagnostic instruments and equipment; monitors, intensive care units, coronary care units, operating room equipment, telemetry systems, ECG machines, life support equipment, respiratory instrumentation, brain monitors, medical ultrasound, electro-surgery units, and hemodialysis machines.*

The primary objective of this course is to teach the principles and design behind typical biomedical instruments encountered in the field. Topics covered include: Signals and noise, Sources of Bioelectric signals, Data acquisition and analysis, Medical diagnostic instruments and equipment; monitors, intensive care units (ICU) and equipment, coronary care units and equipment, ECGs, EEGs, life support equipment, respiratory instrumentation, medical ultrasound, electro-surgery units, and hemodialysis machines. In addition basic principles of electrical equipment safety and troubleshooting are covered. The lab exercises serve to re-enforce the principles behind the design and construction of modern biomedical equipment. Emphasis is place on biomedical signal acquisition, sensors and transducers, biomedical instrumentation amplifier circuits, signal analysis, and design and implementation of basic medical instruments.

IV. Development Biomedical Instrumentation Laboratory Exercises

Giving the cost restrictions on the program as far as purchasing Biomedical Instruments, the faculty has had to be resourceful in developing appropriate and suitable laboratory exercises for Biomedical Instrumentation. The course has been offered three times, initially as a Special

Topics course in Biomedical Instrumentation Technology with limited laboratory component, and the last two times as Biomedical Instrumentation, with an increasing laboratory component.

The approach used for developing laboratory exercises is the wet/dry approach that combines simulation (dry) of instrumentation circuits with a hands-on (wet) practical component. The department was already using the National Instruments LabVIEW simulation software for instruction in its circuits, electronics, and test engineering laboratory course. It was therefore determined that this would be a good tool to use for developing the biomedical instrumentation laboratory exercises. For the first set of laboratory exercises, a total of six experiments were developed that led ultimately to the design and development of a crude ECG that could acquire ECG signals that were then imported into LabVIEW and could be further analyzed using virtual instruments (Vis) that are developed progressively. The experiments were adopted from a set of NI measurement and Automation exercises developed by Dr. Wei Lin of Stony Brook University[7]. In addition to the NI LabVIEW software, the NI PCI-6024 Data Acquisition Card and the NI SC-2075 Signal Conditioning Accessory. The list of experiments that were developed initially is shown in Table 2.

Table 2. Initial Laboratory Exercises Developed.

LAB #	TITLE
1	Data Acquisition with NIDAQmx and LabVIEW
2	Signal Generation with NIDAQmx and LabVIEW
3	FFT and Digital Filtering
4	Instrumentation Amplifier Design with PSPICE
5	Lab 5 - Instrumentation Amplifier in LabVIEW
6	Electrocardiograph (ECG)

Recently, the department acquired the Biomedical Engineering (BME) Laboratory Equipment from CleveLabs, Inc. The CleveLabs BME Lab integrates a wireless BioRadio® technology with interactive software to educate students on electrophysiology, bioinstrumentation, and signal processing. The software which includes material for over 20 lab sessions includes background material, setup movies, a data acquisition section, and data analysis features [8]. The software runs on a LabVIEW platform, and incorporates programmable input channels. It offers the possibility of exporting data to other software such as MS Excel, MATLAB, etc., for further analysis and processing.

The acquisition of the BME laboratory equipment has expanded the number of topics that can be covered in the Biomedical Instrumentation laboratory exercises. Recent additions have included laboratory exercises on the following topics:

- Biopotential Basics
- Blood Pressure Measurement

- Heart Rate Detection
- Pulse Oximetry
- Medical Wireless Telemetry

As faculty develop more familiarity with the BME Laboratory Equipment, it is anticipated that supplemental exercises will be added to base exercises provided with the equipment. Students will be expected to develop their own circuitry to integrate with the BME Lab equipment. This, in addition with skills developed in developing LabVIEW Vis will greatly improve the expertise of students in the progressive development of Biomedical Instruments from design through development and testing to implementation.

V. Conclusion

The development of laboratory exercises for the Biomedical Instrumentation course is ongoing. New laboratory exercises will be added to the core, as more equipment is purchased. It is the ultimate goal to have a total of 12 laboratory exercises covering the scope of topics currently covered in the course. In order to make the new exercises complementary with the capstone course requirements, it is anticipated that these new experiments will be developed with input from our Industry Advisory Board, and others employed in the Biomedical Engineering Technology field.

References

[1] Biomedical Engineering Society Web Page: http://www.bmes.org

[2] URL: http://ecet.spsu.edu/home/Programs/Programs.php

[3] Austin B. Asgill, "Curriculum Development for an EET Degree Option in Biomedical Engineering Technology," ASEE annual conference, Chicago, IL, June 2006.

[4] Austin B. Asgill, "Biomedical Engineering Technology as an Option under EET", ASEE-SE annual conference, Tuscaloosa, AL, April 2006.

[5] URL: http://ecet.spsu.edu/home/Advisory-Board/Advisory-Board.php

[6] ABET Inc. Web Page: http://www.abet.org

[7] NI measurement and Automation Experiments developed by Dr. Wei Lin, Stony Brook University URL: http://www.ni.com

[8] URL: http://www.CLEVMED.com