Section 2648

An Integrated Modular Laboratory for Analog Electronics, Applied Signal Processing, Control Systems and Electronic Communication

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Introduction:

The undergraduate EE or EET students are required to take courses in several knowledge areas, such as circuit analysis, analog and digital electronics, power electronics, control systems, communications and signal processing, etc. The current paradigm in the course instruction builds on a lecture prerequisite structure but ignores the need for a laboratory prerequisite structure and integration. The laboratory for each individual course is designed to reinforce basic concepts but typically has no larger purpose in the curriculum such as logically connecting to laboratory works completed in earlier or future courses. Since laboratory time is short and new concepts must be emphasized, instructors are forced to use oversimplified set-ups for experiments. As a result, students complete laboratory exercises in these courses without realizing that they are all contributing to the development of truly integrated systems used in the modern industrial environment. This type of "isolated learning" is no longer acceptable as nowadays the industry demands engineers not only with a broad set of technical skills, but also a comprehension of the diverse practical applications of engineering concepts. Engineering and Engineering Technology education must provide integrated experience at the undergraduate level to fulfill the expectations of the industry[1-3].

This paper describes an on-going project to develop a multipurpose laboratory that can be used for multiple Electrical/Electronic Engineering Technology (EET) courses in the Division of Engineering Technology (DET) at Wayne State University (WSU). The development aims to provide an integrative experience at the undergraduate level to help students better comprehend the conceptual relationship among various engineering subjects and the applications of these engineering concepts in practical integrated systems used in industry. Specifically, we have planned to develop five laboratory modules that can be concurrently used for four upper division EET courses: Analog Electronics (EET3180), Applied Signal Processing (EET3300), Control Systems (EET4200) and Electronic Communication (EET4400). Each laboratory module will be comprised of hands-on experiments and computer simulations based upon a practical system, such as PID motor control system or audio signal modulation system. The students will use the same laboratory modules, but study different facets of the systems in different courses.

The Multipurpose Laboratory:

This idea of the multipurpose laboratory is motivated by the successful examples of the multipurpose/multidisciplinary laboratories developed in other universities[4-9]. A number of these works were supported by the National Science Foundation DUE CCLI Grants: The School of Engineering and Technology at Lake Superior State University has developed an Integrated System Engineering Laboratory that houses vertically integrated laboratory exercises for twelve courses from three different curricula[10, 11]. The laboratory experiments are built upon five integrated systems: inverted pendulum, mobile robot, ball and plate unit, model train unit, model plane unit and wind tunnel. This multipurpose laboratory is similar to the Interdisciplinary Intelligent Mechatronics Laboratory at the Georgia Institute of Technology[12]. The laboratory at Georgia Tech. is used by nine upper division and graduate courses. The College of Engineering and Applied Science at the University of Colorado at Boulder has developed an Integrated Teaching and Learning Laboratory shared by four departments[13]. The examples of experimental modules already piloted in courses include dynamic strain of a mountain bike, musical signal analysis, computer-controlled motor system and liquid level control system, etc. Rowan University in New Jersey has developed a Multidisciplinary Control System Laboratory based on the theme of system equivalence[14]. Another on-going NSF funded project in the ECE Department at Rowan University is to configure three junior level courses, Communications, Very Large Scale Integration (VLSI) and Digital Signal Processing, under a common framework[15]. The primary prototype that has been developed is a laboratory manual that can be used for the three courses.

We adapted these approaches and implemented them by developing five laboratory modules to be used in the four upper-division EET courses as briefly described in Table 1. Each laboratory module will be built upon a physical system that involves integration of several subsystems as summarized in Table 2.

Table 1: Brief Description of Target Courses

Course	Description
EET 3180 - Analog Electronics	Operational amplifier; adder, comparator, integrator and differentiator circuits; single and multiple input amplifier; mixer; low-pass, high-pass and band-pass filters; signal generators
EET 3300 - Applied Signal Processing	Frequency and impulse responses, Fourier Transform, spectrum analysis, Signal to Noise Ratio, A/D and D/A conversions, sampling theorem, filtering and digital signal processing
EET 4200 - Control Systems	Transfer functions, transient responses, feedback control system, stability, Root Locus method; steady-state error, Proportional, Integral and Derivative controllers, digital control systems
EET 4400 - Electronic Communications	Communication theories and systems, noise, signal-to-noise ratio, filtering of signals, impedance matching networks, amplitude modulation, angular modulation and pulse modulation, antenna impedance matching

Table 2: The Proposed Laboratory Modules

Module	Components
PID Speed and Position Control System	• DC motor • PID control circuits (proportional, integral, derivative amplifiers) • Adder circuit (multi-input amplifier) • Low-pass filter • Tachometer
Audio Signal Amplitude Modulation (AM) System	• Signal digitizer • Audio mixer • Analog multiplier (AD633) • Audio amplifier and band-pass filters • Audio output device
An On-Off Temperature Control System	• Thermocouple/ IC Temperature Sensor • Comparator circuit • Bridge and instrumentation amplifiers • Electronic switch
Voice Commanded Robotic System	• Voice recognition processor (MSM6679) • Audio signal digitizer, A/D converter • Audio amplifiers and filters • Stepper motors
Pressure Control of a Pneumatic System	• Pressure transducers • Conditioning circuits • Differential amplifiers, instrumentation amplifiers, bridge amplifiers • Low-pass and band-pass filters

The Laboratory Modules:

Each laboratory module includes a set of hands-on experiments and computer simulations that can be used in different courses. Students use the same laboratory module, but study different facets of it in different courses. Table 3 summarizes the hands-on experiments that will be conducted using each module.

These experiments are designed to emphasize, not only the practical applications of the engineering concepts, but also the integrated nature of modern systems used in industry. For example, using the PID Speed and Position Control System module, students will use the amplifier, filter, integrator and differentiator circuit designed in EET3180 (Analog Electronics) to carry out PID speed and position controls of a DC motor discussed in EET4200 (Control Systems); using the Audio Signal Amplitude Modulation (AM) System module, students will apply the multiplier circuit designed in EET3180 and the sampling theorem learned on EET3300 (Applied Signal Processing) to carry out amplitude modulation of audio signals learned in EET4400 (Electronic Communication). Students can record and analyze their own voices using MATLAB Signal Processing Toolbox and Communication Toolbox. The analysis further helps students to visualize the concept of speech pattern recognition applied in the Voice Commanded Robotic System module.

Table 3: Hands-on Experiments to be conducted using the Modules

Modules	Courses and Experiments
PID Speed and Position Control System	EET3180: • Design an adder (multiple-input amplifier) circuit • Design of integrator and differentiator circuits. • Design of low-pass filter. EET4200: • Transient responses of closed-loop control system • Proportional speed and position controls • Proportional plus integral speed control • Proportional plus integral plus derivative position control EET3300: • Signal sampling and A/D conversion • Low-pass filtering and noise reduction • Digital signal processing
An On-Off Temperature Control System	EET3180: • Design of comparator circuit. • Design of an electronic switch circuit. • Temperature-to-voltage converter circuit. EET3300: • Introduction to LabVIEW programming • Signal sampling and A/D conversion • Implementation of a digital control system EET4200: • Characteristics of closed-loop control system • Improving transient responses by PD controller
Audio Signal Amplitude Modulation (AM) System	EET3180: • Design of audio mixer and multiplier circuit. • Design of an audio amplifier. • Design of low-pass and band-pass filters. EET3300: • Spectrum analysis of audio signals • Sampling theorem and audio signal sampling • Filtering and noise reduction • Implementation of FIP and IIR filters in LabVIEW. EET4400: • Amplitude modulation, waveform measurements. • AM spectral analysis and AM detectors • SSB modulators and demodulators.
Table continues in Next Page	

Table 3: Hands-on Experiments to be conducted using the Modules (Continue)

Modules	Courses and Experiments
Voice Commanded Robotic System	EET3180: • Design of band-pass filters • Design of signal generator and oscillator circuits • Design of multiple-input amplifiers using op-amp. . EET3300: • Signal sampling and noise reduction • Implementation of digital filters using LabVIEW EET4400: • Signals in the time and frequency domain. • Spectral analysis of audio signals • Signal sampling and noise reduction
Pressure Control of a Pneumatic System	EET3180: • Design of comparator circuit using op-amps. • Design of multiple-input amplifiers using op-amp. • Signal condition circuits: differential amplifiers, instrumentation amplifiers; bridge amplifiers EET3300: • Sampling modes, real and equivalent time sampling. • Signal reconstruction, • Signal filtering EET4200: • Characteristics of a feedback control systems • Control algorithm, hysteresis

Each experiment package includes three components: theoretical background, questionnaires and laboratory menu. The theoretical section is provided for the students to study the theories and engineering concepts applied in the experiment. Questionnaires help to enhance students' comprehension of the theories studied. Students must first answer the concept questions before they can download the laboratory menu for each experiment. This approach has been applied in the engineering and engineering technology programs in other institutes, such as University of Missouri and NSF funded Greenfield/Focus: Hope.

Development of the Modules:

Among the four targeted courses, EET3180 and EET4200 have existing laboratory setups for hands-on experiments, but EET3300 and EET4400 have only computer-simulation exercises. Therefore, the development involves integrating the existing laboratory experiments for EET3180 and EET4200 into the five modules and, at the same time, developing new hands-on experiments for EET3300 and EET4400. Currently, only the first two modules are being used in the classes.

The laboratory modules are PC-based. LabVIEW data acquisition tools and virtual instrument are used for signal generation, display and processing. MATLAB Simulink and

Control, Signal Processing Toolbox and Communication Toolbox are the primary software used for computer simulation. Currently, we have six workstations set up in our Control Lab. We have planned to apply NSF funds to expand this multipurpose laboratory into 16 workstations, consisting of eight stations each in Analog Circuit Lab and Control Lab.

The development of the laboratory modules is partially due to the results of the WSU funded Undergraduate Research Projects as listed in the Acknowledgement section. We have introduced this project in the Senior Project class (ET4999) each semester and encourage senior students and MSET students to participate in the development. As mentioned above, the development of this multipurpose laboratory is an on-going project. We will continue to develop and modify the planned laboratory modules. In the future, we will extend this multipurpose laboratory for other EET courses, such as EET3010 (Instrumentation and Measurement), EET3150 (Network Analysis) and EET3150 (Electric Machines). The long-term goal is to use this prototype development to develop a multidisciplinary laboratory shared by other programs in WSU-DET. An example of such a laboratory would be one shared among MCT3410 (Kinematics and Dynamics Machines) and MCT3180 (Fluid Mechanics) in the MCT program and EET4200 (Control Systems) and EET3010 (Instrumentation and Measurement) in the EET program.

Impact and Significance

The impact of this multipurpose laboratory on engineering technology education at WSU is realized through the integration of practical systems, real-time data acquisition, virtual instrument signal processing, and computer-aided simulation and analysis components to the laboratory. In the Analog Electronics (EET3180) class, students no longer design stand-alone amplifiers or filters testing sinusoidal signals from a signal generator. Instead, they design and test the circuits on a practical system, such as PID controller or AM modulator. In the Control Systems (EET4200) class, control systems are no longer just some abstract "mathematical concepts" and a set of "block diagrams" on paper. Instead, students will actually implement the concepts and realize the block diagrams by the circuits they learned and designed in other classes. These integrated experiences enable students to better comprehend the conceptual relationship of analog electronics, control system, signal processing and electronic communication theories. Further, the laboratory setup provides students the opportunity to work with the modern data acquisition tools and computer software similar to those that exist in the industry. These results match with our goal for engineering technology education to continue equip superior hands-on experiences in the emerging engineering technologists.

Conclusion

This paper describes the on-going project for developing a multipurpose laboratory that can be concurrently used by four upper division EET courses in the WSU-DET. The objectives, target courses, laboratory modules, planned hands-on experiments and the development procedures of the project are explained. The project has been partially supported by the WSU Undergraduate Research Program. We will continue to involve students in the design, development and improvement of the laboratory modules. Although only two modules are currently used in the classes, the impact has been significant. In the future, we will expand this multipurpose laboratory for more EET courses, and eventually lead to the development of a multidisciplinary laboratory shared by other programs in the Division. We will post the laboratory modules on the WSU-DET Website to share our ideas with other institutions in the future.

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5. "*Development of Web-Based Discrete PID Controller for Servo Motor Control*",

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