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Aksense: A General-purpose Wireless Controlling and Monitoring Device for Teaching First-year Electrical and Computer Engineering

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Aksense: A General-Purpose Wireless Controlling & Monitoring Device for Teaching First-Year Electrical and Computer Engineering

FIRST-YEAR PROGRAMS DIVISION CALL FOR PAPERS

1. Abstract

This **Work-in-Progress** paper describes the integration of Aksense, a low-cost general-purpose wireless controlling and monitoring device, within the first-year multidisciplinary Introduction to Engineering at Sonoma State University. Our focus in this project has been creating an affordable educational open source wireless platform that enables first-year engineering and non-engineering students with any background to design their own engaging experiments. A key advantage of utilizing Aksense board is that students, particularly non-engineering students, do not have to have any prior knowledge about electronics, programming, soldering or wiring different electronic components together in order to create exciting individual projects. In this paper we elaborate on architecture and utilization of Aksense and present the limited feedback we have received from our first-year engineering students.

2. Background & Motivation

The first-year Introduction to Engineering at Sonoma State University is a one-unit laboratory course, meeting once a week for three hours. All the engineering students are required to take this course. This course is also offered to students across different disciplines as a 1-unit General Education (GE) laboratory course, in order to satisfy their GE requirements. Thus, in addition to engineering students many students from a broad range of majors, such as Arts, Environmental Studies, Kinesiology, Chemistry, or Biology may also be taking this course. Therefore, multiple sections of the lab are generally offered each year.

The objective of the Introduction to Engineering course is to introduce various fields of engineering (electrical, mechanical, bio, etc.) to the students and expose them to basic engineering concepts, with special emphasis on electrical engineering topics, such as monitoring devices, sensors and actuators, wireless communications, etc. The main approach in introducing such topics is through hands-on activities. Each week the course starts with a half-an-hour lecture covering a particular topic and then the students are asked to complete a laboratory activity related to the discussed topic using the provided components or kits.

Historically, the laboratory experiments in this course have been based on various in-house designed activities or ready-to-go electronic kits in the market. A key challenge in utilizing electronic kits such as Little Bits, Gizmos & Gadgets, Snap Circuits, and Electronics Lab[1], has been the fact that most of these kits are either expensive or primarily designed for enthusiasts or young children.

Three years ago we introduced Arduino-based projects [2,3] into the course. Using Arduino Integrated Development Environment (IDE) students can learn and implement a C-like language to program Arduino and interface it with other actuators and sensors. A major advantage of utilizing Arduino, as suggested by many authors [6-9], has always been the ease of learning and use, as well as its availability.

Since the introduction of Arduino-based activities, we have noticed that many students have become far more engaged in the laboratory activities. Majority of these students, however, are the ones with previous Arduino and programming experience. On the other hand, many of engineering and non-engineering students, still have difficulty following the laboratory activities. These students generally lack any previous Arduino experience, and had no or very little programing or electronic background. In several activities, where Arduinos were already pre-programed and students were only asked to interface the boards to various sensors and actuators, the same students had difficulty wiring the components together on their own.

In order to engage the less technically experienced students, in 2016 we started exploring alternative devices and laboratory activities that can be engaging for students across all majors, particularly the ones with very little electronic or programming background.

This motivated us to design *Aksense* as a learning tool to replace Arduino, discrete sensors, and breadboards in our Introduction to Engineering course. The purpose of developing Aksense was several-fold: (1) generating early interests in engineering, (2) introducing students from all majors to real-world engineering concepts and physical measurements, and (3) encouraging students to truly see the impact of engineering.

Another key motivation in developing Aksense has been eliminating or minimizing the tedious steps in setting up and wiring electronic components and instead engaging freshman students in real-world engineering problem solving and programing.

In this paper we elaborate on features of Aksense and report on it utilization in our first-year Introduction to Engineering course, offered as a General Education laboratory. In this report we also describe how Aksense can be a useful educational tool assisting first-year college students across different disciplines, including Kinesiology, Chemistry, Arts, or Biology, to set up their own experiments. For example students can visualize body movements, determine the path of a projectile, measure plant sensitivity to lights, or determine light intensity of the sun as it rises or sets.

In the remaining of this paper, we first briefly describe the structure of the Introduction to Engineering course. We then elaborate on the high-level architecture of Aksense and its components and design methodology. We briefly elaborate on the hardware and software features of the device and present several introductory experiments that first-year engineering students can complete in order to learn about basic digital electronics, sensors, and wireless transmissions. We conclude the paper by presenting the limited feedback we have received from our first-year engineering students.

3. Course Description

The Introduction to Engineering course has been identified as the gateway to the engineering curriculum. Typically, 60-70 percent of students taking the course are engineering majors and the rest are from a wide range of majors.

Over the past several years, many first-year engineering students have dropped out of the engineering program after taking the Introduction to the Engineering course. On the other hand, many undeclared students or non-engineering majors switched to engineering following completion of the course. Therefore, the Engineering Department has always been looking into ways to improve this introductory course and making it relevant and engaging.

Last year we introduced Aksense-based laboratory activities. The course plan for utilizing Aksense in Fall 2017 is shown in Table 1. These activities replaced typical electronic laboratories involving discrete components and Arduino-based projects. As shown in Table 1, over the first couple of weeks the students became familiar with the basic features of Aksense. During this time, we briefly introduced the principles and applications of the following electronic components integrated in Aksense:

- Light sensor (photoresistor),
- Temperature sensor,
- Potentiometer,
- LED,
- RGB,
- Push-button switches and relays.

We note that due to lack of time we did not include any discussions around applications of accelerometers and gyroscopes in the course. As we will mention later, these devices are add-on options for Aksense and depending on the cost constrains they can be eliminated from the curriculum. In our case, we did not perform any experiment with these devices.

A Bluetooth module can also be added to Aksense in order to establish wireless communications to a PC or a smartphone. Bluetooth modules (such as HC-05 Arduino Wireless Bluetooth Receiver [12]) can be purchased for about $5 and added to the kits in order to make the experiments more engaging and interesting. During weeks 6, 8 and 12 we asked students to design their own experiments solving a particular problem or monitoring one or more physical parameters. No extra configuration steps are required when adding the add-on modules.

Table 1. Project deadlines and expected deliverables.

Week	Activity	Project Example
Week 3,4	Introducing Aksense and its features; demonstrating how the kit operates.	Using ADC, Switches, LEDs, Temperature sensor, etc.
Week 5	How to read the data from Aksense; setting up the terminal and sending commands to the sensor.	Reading the potentiometer and photoresistor values, turning on the LED, changing RGB color, etc.
Weeks 6	Design a project using the light sensor, potentiometer, and RGB	Measure outside sunshine; record the measurements on a computer and plot them using excel.
Week 8	Design a project using the potentiometer and the temperature sensor	Explore how potentiometers can be used in detecting directions and orientations
Week 10	Introduction to LabVIEW and VISA and how to use an existing template to capture serial data.	Use LabVIEW and Aksense to record the received light/temperature over time.
Week 12	Build a data-logger based project which has a feedback mechanism	Show the temperature change outside the house. If the temperature is higher than a certain value turn the RGB red, else keep it green.

3.1. Course Grading

All students were expected to compete all the weekly lab assignments. No partial credits were given to incomplete laboratory assignments .

4. Aksense Architecture and Features

Aksense is a single node wireless device with various sensors and actuators (such as temperature, switches, LEDs, an RGB, and a potentiometer) all of which are interfaced with a PIC microcontroller [4]. Although, Aksense can be directly connected to a PC or a smartphone using a USB cable, it can also optionally be equipped with a low-power Bluetooth chip to communicate with any Bluetooth enabled device (laptop, smartphone, etc.).

A unique aspect of Aksense is the fact that it is *command driven* and at its basic level no programing is required to communicate with the device or receive sensor data. Following sending the appropriate command character (e.g., “T”), students can enable the onboard LEDs and the RGB, read the temperature data, or receive the status of the switches.

Thus, using any serial terminal program, such as Chrome Serial Terminal [11], the students can easily receive the sensor data from Aksense node, store or simply plot them. In the same manner, they can also communicate with Aksense and control its onboard LEDs and RGB components. Various programming platforms (Matlab, LabVIEW, Python, App Inventor, Python, etc.), can be used to communicate with Aksense, allowing students to control and monitor the device using the software platform of their choice. Thus, more advanced students can design their own monitoring and feedback systems. For example, using Matlab students can design an experiment in which if the temperature goes beyond a particular set point the LED can be turned on.

The base-cost of a fully functional Aksense board is only $5. With added Bluetooth module, accelerometer, and a gyroscope, the cost can go up to about $25. Therefore, in more cost-constrained classroom environments, students can only use the basic sensors and actuators on the board.

4.1. A Brief Comparison With Arduino Board

Below, we briefly list the key differences between Aksense and Arduino-like hardware platforms:

- Aksense is already equipped with light sensor (photoresistor), temperature sensor, potentiometer, two LEDs, one RGB, one slide SPST switch and two tactile switches.
- Aksense requires no external wiring.
- Additional modules, including a Bluetooth, gyroscope and an accelerometer can be optionally added to the Aksense board.
- Aksense has a rechargeable battery allowing the board to function for about 8 hours.
- All communications with the board can be done via a serial terminal software and thus, no extra software is required to be installed.
- A fully populated Aksense board is 1/5th of the size of an Arduino Uno.
- A fully loaded Aksense, equipped with all its actuators and sensors, costs about half of a typical Arduino loaded with similar off-the-shelf devices.

In addition to the above differences, Aksense board can be interfaced with external devices such as additional sensors and switches, in a similar manner as an Arduino.

We emphasize that our goal in this project is only to present an alternative educational tool to enhance learning experience and not to promote Aksense as a replacement to Arduino hardware and software.

4.2. Project Examples

Figure 1 shows the basic communication protocol between Aksense and a PC (or alternatively a smartphone). Using a serial terminal program such as RealTerm[10] or web-based Chrome Serial Terminal, the students can directly communicate with Aksense. The communication medium between Aksense and the computer can be stablished either using a Bluetooth wireless or a USB cable.

In order to program Aksense the students only have to know the basic commands to activate various components, such as LED and RGB. For example, using Chrome Serial Terminal if the command "G" is sent to Aksense the RGB will turn Green. Similarly, if we press the Push button switch on Aksense, character "S" will be displayed on the terminal. If the user send character "P", then the current value of the voltage set by the potentiometer is displayed.

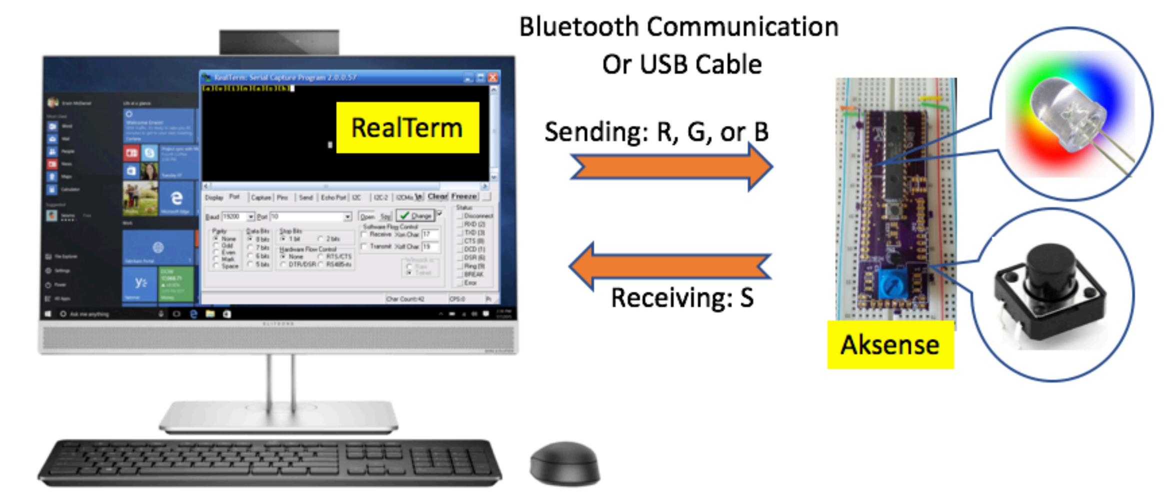


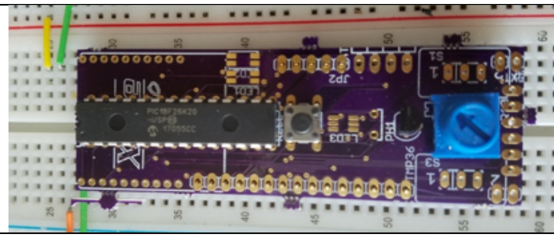
Figure 1: Basic communication between Aksense and a PC (or smartphone) using pre-assigned command lines (e.g., "R" to turn the RGB RED).

Figure 2(a) depicts Aksense's PCB. Should time permits, the device can be used in conjunction with a breadboard and other external electronic components to design more complex projects. For example, students can connect Aksense to a microphone to detect the noise level and set a buzzer if excessive level of noise is detected. Figures 1(b)-(c) show the plots of the received data using Excel.

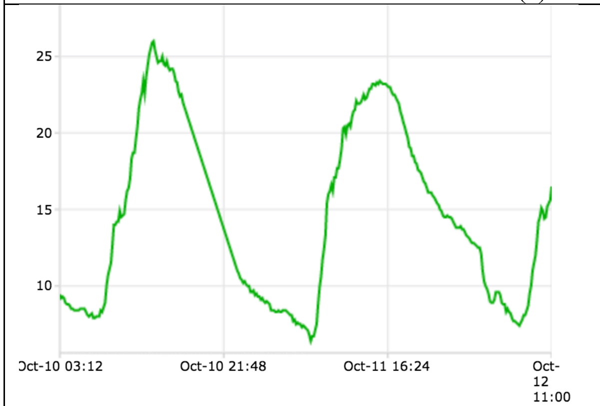
We should note that for many students finding a clear project idea was initially a bit daunting. Many did not know how to find a good project. Therefore, over the first several weeks the instructor had to dedicate a fair amount of time explaining different practical scenarios and how Aksense can be utilized for various measurements. As the semester passed by, it appeared that most students became more comfortable with finding interesting applications for Aksense.

5. Experiment Outcomes

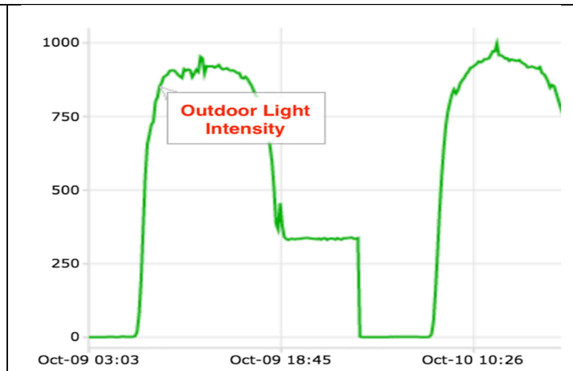
Over the past three years, at the beginning and end of each semester, we have asked the students to complete mandatory short surveys for the course and give their feedback regarding the hands-on projects. Both surveys are identical in order to compare the overall students' views before and after taking the course. In each case, the survey is primarily based on quantitative questions with the last question asking for student comments and suggestions.



(a) Aksense PCB.



(b) Monitoring outdoor temperature using Aksense.



(c) Monitoring outdoor light using Aksense.

Figure 2: Example of graphs generated by students using Aksense.

The combined demographics for each course is generally about 20-30 percent females and 80-90 percent freshmen. Over the past several years the Introduction to Engineering has also attracted many non-engineering majors and undeclared students. In each section about 30-40 percent of students are typically non-engineering majors.

As we mentioned before, in Fall 2016 and Spring 2017 the general topics covered by the course included basic concepts of engineering and electronics using various laboratory activities. These hands-on activities involved building basic monitoring devices, measuring pressure, temperature, and force, introducing LEDs, etc. In weeks 10-12, the course introduced the students with basics of LabVIEW programing.

In Fall 2017 we modified some of the laboratory activities involving discrete components and replaced them with Aksense kit. We asked the students to utilize the kit in various applications in order to solve specific problems. In Table 1 we summarized some of the activities that students were asked to perform using Aksense.

The responses to some of the quantitative questions concerning the overall view of the students towards the hands-on projects are shown in Table 2. For each of the three semesters (Fall 2016, Spring 2017, & Fall 2017), we include student responses at the beginning and end of each course (etc., *before* and *after*). In each case, N represents the total number of students enrolled in the course. The survey questions are based on a Likert Scale (higher value indicates a more positive response). The *average* represents the mean of the student responses to each question.

Table 2. Responses of students to pre- & post-course survey.

Survey Question	Fall 2016; N=20		Spring 2017; N=22		Fall 2017; N=25	
	Before	After	Before	After	Before	After
I have a good understanding about what engineers do	2.9	3.8	3.0	4.0	2.9	4.4
I have a good understanding about engineering problems	2.4	3.4	2.1	3.1	2.4	4.1
I have a good confidence to solve engineering problems	2.7	3.6	2.7	3.6	2.4	4.2
I am comfortable with hands on experiments	2.9	3.8	2.9	4.0	2.9	4.3
I am glad I enrolled in this course	3.1	4.2	3.0	4.1	3.1	4.5
I recommend this course to anyone interested to learn more about engineering	3.3	4.2	3.1	4.1	3.4	4.6
Average:	2.9	3.8	2.8	3.8	2.8	4.3

Table 3 breaks down the student responses in terms of their gender and major. As we mentioned before, since the course is the first introductory course to engineering we pay close attention to the feedback we receive from students. We have particularly been mindful to ensure the course is well received by both male and female students.

Table 4 depicts the percentage improvement in student responses before and after taking the course as we introduced Aksense-based activities. Based on the existing student responses, following the introduction of Aksense board it appears that we managed to increase student engagement in engineering projects.

It is important to note that in the comments section of the post-course survey many students were very pleased that they used their design for a very specific real-world application. According to the class survey, 75 percent of the students enrolled in the course had never built anything prior to taking the course.

Figure 3 shows the aggregated student responses *after* taking the course over the last three consecutive semesters. These results indicate that after introducing Aksense the overall student satisfaction increased by more than 12 percent. We believe that should we repeat the course using Aksense, we will be able to further improve the course organization and observe a higher level of student satisfaction.

We recognize that student perception of learning and true learning may be different. Thus, the fact that students *feel* they learned the concepts cannot be a definite indication of true learning success. Clearly, more data is required to fully validate the effectiveness of Aksense.

6. Future Works

Although, in this paper we mainly focused on utilization of Aksense within an interdisciplinary introductory course to engineering, we believe the board has the potential to be integrated within first-year or second-year engineering courses, composed of only the engineering students. Aksense board can be utilized to familiarize the engineering students with key electrical engineering concepts such as microcontrollers, sensors, wireless transmission, switches and potentiometer without having to spend too much time setting up the circuit or interfacing discrete components together.

In more advanced first- and second-year engineering courses students can interact with advanced features of Aksense. Such features include: (1) programing the microcontroller to enable new functionalities; (2) developing new smart phone applications for Aksense; (3) communicating with Aksense using different programing platforms; (4) learning soldering using a real PCB and variety of SMT and through-hole components.

Therefore, in the near future it is our intention to integrate Aksense in the second Introduction to Engineering Laboratory (EE 112), which is primarily for engineering students.

7. Conclusion

In this paper, we reported on our pilot project using an in-house developed sensor kit called Aksense. The purpose of this project was to integrate Aksense in the Introduction to Engineering course and replace it with the typical electronic experiments, involving breadboards and discrete components. Our motivation in this project was to eliminate the tedious steps in setting up and connecting electronic components and engage students in real engineering problem solving using physical sensors and electronic devices. Our preliminary student survey results indicate that in spite of some shortcomings, integrating Aksense created an engaging learning environment. We acknowledge that there is more work to be done on this topic. Specifically, more data is required to validate the impacts of integrating Aksense throughout the first-year programs.

Table 3. Responses of students based on their gender and major to pre- & post-course survey.

Survey Question	Fall 2016; N=20				Spring 2017; N=22				Fall 2017; N=25			
	M	F	Mj	NMj	M	F	Mj	NMj	M	F	Mj	NMj
I have a good understanding about what engineers do	3.9	3.8	3.85	3.75	4	3.8	3.9	3.5	4.5	4.1	4.3	4.2
I have a good understanding about engineering problems	3.5	3.4	3.45	3.05	3.2	2.9	3.05	2.95	4.3	3.9	4.1	4
I have a good confidence to solve engineering problems	3.6	3.5	3.55	3.45	3.8	3.4	3.6	3.2	4.3	3.9	4.1	4
I am comfortable with hands on experiments	4	3.8	3.9	3.7	4.1	3.7	3.9	3.5	4.5	4.4	4.45	4.25
I am glad I enrolled in this course	4.3	3.9	4.1	4	4.2	3.9	4.05	3.75	4.6	4.5	4.55	4.35
I recommend this course to anyone interested to learn more about engineering	4.2	3.8	4	3.8	4.1	3.9	4	3.8	4.8	4.4	4.6	4.3
Average Percentage (%):	78.3	74.0	76.2	72.5	78.0	72.0	75.0	69.0	90.0	84.0	87.0	83.7

Mj=EE Major; NMj=Non-EE Major; M=Male/F=Female N=Total Enrollment.

Table 4. Overall percentage improvement in student responses before and after taking the course.

Survey Question	Fall 2016	Spring 2017	Fall 2017
I have a good understanding about what engineers do	30.51	34.48	56.36
I have a good understanding about engineering problems	46.81	48.78	67.35
I have a good confidence to solve engineering problems	39.22	33.33	67.35
I am comfortable with hands on experiments	30.00	30.00	48.33
I am glad I enrolled in this course	32.26	37.29	46.77
I recommend this course to anyone interested to learn more about engineering	37.93	37.93	70.37
Average:	36.12	36.97	59.42

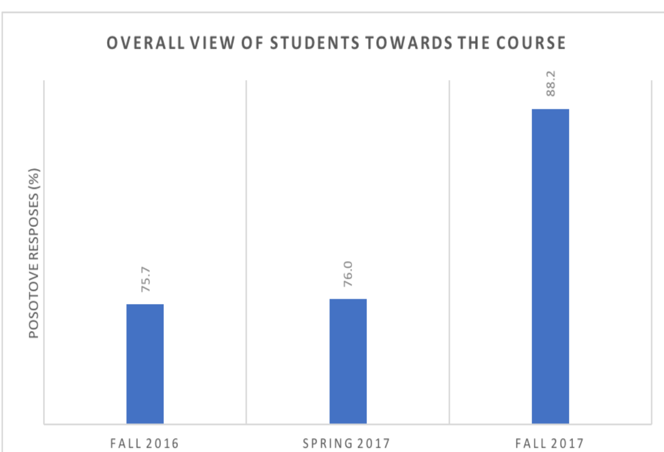


Figure 3: Aggregated student responses after taking the course.

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