AC 2010-1887: STEM-BASED PROJECTS TO INTEGRATE THE UNDERGRADUATE ELECTRICAL AND COMPUTER ENGINEERING PROGRAM WITH THE K-12 STEM CURRICULUM

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STEM-based Projects to Integrate the Undergraduate ECE Program with the K-12 STEM Curriculum

Introduction

This paper discusses how electrical and computer engineering (ECE) projects with science, technology, engineering, and mathematics (STEM) components will integrate the undergraduate degree programs in ECE with the K-12 STEM-based curriculum. The high school students in the K-12 school programs participate in an Engineering Day event. During this event, the students work on the ECE projects selected to have the necessary STEM components that enable the student to observe and relate scientific theory to engineering design principles and practices. The Engineering Day at Gannon University will form the direct outreach component of University partnership program with K-12 schools to (a) raise the level of awareness among K-12 students of the promising careers in the engineering disciplines upon graduation with baccalaureate and/or advanced degrees (b) establish and sustain the dialog between the K-12 schools and Gannon University to encourage the K-12 school students to pursue and excel in subjects with STEM components (c) promote the interaction between the engineering faculty at Gannon University and the K-12 school students through activities which deliver critical STEM components.

Recently, the ECE department at Gannon University, Erie, PA organized two Engineering Day events in its system integration laboratory. The laboratory accommodated nearly 105 high school students in six hour-long sessions with up to 20 students in each session. During each session, the students worked on a traffic signal control circuit. The project activities comprised the following steps (1) complete the design of the circuit (2) test the operation of the circuit. Two ECE faculty members and sixteen ECE students currently enrolled in the undergraduate ECE program coordinated the project activities. The students followed step-wise instructions to assemble and test the circuit. Each student completed a survey at the end of the session. The survey consisted of two sections. The quantitative section asked the student to grade (on a scale from 0 to 5) the effectiveness of the project activity to stimulate their interest in ECE system design. The qualitative section asked the student to comment on the overall experience. Through the STEM-based ECE project activities during the Engineering Day events in the future, the ECE department at Gannon University expects to achieve the following (a) encourage K-12 students to consider careers in ECE (b) strengthen or increase the undergraduate enrollment in ECE (c) integrate the undergraduate ECE program with the K-12 STEM curriculum.

The University partnership with K-12 STEM schools to integrate K-12 STEM learning with the engineering disciplines at institutes of higher education comprises (a) *direct* *outreach*, delivered through Engineering Day events, which offer K-12 students the opportunity to participate in hands-on STEM-based engineering project activities at the institute of higher education (b) *extended outreach*, delivered through cyber-learning networks, which enable K-12 students in schools within and across school districts to interact and share their STEM learning experiences.

Through participation in *direct* and *extended outreach*, the K-12 students will improve their STEM preparation for admission to colleges and universities, and be motivated and encouraged to pursue degree programs in engineering and/or engineering technology. In addition, these networks create the environment for K-12 students of schools and school districts to participate in engineering project activities through a *virtual* STEM education experience. The *extended* outreach will enable K-12 students and teachers to establish dialog across schools and school districts. The K-12 teachers can adopt new and/or revised instructional practices to raise the STEM learning standards of the students.

This paper consists of five sections. Section 2 provides a description of the experimental set-up, the laboratory activities, and the execution of the STEM-based ECE project. Section 3 summarizes the assessment of learning outcomes based on the on-line survey completed by the students. Section 4 outlines the conclusions and future considerations. Section 5 lists the references.

Section 2: STEM-based ECE Project

The broad objectives of the STEM-based ECE project chosen for the Engineering Day event were to (a) complete the design, and (b) test the operation of the circuit to control the operation of a three-light traffic signal.

Project Description

The project comprises the timer and the counter circuit to operate the red, yellow, and green light-emitting diodes (LEDs) in the sequence as shown in Figure 1. The timer circuit provides clock pulses to the counter. The counter produces ten outputs. Each output becomes high in turn as the clock pulses are received. The red LED is connected to the divide-by-ten output which is high for the first five counts. The appropriate outputs are combined through diodes to supply the yellow and green LEDs. The timer and counter circuits are setup on a solder-free protoboard with the required components.

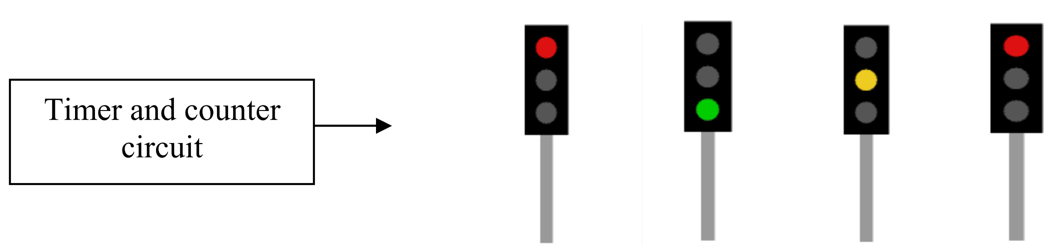


Figure 1: Three-light traffic signal sequence

Project setup

Figure 2 shows the circuit diagram of the components used to control the three-light LED traffic signal. The 555 timer is used to provide the clock pulses for the 4017 decade (1-of-10) counter. The outputs of the decade counter are connected to the red, yellow, and green LEDs through diodes and resistors.

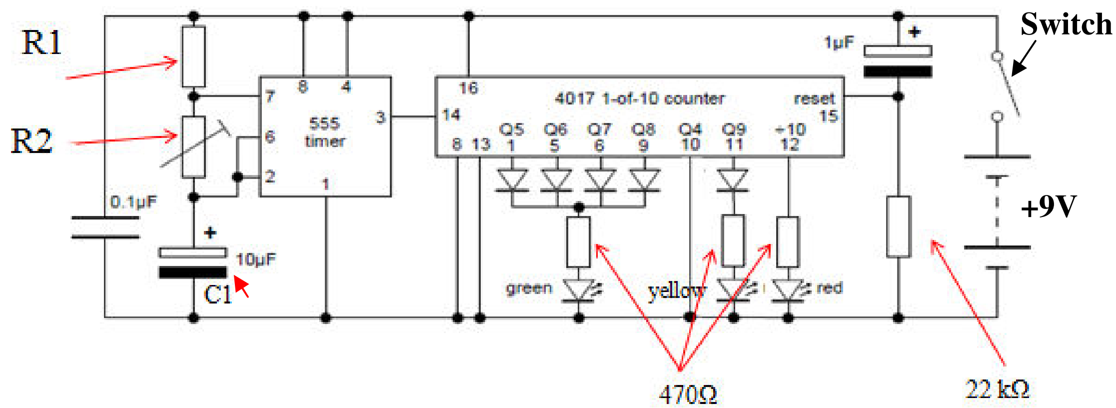


Figure 2: Circuit diagram

The circuit components and the equipment required are described in a project write-up. This write-up is provided to each student and served as the reference for circuit analysis and validation. In addition, the students have access to the slide presentation which overviews the project and the video which illustrates the steps required to complete the assembly of the circuit. Figure 3 shows the view of the protoboard after the assembly is complete.

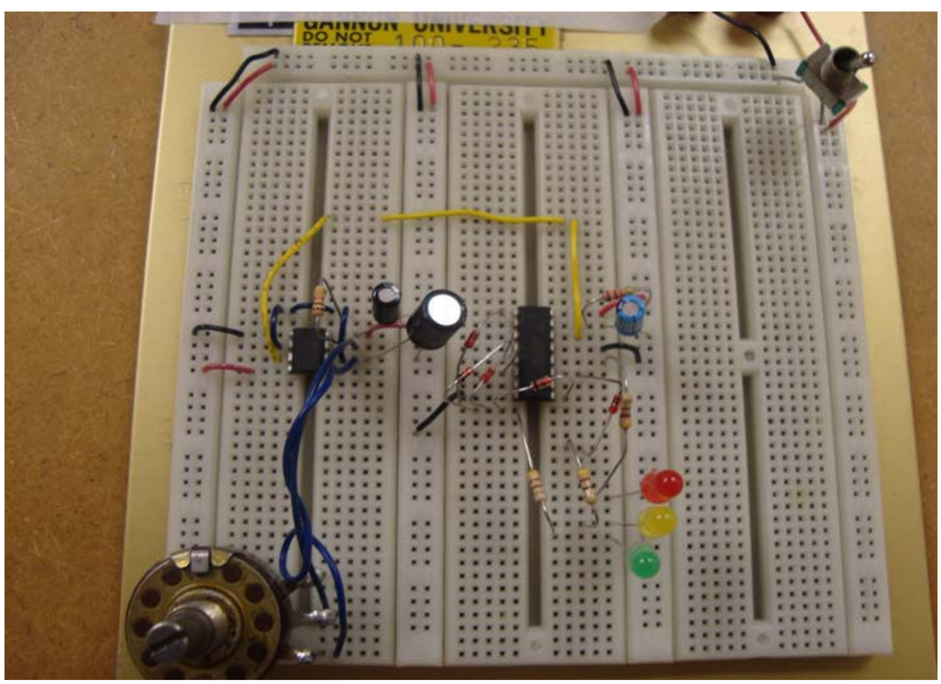


Figure 3: Completed design before test

Project activities

The components R1, R2, and C1, as identified in Figure 2, are assigned the following values. (1) R1 = 1kΩ (fixed) (2) R2 = 50 kΩ (variable, potentiometer) (3) C1 = 10μF.

Although the circuit is mostly pre-assembled, the students must refer to the slide presentation and project write-up to perform the following activities.

1. *Place the 555 timer in the circuit.*
   Make sure the timer chip is oriented with the notch facing upward as shown in Figure 3.

2. *Connect the switch.*
   The switch is placed between the 9V DC power source and the positive terminal of the 1μF capacitor as shown in Figure 2.

3. *Connect pin 3 of the 555 timer to pin 14 of the 4017 counter.*
   The yellow wire is used to set-up the connection.

4. *Set the DC power supply to generate +9V.*
   Use the multimeter (yellow hand-held unit) and cables to measure and set the DC voltage to +9V.

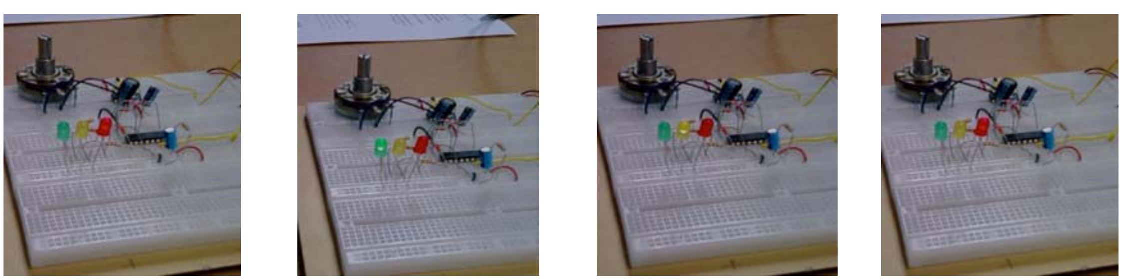
5. *Connect the DC power supply to the protoboard.*
   Use the red cable to connect the positive terminal of the DC power supply to the red post on the protoboard. Use the black cable to connect the negative terminal of the power supply to the black post on the protoboard. Also, connect the negative terminal on the DC power supply to the ground terminal on the power source (labeled ⏚).

6. *Turn on the DC power supply and set the switch to apply the DC voltage to the circuit.*

7. *Adjust the potentiometer and observe the LEDs.*

Project execution and outcomes

The students observed the operation of the completed circuit and some of them were able to capture snapshots of the working circuit using the camera in their cell phone. Figure 4 illustrates the outcomes captured.



(a) (b) (c) (d)

Figure 4: LED sequence of working circuit (a) red (b) green (c) yellow (d) red

Section 3: Survey and Learning Outcomes Assessment

Each student completed a survey at the end of the project as part of the summative evaluation[1-5]. The survey consisted of two sections (a) quantitative (b) qualitative.

Quantitative section

The quantitative section required graded responses (on a scale from 0 to 5) to the following questions.

1. Did the project on *Traffic signal control* stimulate your interest in the following categories?
   (a) Design and validation of engineering systems
   (b) Application of STEM concepts to solve real-world problems
   (c) Understand the different components used in the project activity
   (d) Consider electrical engineering as a career option

2. Rate your contribution to the project activity in the following categories.
   (a) Assembly and set-up of the project
   (b) Design and implementation of the project
   (c) Test and validation of the project

Qualitative section

The qualitative section asked each student to comment on the project, and propose approaches to streamline and improve the presentation of the project as identified by the following questions.

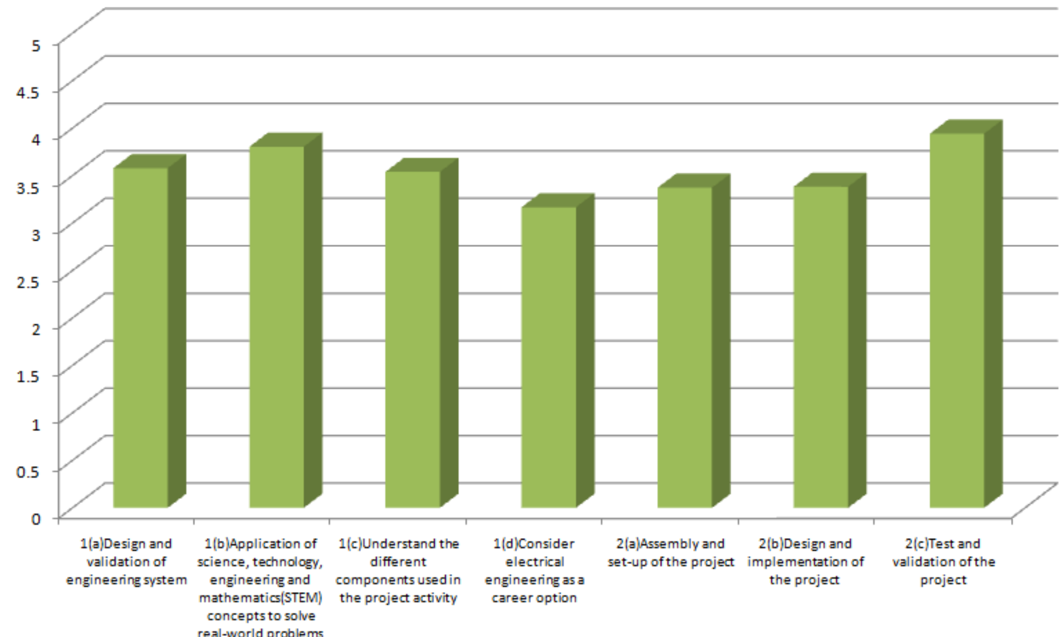
- Are there any components of the project activity which must receive more emphasis?
- Are there any components of the project activity which must be excluded?
- Propose ways to improve the project activity.

Survey results and analysis

The survey was completed by 102 students across the two Engineering day project activities. The results for the quantitative section are shown in Figure 5. The average score in the following two categories ranked the highest (3.94) and second highest (3.80) on a scale of 5.

1(b) Application of STEM concepts to solve real-world problems
2(c) Test and validation of the project

In the qualitative section, the students felt that additional time (more than the 50 minutes allotted) and more project activities (additional steps in the assembly) would enhance the experience. In retrospect, the choice of the traffic signal control using an electrical circuit does contain significant STEM components in diodes (science), LEDs (technology), engineering (integrated circuits or ICs), and boolean algebra/combinatorial logic (mathematics). The project activities focused more on the aspects of system integration and less on the specific operation of each component. The activities were intended to engage the K-12 students at the system level so that they recognized how real-world problems have engineering solutions that can be designed and tested in the laboratory using relatively simple and inexpensive components.



3.58	3.80	3.54	3.17	3.37	3.38	3.94

Figure 5: Average scores on quantitative survey questions

Section 4: Conclusions and Future Considerations

The STEM-based ECE project activities to engage K-12 students on Engineering Day at Gannon University make a conscious and concerted effort to introduce and reinforce STEM concepts through engineering problem solving with hands-on STEM learning experiences. The K-12 students learn to work on teams, acquire the skills to communicate with team members, lead teams, and work across teams. The students have the opportunity to explore the different career paths and options for higher education in engineering.

The Engineering Day is planned to be a regular event for the different engineering disciplines at Gannon University to showcase their laboratory facilities and pre-eminent faculty to students at all levels of the K-12 curriculum. In addition, discipline-specific interaction between the K-12 STEM students and the engineering faculty are also planned for each academic year. Through these events, the partnership between the ABET-accredited engineering programs at Gannon University and the K-12 schools and school districts is created and strengthened. The partnership ensures that institutes of higher education and K-12 schools work together to assemble the engineering workforce of the future. The K-12 students benefit from the early and frequent engagement in engineering design and practice as part of their STEM education.

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