Ultrasonic Alarm Glove

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Abstract

This paper presents the design of an Ultrasonic Alarm Glove for visually impaired individuals that a group of Engineering Technology students at Sam Houston State University (SHSU) implemented as part of their Digital Electronics course. The prototype has worked successfully during demonstrations for outreach and recruiting events that pre-college, high school and transfer students attended. The components used are two ultrasonic sensors, a haptic motor, a tilt switch, and an ARDUINO microcontroller. The sensors capture and determine the physical distance of an object within a range. The sensors are programmed to emit a signal, know when to expect a return signal and then calculate the distance of an object based on the elapsed time between the signals. Digital-to-analog conversion takes place during this process. The wrist of the glove will vibrate to alert the user of an object that is within a certain proximity through the use of the haptic motor. This process needs the reverse operation of analog-to-digital conversion. The vibration pulses vary as signaled by the duration that is detected by the two ultrasonic sensors on the front of the glove and the calculated distance in the program. With the use of a display or serial monitor in Arduino IDE itself, the calculated distances and corresponding vibration lengths sent to the haptic motor can be observed. The current prototype is activated when the hand is extended forward and deactivated by use of a tilt switch when the hands are down. At its current state, this project has earned strong attraction from attendees in various recruiting events regardless of age, sector, or orientation. The success of the project and real time presentation has encouraged students to participate in more active learning and innovative challenging projects integrated in many other courses in Engineering Technology department at SHSU by offering new and challenging concepts to the curriculum.

Index Terms-- Analog-Digital Integrated Circuits, Analog to Digital, Digital to Analog, Digital Circuits, and Ultrasonic Variables Measurement

1. INTRODUCTION

The first human interaction of an ultrasonic wave was in 1794 by Lazzaro Spallanzani when he was demonstrating how bats were able to fly safely and effectively in the dark. Through further study and experiments, scientists were able to develop a method to use the waves for detection. After World War I began, new inventions and weapons were created that included the use of ultrasonic waves. Paul Langevin and Chilowsky invented the first technological application of ultrasound occurred in 1917. The two scientist used the piezoelectric effect (discovered in 1880) to develop an ultrasonic sensor. During World War I, he Allied Powers could detect the presence of Central Powers; Langevin and Chilowsky's invention easily changed the tide of the naval warfront.

After the war ended, the study of using ultrasonic waves for warfare switched to medicinal and research purposes. The use of ultrasonic equipment can be used in a wearable alert system for the visually impaired. In a simple implementation of this idea, a glove can be outfitted with several sensors that can capture and determine the physical distance of an object within a field of range. For these sensors to be able to work in such a fashion, they would need to be programmed to emit a signal, know when to expect a return signal, and then calculate the distance of an object based on the elapsed time between the emitted signal and the return signal. To alert the user of an object that is within a certain proximity to the glove, there will need to be a type of alert from the glove; in this case, the alert would be in the form of a vibration coming from the wrist part of the glove. Because the glove may not be in use at all times, there should be an on/ off switch so that when a user's hands are at his or her sides, the glove will be inactive.

2. BRIEF DESCRIPTION OF THE IMPLEMENTED PROTOTYPE

2.1 COMPONENTS USED FOR THE PROJECT

a. HC-SR04 ULTRASONIC SENSOR

The HC-SR04 ultrasonic sensor that our group is using has a range of 2 centimeters to 4 meters with an accuracy of 2 millimeters. The wiring for the sensor includes four pins: 5 volt, Trigger, Echo, and Ground, as shown in Figure 1. It has a working frequency of 40 hertz and a working current of 15 mA. The trigger input signal has a 10 µS TTL (transistor-transistor logic) pulse. When the trigger receives this supplied pulse, the

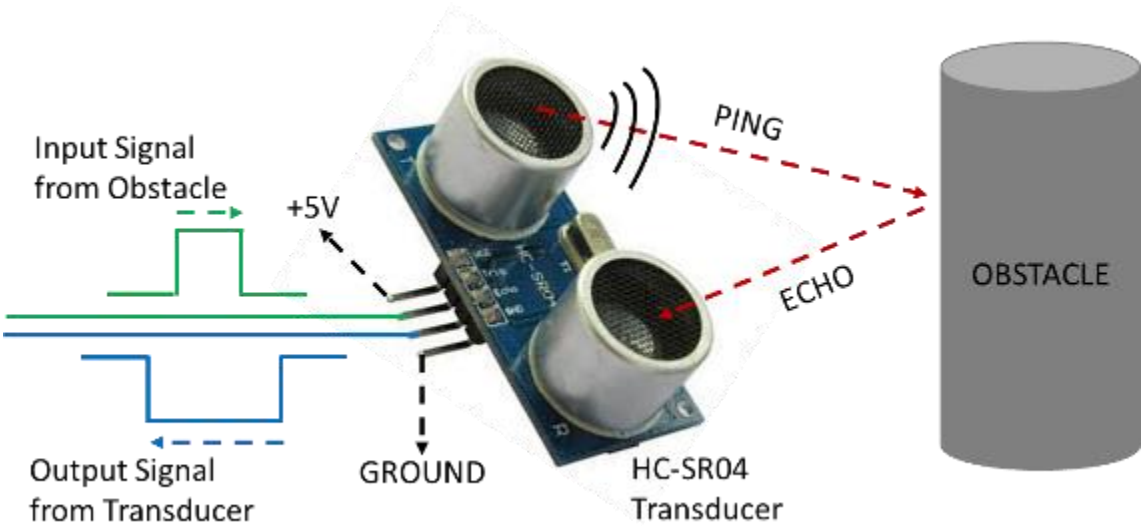

Figure 1. Ultrasonic Sensor object detection

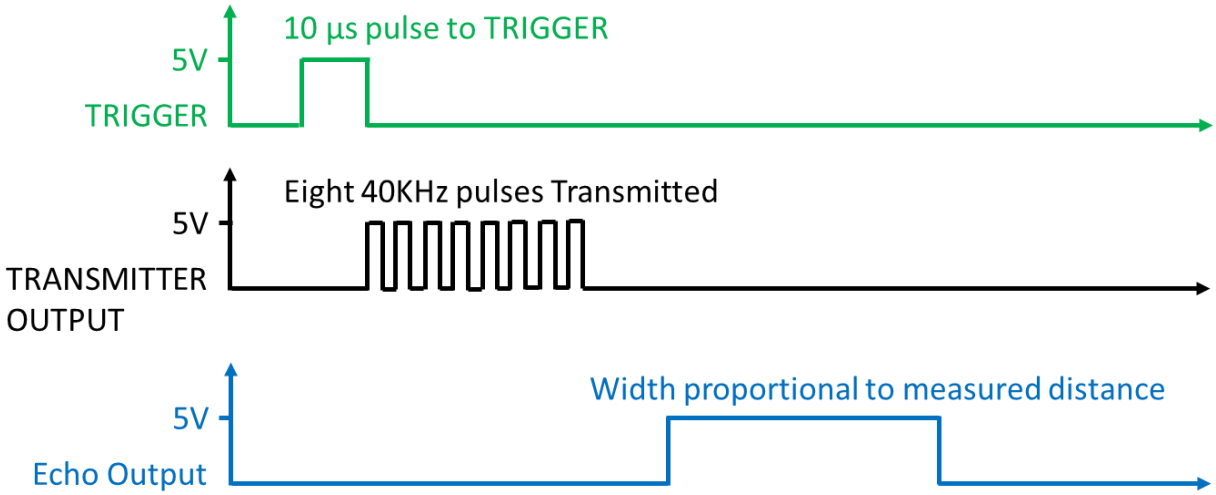

Figure 2. HC-SR04 Timing Diagram

transmitter sends out an eight-cycle burst of ultrasound at 40 kilohertz. The operation is summarized in Figure 2. A timer starts when this occurs and continues as the waves encounter an object. The waves then bounce back and are received back at the sensor. This stops the timer and the distance of the object that it detected can then be calculated with the TRD (time/rate/distance) measurement formula. The velocity of the ultrasonic burst is 340 meters per second. The time is divided by 2 because the time interval recorded by the sensor

includes travel time to as well as from the object. The formula is Distance = (time/2) * (340 meters per second). Two ultrasonic sensors were used to be able to detect a broader range of possible objects.

$$D = T/2 * V \qquad (1)$$

where D = distance of object, T = time elapsed and V = velocity of ultrasonic burst.

b. TILT SWITCH

We implemented a tilt switch to our circuit so that when the glove is in the downward position (the user's hand is down), the ultrasonic sensors will be deactivated. This will prevent the glove from detecting the ground when the user is not using the glove to locate objects in front of the individual. The tilt switch is named accordingly due to the metallic ball on the inside of its container that acts as a switch to either complete the circuit (ON position) or not (OFF position), similar to a push button. These switches were once commonly made with mercury that was used to complete the circuit if the switch was at a certain angle. This method worked well because mercury does not bounce, and therefore cause unwanted circuitry noise of vibrations. However, since this substance is known to be toxic, it is no longer commonly used.

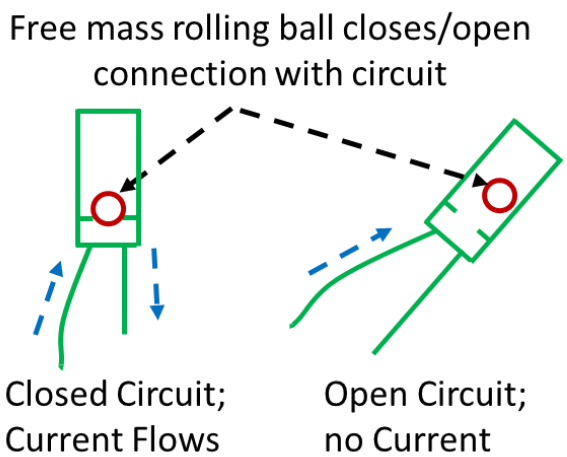

Figure 3. Tilt switch working principle

Figure 4. Haptic Motor

c. HAPTIC MOTOR

Ways of alerting users of an occurrence on a device have changed through the years. While vibration motors have been around since the 1960s, they became an necessity in the 1990s for cell phones and pagers. It became apparent that vibration motors were beneficial to consumers for alerts on their personal devices. They are used in a variety of products and are also used for haptic feedback that people are familiar with on their smartphones. The haptic motor used in this project is a DC 3 Volts/0.1 Amps and its dimensions are 10 millimeters x 2.7 millimeters. Typically, there are two types of vibration motors that are commonly used, an eccentric rotating mass vibration motor (ERM) and a linear resonant actuator (LRA). The ERM "uses a small unbalanced mass on a DC motor; when it rotates it creates a force that translates to vibrations." The LRA "contains a small internal mass attached to a spring, which creates a force when drive." For this project, ERM coin motors were used. The original plan was to use one haptic motor in the glove as the alarm, however, we decided to use two—one placed on either side of the wrist so that one would vibrate in accordance with which sensor was detecting the object. Both haptic motors will go high if the ultrasonic sensors are reading a similar distance away from an object.

d. LCD SCREEN

We included a liquid crystal display screen for simplicity purposes so that we will be able to see the distances being calculated by the ultrasonic sensors on the glove without needing a visual readout from a computer to use the serial monitor. The LCD used is a sixteen by two matrix grid. This was used with the I2C bus in order to use fewer pins on the Arduino board. The I2C bus has two signals—SCL (the clock signal) and SD (the data signal). A different library than the regular LCD library had to be imported for this particular screen using the I2C module. We researched the necessary commands to use for the coding. Figure 5 shows the implemented prototype.

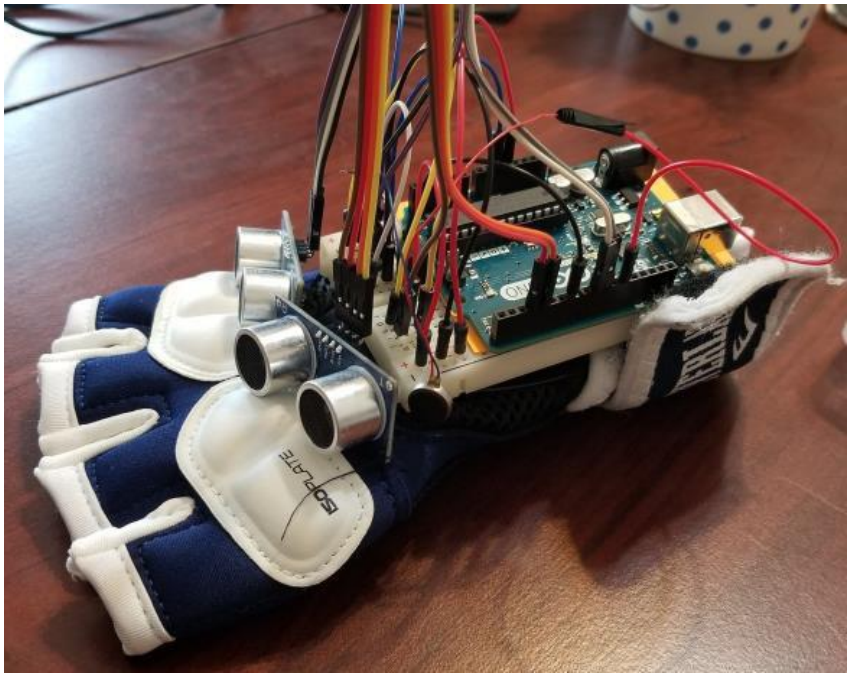

Figure 5: Ultrasonic Alarm Glove Prototype

2.2 PROCESS AND TROUBLESHOOTING

Developing this ultrasonic sensor glove proved to have many challenges. When doing any sort design with simultaneous coding, it is expected to run into unforeseen hurdles that cause everyone involved to step back and reevaluate the end goal and the processes necessary to get there. Getting the first sensor up and running was simple enough. We just wanted to see how the ultrasonic sensor operated, since we had not done any previous projects with one. We plugged one into a breadboard and then into the Arduino so that we could visually determine what it was sensing and reading. We then printed out the distances in centimeters to the serial monitor. This had to be derived from a calculation which required the knowledge of the velocity of the ultrasonic bursts. We researched that value and included it in the calculation to be printed out.

Our next task was applying a haptic motor to be used as the alarm to signal when the sensor detected an object within certain distances. We wrote basic conditions into the code to get an idea of whether it was working with the sensor. One of these conditions was that the haptic motor would go high if the distance recorded by the motor is within 0 centimeters to 30 centimeters, and if the distance was greater than 30 centimeters it would go low. The haptic motor was very strong when it vibrated, so we looked into some alternative motors and ways to make the vibration less intense. We decided that we would place the motor on the inside of the material in the glove so that it was not such an intense vibration, but was still effective as an alarm.

The more time consuming challenges started when we implemented a second ultrasonic sensor. Our plan was to have two sensors on top of the glove so that the user got a wider range of detection area. However, when the second sensor was added, including what we assumed to be the necessary coding, it became apparent that there was a conflict when triggering the haptic motor. First, we attempted to add a second haptic motor. The second one would react to the second sensor, and the first motor would react to the first sensor. Our initial thought was that one motor would be on the left side of the wrist and the other on the right side of the wrist. This way the user would have a way of determining in which direction the object was being detected. This worked to a certain extent. Each sensor was triggering its respective motor, but with both of them vibrating at the same time, we felt that it was confusing for the user of the glove. To simplify it, we removed one motor and decided to have only one which would be triggered by both sensors. When we tried this, the haptic motor no longer followed our conditions of vibrating quicker as the object was detected closer within a specified range. We realized that we needed to throw a flag in the code for each sensor, indicating that if one was detecting an object, it bypasses the other sensor to avoid any conflict.

Once the two sensors were correctly working with each other to signal the haptic motor, we were ready to implement the tilt switch. In order to smoothly add the tilt switch, we wanted to go assemble what we had developed thus far into the glove itself. We discussed several options for adding the sensors to the glove, which included putting them on a small, thin, flat board and then feeding the wires through the glove or attaching the sensors to the glove directly. After some back and forth pondering, we decided to use the holes on the chip of the sensor; we then directly sewed them onto the glove. Due to the design of the glove and the tightness of the sewn thread, the sensors actually stood up on their own without any extra stabilization necessary. All that we wanted to accomplish with the tilt switch was to deactivate the sensors when the glove was in the downward position, indicating that it was not currently in use, and it was not necessary to alert the user of anything.

We installed the tilt switch and amended the code so that it would only run the sensor detection portion when the tilt switch was in the upwards position. However, when we ran the program, the haptic motor just stayed on and never disabled no matter what position the tilt switch was in. This took some research into the code, and we discovered that the tilt switch was initially set on high. Changing that still did not fix the problem; we discovered that it was still not pulsing the haptic motor as it had previously. We checked that all of the sensors were working correctly by printing out the distances on the serial monitor. This showed us the error—both of our sensors were displaying a constant of 0 continuously for the distance. We put them on separate breadboards and tested them with a basic code to see if we had somehow destroyed them. During the frantic checks of each motor, we noticed that the VCC line had been replaced in the 3.3 volts instead of 5 volts. Once that was fixed, we were back on track and the tilt switch worked for disabling the sensors when the glove was in the downward position.

2.3 ARDUINO PROGRAM

For the coding in this project, we used Arduino IDE. We initialized the trigger and echo pins for both ultrasonic sensors, a pin for the tilt switch, and a pin number for the haptic motor. Two Boolean flags were declared as well, so that they could be used to disable or enable the other sensor. This was incorporated into the code so that the sensors were limited when conflicting with each other as to which one was triggering the vibration of the haptic motor. Next, variables for the duration of the pulse from trigger to echo pins on each ultrasonic sensor were declared, as well as variables for the upcoming distance calculation in the loop portion of the program.

In the setup section of the code, the tilt switch echo pins of both sensors were set up as inputs using the digitalWrite() function. The trigger pins and the haptic motor pin were set up as our outputs. The haptic motor was also initialized as low so that the vibration did not begin before the sensors detected anything in the loop.

We also began a serial communication in the code so that we could see what the distance was on the serial monitor in real time. Inside of the loop, we included a while loop that runs the sensor detection and calculation portion of the program only while the tilt switch is in the correct orientation. This allowed us to have the tilt switch act as a temporary on and off switch for when the glove might be pointed in the direction of the ground and not needed by the user. Next, the trigger pins of the ultrasonic sensors are set to low with a delay of two microseconds until they are then set on high. At that point, they have a delay of ten microseconds before returning back to low. Using the pulseIn() function, the echo pins go high, receiving the duration of the pulse from the trigger pin back to the echo pin. This allows us to know how long it took for the pulse to reach an object before returning back so that we could later calculate that into a functional distance. The distance was calculated by multiplying the duration of the pulse with the velocity of the ultrasonic pulses and then dividing by two so that we could read just the distance of the object and not the total distance for the pulse to the object and back.

The distance calculations were used to signal the haptic motor when to vibrate. We used if/else statements for both sensors to accomplish this. Within a specified long range of object detection, the vibration goes high, then there is a delay of one hundred millisecond before it returns to low, with another delay of one hundred milliseconds. If the object is detected in a closer range, the delay for logic high of the haptic motor is longer. These steps repeat so that the output of the haptic motor is continuously updated which provides for an effective alarm for the user of the glove. This allows the user to have an accurate reference to objects that are detected close or further away in front of them.

3. CURRICULUM CHANGES AND FEEDBACK FROM STUDENTS

3.1 GOAL AND LEARNING OBJECTIVES REVISED

Based on previous years of student feedback and continuous meeting between assigned faculties (hired in Spring 2017 and Fall 2017), the GOAL of the Electronics and Computer Engineering technology (ECET) program is revised as below:

a. Students will develop knowledge and understanding of key concepts and skills relevant to Electronics and Computer ET.
b. Students will develop knowledge and understanding of key concepts and skills relevant to Design, system and application engineering.

Learning objectives are also updated:

a. The students will be able to conduct standard tests and measurements; analyze and interpret experiments; apply experimental results to improve processes; and design the system.
b. The students will be able to function effectively as a member or leader on a technical team.
c. The students will be able to apply written, oral, and graphical communication; also will be able to identify and use appropriate technical/ non-technical literature.

3.2 GRADING CRITERIA for ETEE 4373

To accommodate the hands-on project section in which students apply their knowledge and build something, the grading criteria for Digital Electronics course is modified as well. Previously, students were evaluated based on single mid-term and final exams alongside 5-6 labs. However, the students enrolled in Spring 2018 were evaluated based on the following rubric:

Mid-term Exam (Average of Two)	20%
Final Exam	20%
Laboratory Experiments	30%

Homework Assignments (Best Two of Minimum Three)	10%
Attendance, Observed performance, Attitude	5%
Project Presentation	15%
Total	100%

Percentage range	Grade
90 – 100	A
80 – 89	B
70 – 79	C
60– 69	D
0-59	F

Two mid-term exams are introduced to cover more topics, so students have a better and clearer idea about different projects to work on. The major change is to introduce a Final project to be demonstrated on relevant topics. The main goal is to generate ideas for a capstone project that is required of students and is now integrated in the new curriculum (ETEE 4099). Each student submits HWs (10%) based on the lectures given on Number systems, Gates, Boolean Algebra, De-Morgan's, Logic Minimization, Latches, Counters, Shift Registers, different applications like MUX/DEMUX, Encoder/Decoder, Half/Full Adder etc. The students sit for two mid-term exams (each 20%) and a final exam (20%). The first mid-term exam is on Number Systems and basics of Digital Electronics; the second mid-term exam is on Logic minimization, De-Morgan's and gates. The final exam is on Latches, Counters, Shift Registers, different applications like MUX/DEMUX, Encoder/Decoder, Half/Full Adder, etc. Each student is assigned to a group of three who must work together on the final project (15%). The students also must attend extensive LABS through LabVolt's mindsight application (30%, a total of 11 labs, compared to 5-6 in previous years). Students also are required to troubleshoot inserted problems by studying, measuring, and analyzing the response of the fault inserted. For example, LAB#5 is on J-K flip-flops and LAB#11 is on Synchronous Counter.

Other examples of the projects introduced and demonstrated by the students are listed below:

a. Digital Fan Control
b. Adaptive Car Lighting
c. Full Adder using Transistors
d. Digitizing Signals from Electronic Stringed Equipment
e. Auto Routing Car
f. Home Alarm System
g. Imitating FANUC Robotic Arm

This course is a study of the principles and applications of digital logic circuits including number systems; logic gates; counters; shift registers; sequential and combinational logic circuits; and laboratory experiences that consist of experimental problems. The Engineering Technology programs generally assess the criterion description—at least 80% of the students will perform at an acceptable level of a score of four or higher. As suggested by the course instructor and agreed by other ETEC faculty, the majority of students (80%) should be able to get a grade of B (80%) or higher. The final project has to be prototyped and demonstrated, because this will demonstrate the applications of the course materials. The students should also be able to identify and use appropriate technical/ non-technical literature.

3.3 PROPOSED CURRICULUM CHANGES

The following table summarizes necessary program improvement on the curriculum that will prepare the ECET program for a future ABET-ETAC accreditation application. These improvements are necessary because students will be required to complete a hands-on project to be demonstrated in each course:

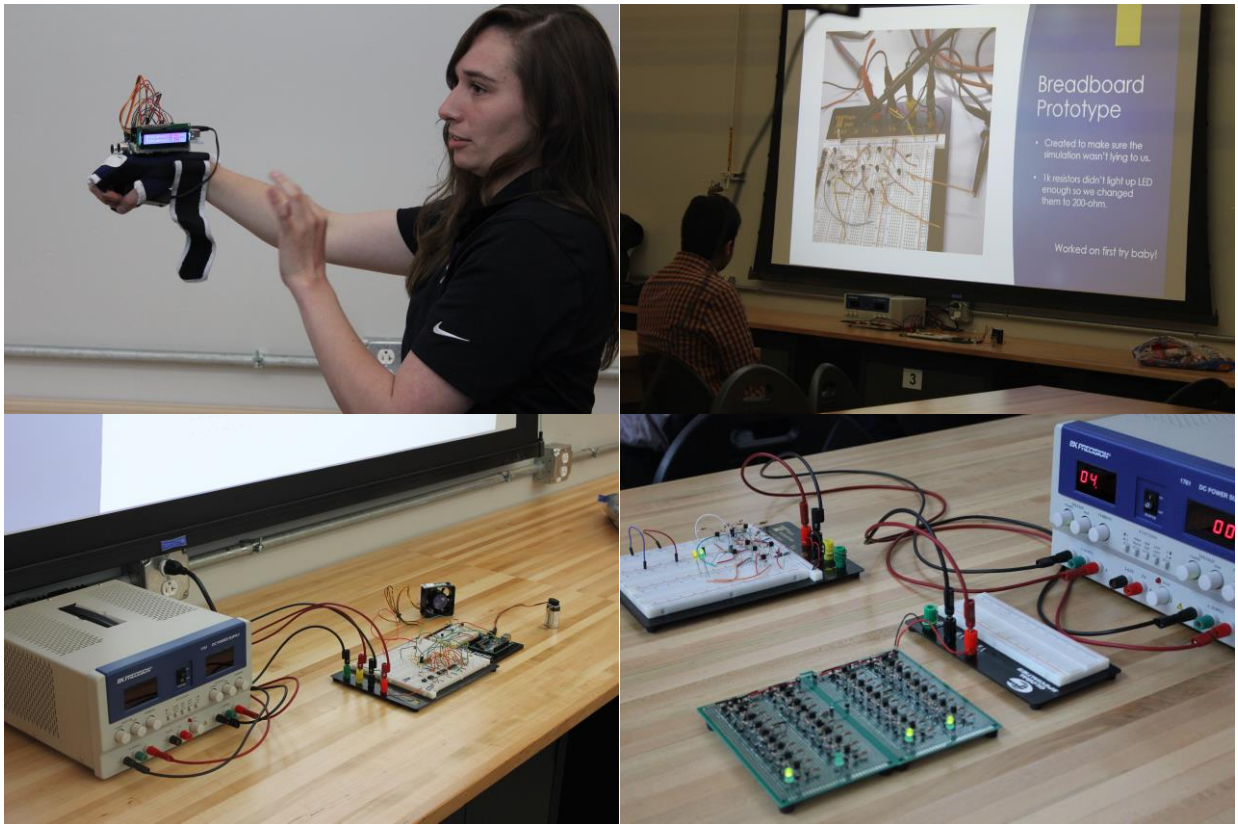

Figure 6: Glimpse of few project prototypes during final demonstration

Course Number	**Current Course Name**	**Proposed Name**	**Course Description**
ETEE 1340	Electronics Technology I	Intro to Circuits	Updated and includes final project requirement.
ETEE 2320	Electronics Technology II	Circuits & Systems	Updated and includes final project requirement.
ETEE 3350	Solid State Electronics	Analog Electronics	Updated and includes final project requirement.
ETEE 3373	Industrial Electronics	Automation & Control Systems	Updated and includes final project requirement.
ETEE 4351	Automation & Control Systems	Programmable Logic Controllers (PLCs)	Updated and includes final project requirement.
ETEE 3360	N/A	Electrical Power & Machinery	New Course to be offered beginning Summer 2019 semester
ETEE 4099	Engineering Innovation	Engineering Innovation “Senior Design/Capstone”	Updated and will be offered beginning Fall 2019 semester

3.4 FINDINGS DESCRIPTION

There were 21 students enrolled for Spring 2018. Following is a finding summary in relation to the learning objectives:

Summary of Students' Course Achievements of Program Outcomes Form	
Course Name: ETEE 4373 Digital Electronics, Spring 2018	
Directly supported Goals and learning objectives:	1. The students will be able to conduct standard tests and measurements; analyze and interpret experiments; apply experimental results to improve processes; and design the system: • Different number systems and conversion between them. • Logic Gates, Boolean algebra, sequential logic, minimization. • Timing Diagram, multi-level gating. • MUX/DEMUX, Half/Full Adder, Comparator, Encoder/Decoder. • Shift registers: Serial In–Serial Out, Serial In–Parallel Out, Parallel In–Serial Out, Parallel In–Parallel Out. • Counters, Ring counter, Johnson Counter, Asynchronous and Synchronous counters. • Learning the theory in lectures and then build, troubleshoot, and test above concepts through LabVolt's Mindsight and DiTac boards.
	2. The students will be able to function effectively as a member or leader on a technical team: • Students teamed up as 2 or 3 members in a group and there were a total of 8 groups with 8 different projects. • Some examples were: Implementing a full adder with transistors, ultrasonic hand gloves for blind people etc.
	3. The students will be able to apply written, oral, and graphical communication; also will be able to identify and use appropriate technical/ non-technical literature: • All students needed to submit a 4-page report on their project in IEEE conference format. • Each group were required to present their project implementation, problems faced, how they resolved and finally a demonstration of their prototype in front of their peers for 6-7 minutes. • For each lab (11 of them), every student uploaded a LAB report to summarize what they had learned on a corresponding day and how theory and experiments complemented each other.

Total number of students assessed (N_s): 21 during Spring 2018		
Outcome 1	Average (M_s): Mid-Term 1: 65.3% Mid-Term 2: 63.15% Final Exam: 61.6%	Standard deviation (σ_s): Mid-Term 1: 4.24 Mid-Term 2: 3.76 Final Exam: 3.48
Outcome 2	Average (M_s): Final Project: 90.13%	Standard deviation (σ_s): 1.12
Outcome 3	Average (M_s): LABS: 97.53%	Standard deviation (σ_s): 0.67
Total Grading	Average (M_s): Final Grade: 87.52%	Standard deviation (σ_s): 7.6

The whole course grade breakdown (out of 100)	
Above average/ Excellent (90%+)	7
Met Expectation (80%+)	12

Needs Work/ Developing (70%+)	2
Below Par (60%+)	0
Total	21

As a whole class, almost 90.5% of the enrolled students achieved 80% or higher, which met the primary expectation. Only 2 out of the 21 students got less than 80%. We feel improvement in the scope of the course is needed on the theory side, for students failed to perform as expected (60-65% average) throughout the three exams taken.

3.5 STUDENTS FEEDBACK

The students' feedback are recorded through university IDEA evaluation and online. We, as faculty, set up the criteria to be evaluated, and the online feedback questionnaire is open for students for two weeks at the end of each semester. The following figure shows a comparison of different criteria regarding introducing the project, hands-on techniques, and other performance metrics. Among 21 students, 17 responded to this. Figures 6 and 7 show visual comparisons. The MEAN for these criteria ranged between 4.12 and 4.59 while the STANDARD DEVIATION ranged between 0.49 and 0.83.

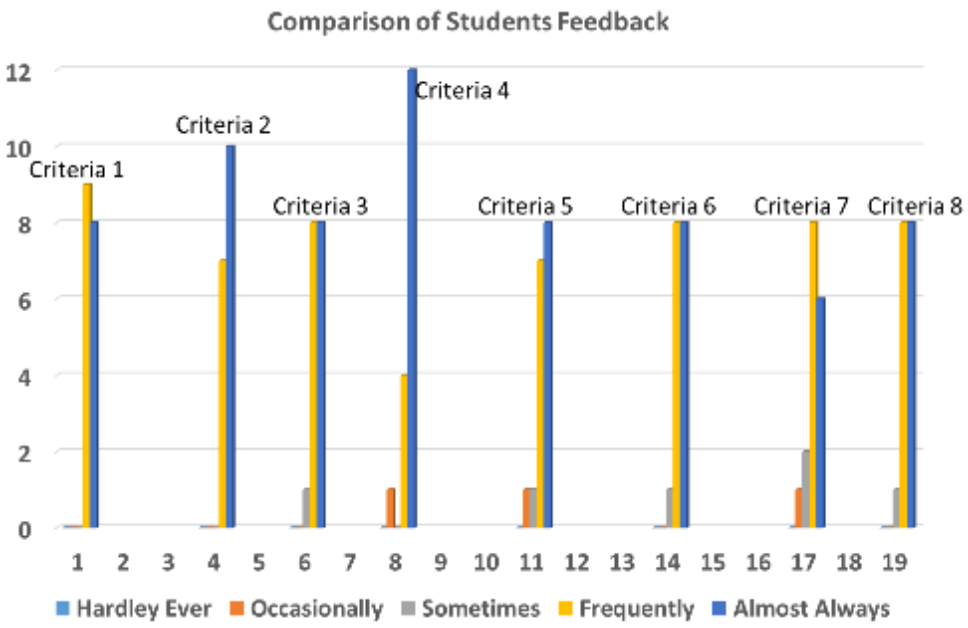

Figure 6: Students' feedback on new project

Criteria 1 Demonstrated the importance and significance of a project
Criteria 2 Made it clear how project fit into the course
Criteria 3 Helped stimulating ideas about the subject
Criteria 4 Involved students in hands-on projects such as research, case studies, or real life activities
Criteria 5 Acquiring skills in working with others as a member of a team
Criteria 6 Learning to apply course materials (to improve critical thinking, problem solving, and decisions) into project
Criteria 7 Developing skill in expressing myself orally or in writing
Criteria 8 Learning appropriate methods for collecting, analyzing, interpreting numerical information

4 RECRUITMENT IMPACT

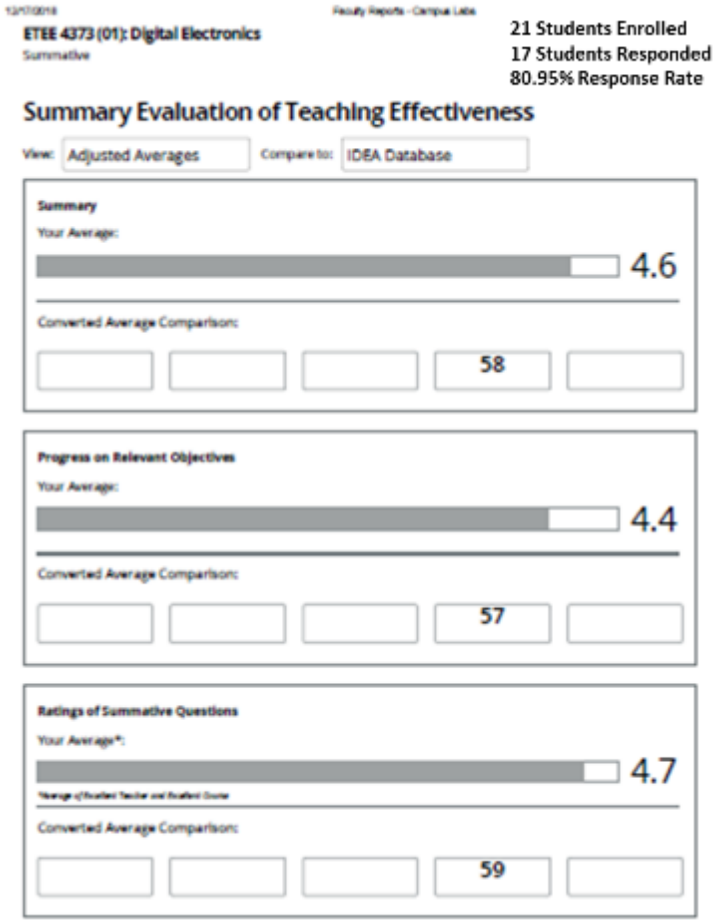

Figure 7: Summary evaluation of teaching effectiveness

Engineering Technology (ETEC) ambassadors attended several recruiting events over the year and demonstrated these hands-on projects. The attendees (especially the high school students) enjoyed the presentations and appreciated getting to learn about our work. We found that many of those students returned to attend campus events that were presented at later dates. We had 404, 175, and 485 students enrolled in Engineering Technology department under various major for Spring, Summer, and Fall of 2017, respectively. The enrollment increased to 458, 227 and 525 for Spring, Summer, and Fall of 2018, respectively. This shows the impact and steady growth of our department. Figure 8 shows a comparison of two years' enrollment by semester. The recruitment of faculty also points to the growth of this department. Since Fall 2015, the department has actively recruited seven new tenure-track faculty and currently is conducting a search for two more tenure-track positions. Figure 9 shows a snapshot of few recruiting and outreach events that we attended in 2017 and 2018.

5 FUTURE WORKS

To improve this project, we could attempt to add the second motor back in so that the user has the capability of knowing from which direction an object is being detected. Then, if both sensors are detecting objects within a certain range, the haptic motors would sync up with each other and vibrate simultaneously. The next step to further improve the overall product would be to design a case for the entire board and solder the wires rather than using the breadboard. This way it would be one complete and compact piece which could be attached to

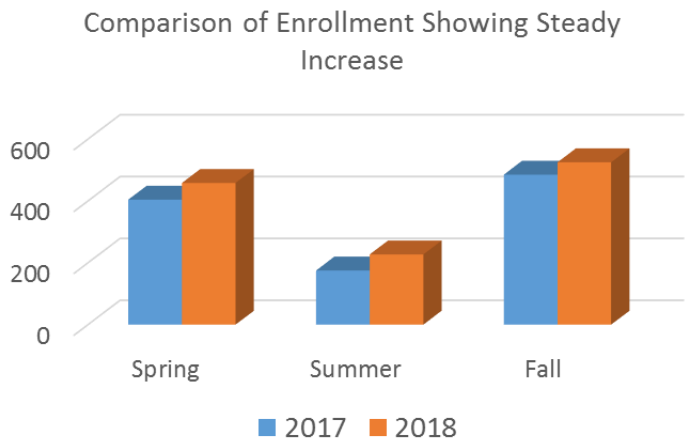

Figure 8: Student enrollment over last two years

Figure 9: Different hands on projects being displayed during career fair and high school visits

the glove. To further reduce the size of the device that fits on the glove, more compact sensors could be used to replace the rather large HC-SR04 sensors that we used in this implementation. This would be very beneficial as the size of the device will be reduced. In addition, if sensors that mount flush to the glove could

be used, there would be no fear of the sensors breaking off of the glove. We would also like to add an on/off on the side of the case so that the device could be switched off when not in use. This would save the battery and avoid having to disconnect it every time. An exciting and useful feature to add to this device would be Bluetooth capabilities, which would include the ability to use Bluetooth headphones. With this feature, the users could audibly hear the alarm if they desired. We could also put in voice output of the distance and which sensor is detecting an object.

6 CONCLUSION

This ultrasonic sensor glove for the visually impaired serves as a working prototype for close-range object detection. Our project offers a vibrating sensory alarm. The vibrations vary in pulses as signaled by the duration that is detected by the two ultrasonic sensors on the front of the glove and the calculated distance in the program. With the use of a display or serial monitor given by the Arduino IDE itself, the outputs of the calculated distances can be seen for monitoring purposes and correspond to the vibration lengths of the haptic motor. We experienced many obstacles developing this project, and there are many improvements that could still be made. However, we created a functional and compact ultrasonic sensor glove that can be useful as is, as well as improved upon as needed.

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