NAVSEA Robosub
EE 416 Final Report
Team Naura
April 15, 2018

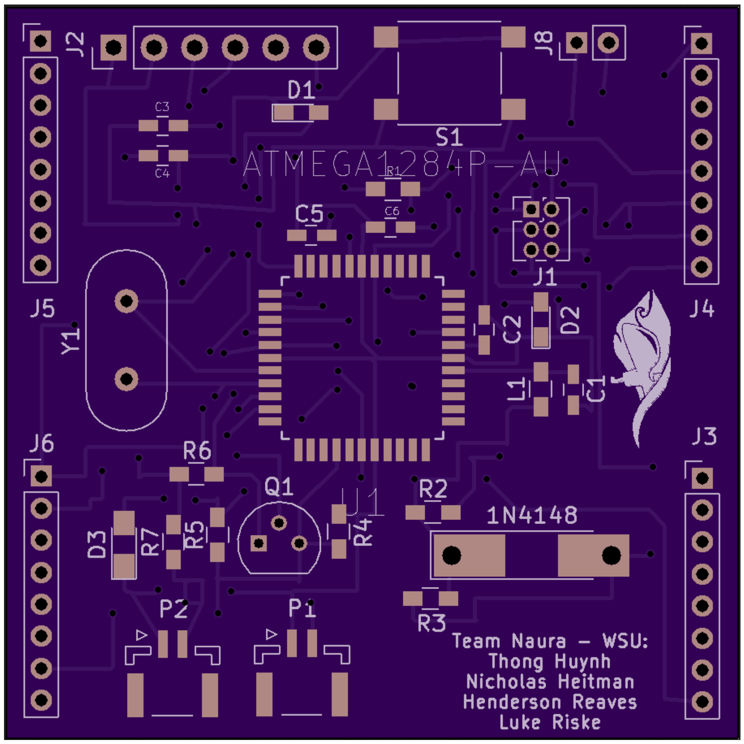

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Table of Contents

Executive Summary

This report covers the design process used by the EE416 Senior Design Team, Team Naura, to create a leak detection system for the Autonomous Submarine created by the WSU Robosub Club, sponsored by NAVSEA. Per the Robosub Club's requirements, the leak detection system was to use a modular approach: One system for detecting leaks prior to submersion, and one system for detecting leaks onboard the submarine during operation. For the EE415 fall semester, our Team brought the pre-submersion module to an alpha prototype level. The objective of the EE416 semester was to bring the pre-submersion module to a beta prototype level and the onboard module to an operational alpha prototype level, of which both objectives were met. Details of both designs, the results to date, broader impact considerations, and conclusions made throughout the process are also described. All external resources used throughout this process have been cited and are included in the reference page.

Introduction

To detect leaks within the autonomous submarine prior to submersion, air pressure was utilized. The design would connect to the subject test vessel and create a sealed apparatus and then use a vacuum pump to reduce the air pressure within the system. Because air pressure is naturally maintained at a level of one atmosphere, the air pressure within the sealed apparatus would try to rise back up to atmospheric pressure. If it was able to successfully rise back to one atmosphere within a certain time constant, that would mean there is a leak in the system that needs to be investigated. Otherwise, the air pressure would remain at the level that the vacuum was shut off at.

To detect leaks within the autonomous submarine during operation, a water sensor would be used. This water sensor was created by Blue Robotics and functions by using an absorbent sponge material that expands upon contact with water and sends an analog signal. This analog signal would then be processed by our design into a usable digital signal that would be sent to the autonomous submarine to indicate if a water leak has been detected.

Therefore, transitioning into this semester, our team's objective was to bring the pre-submersion module into a beta level prototype. This included moving our alpha prototype, which was a breadboard circuit, onto a printed circuit board and creating an enclosure to make it more usable by the club. The goal for the onboard system was to get an operating alpha prototype. This meant creating and testing a breadboard circuit and then transitioning that circuit onto a printed circuit board to be integrated onto the submarine.

Description of Culminating Design

The design for the pre-submersion module consists of a PCB interface shield for the Arduino UNO microcontroller. This system is used to test the airtightness of the Robosub autonomous submarine before being submerged. This test consists of pulling a vacuum on the submarine to a threshold of 0.9ATM, monitoring pressure deviations over time, and providing results dependent on total pressure deviation. The design features its own portable case that encloses the vacuum pump, and electronic components needed to perform the pressure test. A vacuum hose that connects to the vent plugs of the submarine, and a wall outlet plug are easily accessible from the outside of the case. This final design is ready for use by the Robosub Club and will perform as intended.

The onboard leak detection system has been developed exclusively throughout the course of EE416. This system consists of a PCB controlled with the atmega1284P microcontroller, and SOS probes provided by Blue Robotics. The objective of this design is to detect water leaks onboard the submarine by monitoring the SOS probes and send a flag bit to the sub’s CPU in an instance of a leak. When the system is fully integrated into the submarine, two probes will be placed on each end of the center bulkhead. This will provide enough reliability to detect water infiltration, because the submarine only experiences minor changes of pitch during movement underwater. This PCB is also setup to provide the Robosub club with more functionality from the microcontroller if need be, which includes: ADC (Analog Digital Conversion) inputs, temperature measurement, PWM outputs, and more.The dimensions of the onboard leak detection PCB are oriented to meet the specifications provided from Robosub club members.

Because of component arrival times, and inexperience with programming a blank microcontroller, a backup plan has been set in place to ensure a beta prototype is presented for the onboard system. The backup plan consists of a shield design for the Arduino NANO microcontroller to operate with the Blue Robotics SOS probes. The NANO shield is designed to meet all general requirements of the PCB created with the atmega1284P microcontroller but lacks the extra functionalities that the Robosub club could use for additional projects. The NANO shield PCB is less expensive than the one created with the atmega1284P and offers a smaller footprint. The only downfall to this backup plan is that it is specifically made for water leak detection onboard and will not provide the extra I/O pins.

Project Management

Before beginning work on the project, our team decided that it would be best if we had a team member keep track of the project schedule that we all agreed to. This team member would have the role of Team Lead and would be responsible for adhering to the project schedule and making sure the other team members had the necessary support. This is the primary method for managing our project. The secondary method was to have each team member hold each other accountable for completing tasks assigned to them. This secondary method would assist the Team Lead to ensure the success of the primary method for meeting project deadlines. Once the role of Team Lead was assigned each team member contributed to the creation of a project schedule shown in Figure 1. This project schedule indicated tasks for each member to complete and a timeframe to complete it in. Upcoming tasks would be identified with a blue bar while current tasks or tasks in progress would be indicated by a yellow bar. Once tasks were completed they were changed by the Team Lead to be a green bar. Should tasks extend beyond the given time frames, they would have been changed to a red bar which would prompt the Team Lead to contact or meet with the team members to discuss the best course of action. Finally, the vertical blue bars indicated the beginning and end of the semester and the vertical red bar indicated what day it was currently, or rather. This red bar helped the Team Lead and the other team members keep track of what is currently being worked on.

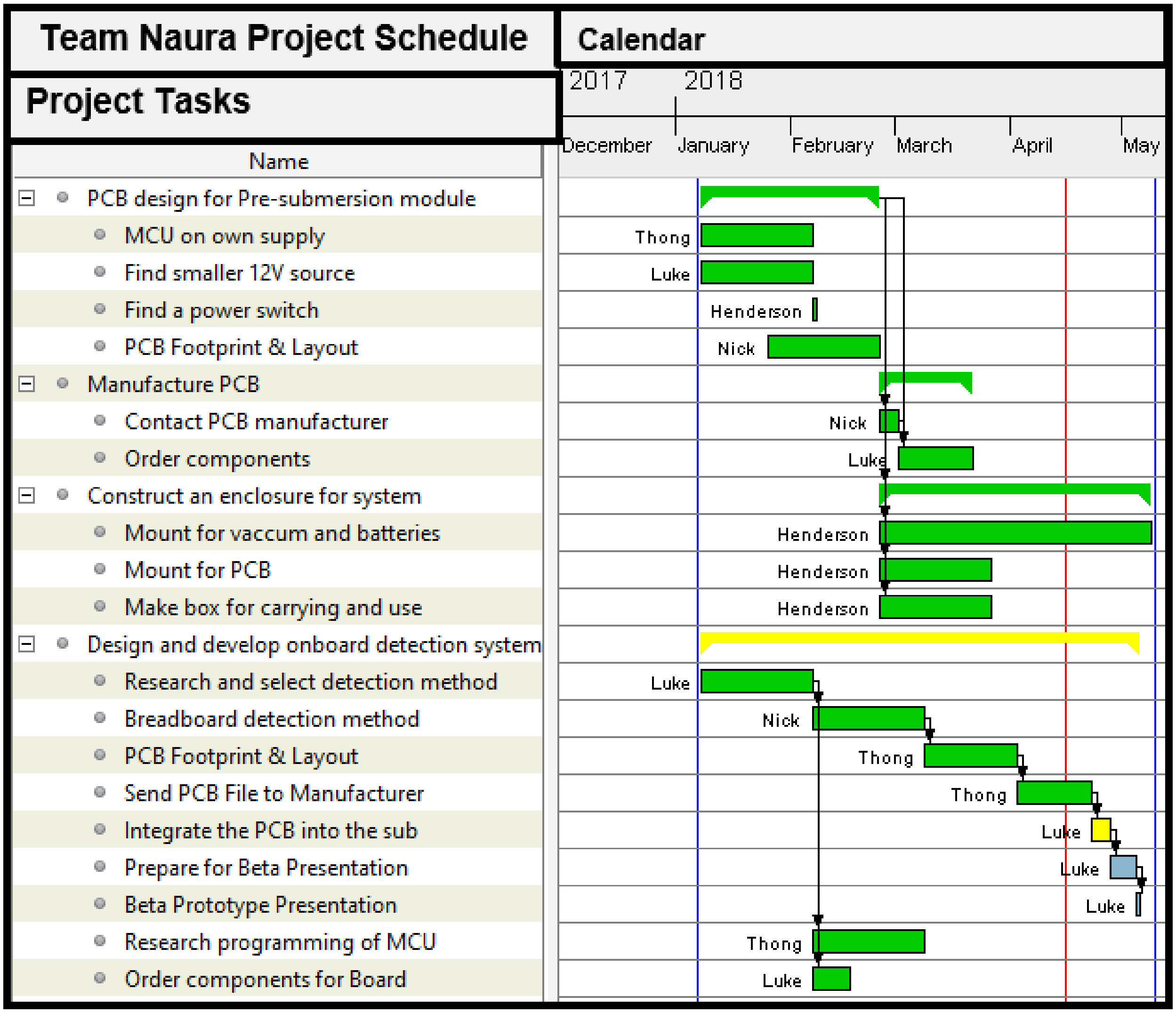

Fig 1. Project Schedule used by Team Naura for the EE416 Spring Semester

Results

Both onboard, and pre-submersion PCBs were modeled with KiCad EDA software. KiCad is an open source software suite for Electronic Design Automation (EDA). The program handles Schematic Capture, and PCB Layout with Gerber output. The suite runs on Windows, Linux and Mac OSX and is licensed under GNU GPL v3.

The pre-submersion leak detection system PCB is designed as a shield for the Arduino UNO microcontroller. The design consists of a 16x2 LCD display, BJT controlled vacuum relay circuit, and Honeywell HSCDAND015PDSA3 pressure sensor. All components are powered with a

5.5mm, and 2.1mm center pole diameter barrel jack that supplies a maximum of 24W. The schematic of the shield design is modeled in Figure 2, which exhibits all necessary connections for the PCB. The JZC-11F relay controls the operation of a 12V vacuum generator and can easily be turned on with manipulation of the base pin (D2) of the BJT. The Serial Peripheral Interface (SPI) pins of the UNO microcontroller are used to control the Honeywell pressure sensor, which is set to transmit data at a rate of 9600 bits per second. A $10\ k\Omega$potentiometer is used to change the brightness settings of the 16x2 LCD screen that displays live data while testing is underway. This LCD screen accounts for most of the digital pin connections (D8, D7, D6, D5, D4, D3) that are shown in the schematic.

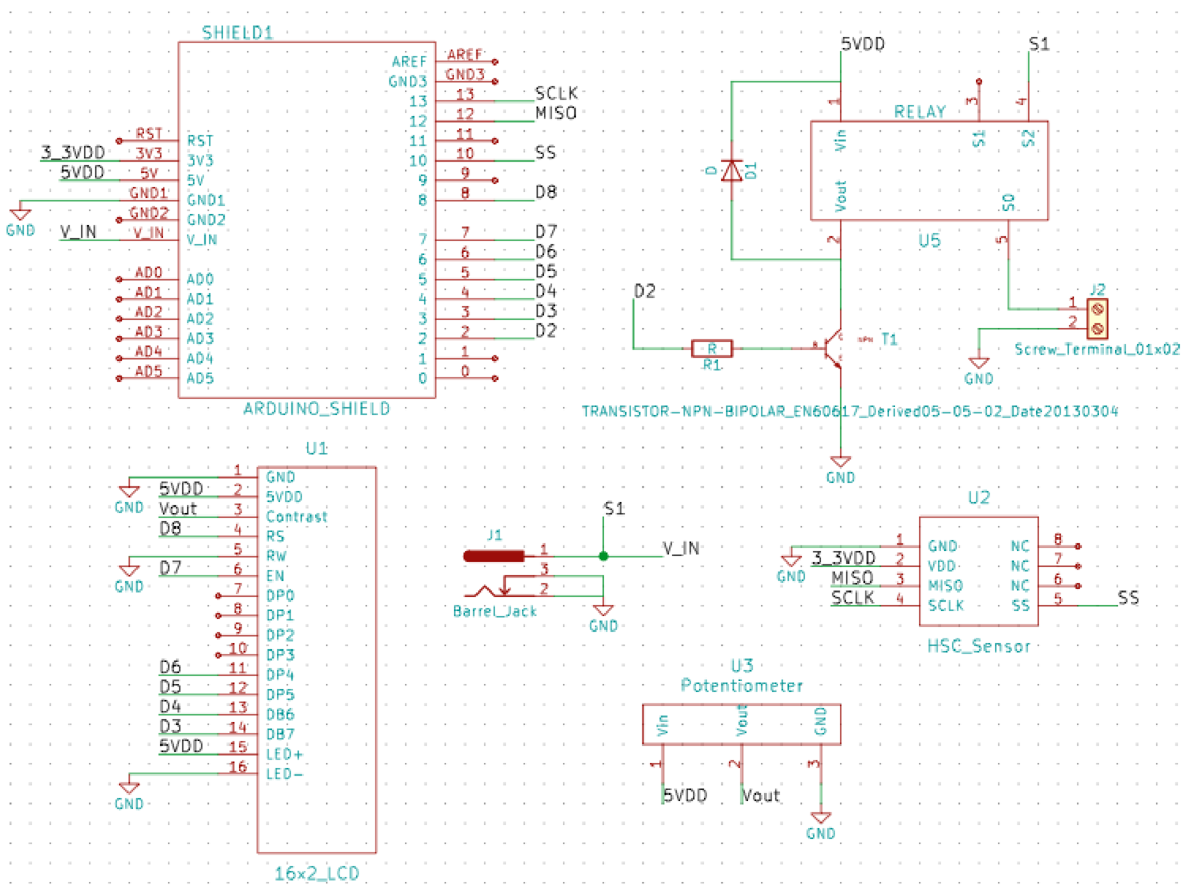

Fig. 2 Schematic for Pre-Submersion Pressure Testing System

The PCB layout for the pre-submergent system is shown in Figure 2, and has dimensions of 70.61 mm x 56.14 mm. This layout follows design rules provided by the manufacturer OSH Park. Most of the trace widths for this design are 0.300mm, with the exception of the connection made from the barrel jack to the vacuum generator, which is 1.000mm. The large trace is to account for 0.53A of current that was measured between our 12V supply, and the vacuum with the breadboard circuit model of the design. The red traces correspond with connections made on the front copper layer, and green traces correspond with ground connections on the back copper layer of the board. No conductor vias were needed for this PCB layout. Each of the outer pins on the PCB layout are soldered with male pin headers, which fit directly into the Arduino UNO. The barrel jack splits power between the microcontroller, and vacuum generator. This layout is what will be presented at the beta prototype poster session, which is in Rev. 0. Since receiving and testing the PCB, minor revisions have been made to the layout in case the Robosub club needs to reprint the PCB in the future. The reasons for these revisions have been assessed, and are included in the "Limitations and Recommendations" portion of this document.

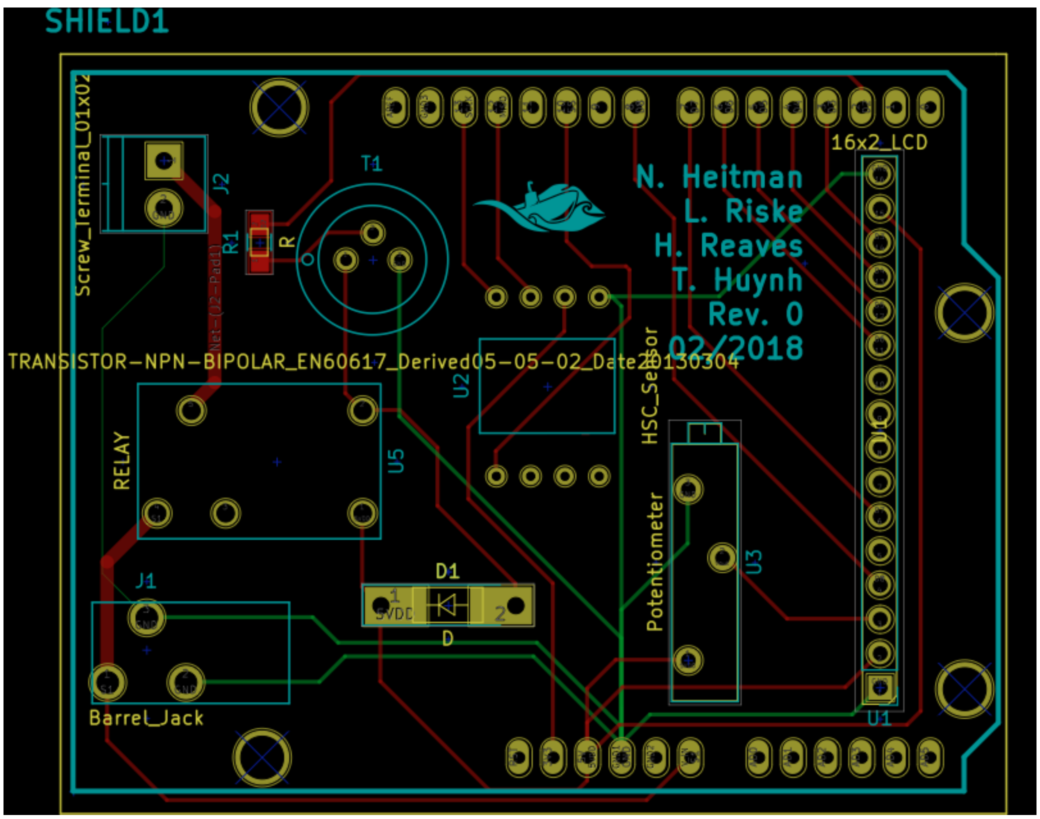

Fig. 3 Layout for Pre-Submersion Pressure Testing System

Fig. 4 The Testing Case for Pre-Submersion Pressure Testing System

The functionality of the pre-submersion system has been validated with a testing chamber, and the Robosub club's autonomous submarine itself. The testing procedure consists of attaching the vacuum hose to the vent plug located on the vessel being tested, before plugging the system into the wall. A short delay should occur before the vacuum turns on, and the LCD starts displaying data. Once the internal pressure of the vessel being tested reaches 0.9ATM, the vacuum generator will turn off. For two minutes the LCD screen will print the live pressure data in ATM, and be in "TESTING" mode. After the two minutes pass the LCD will either display "PASS," or "FAIL." The "PASS" condition occurs if the internal pressure does not rise more than 0.15ATM, from the initial 0.9ATM threshold. This indicates that the vessel contains no major leaks before being released underwater. The code for this system has been written in Arduino, which is an open source programming software. Robosub club members have full access to the code, and are capable of changing the pressure threshold, testing condition, and duration if needed. Data has been obtained with the pre-submersion beta prototype to determine the length of vacuum operation, and deviation of pressure from initial threshold for both vessels. The results in Table 1 show the data for both the Robosub, and testing chamber vessels.

Table 1 Pre-submersion Pressure Testing System Performance on Testing Chamber, and Robosub Autonomous Submarine

Testing Chamber			Robosub Autonomous Submarine		
Vacuum Operation	Initial Pressure	Final Pressure	Vacuum Operation	Initial Pressure	Final Pressure
4.28 s	0.89 ATM	0.91 ATM	48.7 s	0.89 ATM	0.90 ATM
3.44 s	0.90 ATM	0.91 ATM	45.9 s	0.90 ATM	0.90 ATM
3.68 s	0.90 ATM	0.91 ATM	43.8 s	0.90 ATM	0.90 ATM
3.52 s	0.90 ATM	0.91 ATM	45.8 s	0.90 ATM	0.90 ATM

The tests were run for two minutes after reaching the initial pressure threshold. The Robosub autonomous submarine has a volume of approximately 0.02512m^3 without subtracting the internal electronics, while the testing chamber has a volume of 0.002059m^3.

The onboard leak detection system is designed with the atmega1284P-AU chip and SOS Leak Sensor to detect water quickly and reliably, before any major damage can occur. The schematic of the onboard system is shown in Figure 5.

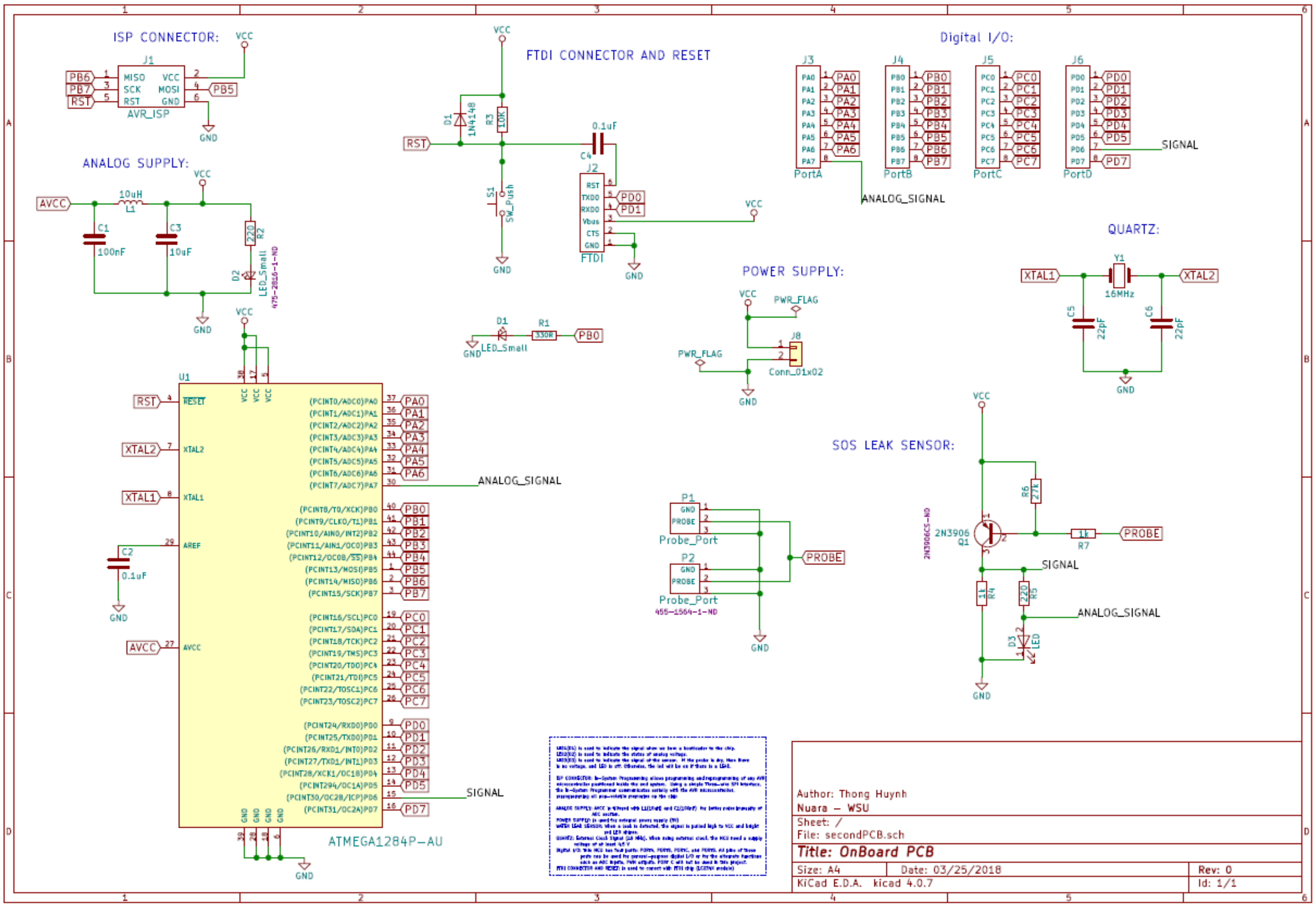

Fig 5. The Onboard System Schematic

The ATmega1284P microcontroller is the MCU (Microcontroller Unit) used in the onboard system as a main controller. It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. Its data-bus architecture and internal registers are designed to handle 8 parallel data signals. The chip has three types of memory:

- **Flash Memory**: 128KB non-volatile memory combine with read-while-write capabilities. It is used to store applications on the chip.
- **SRAM Memory**: 16KB non-volatile memory. It has a larger SRAM memory compare to other microcontrollers. This is used for storing variables used by the application while it's running.
- **EEPROM Memory**: 4KB non-volatile memory. It is used to store data that is available even after the board is powered down and then powered up again.

The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core [1].

- **ISP (In System Programing) connector:** In-System Programing allows programming and reprogramming of any AVR microcontroller positioned inside the end system. Using simple three wire SPI interface, the In-System Programing communicates serially with the AVR microcontroller, re-programming all non-volatile memories on the chip.

- **FTDI (Future Technology Devices International) connector:** 6-pin connector with the following pinout: RTS, RX, TX, 5V, CTS, GND. This is used to power our board and transfer the data to the main CPU on the sub.

- **Analog Supply:** Analog power supply from the microcontroller. AVCC is filtered with L1(10uH) and C1(100nF) for better noise immunity of ADC section. The decoupling capacitor C3(10uF) is placed as close as possible to the power supply.

- **External Power Supply**: 5V external power supply.

- **Digital I/O**: This MCU has four ports: Port A, Port B, Port C and Port D. All pin of these ports can be used for general – purpose digital I/O or the alternate functions such as ADC inputs, PWM outputs. Port C will not be used in this project.

- **Quartz**: External clock signal (16Mhz). When using the external clock signal, the MCU need a supply voltage at least 4.5V

- **SOS Leak Sensor**: It is used to detect the water infiltration. The probe is connected with a PNP transistor (2N3906), VCC (5V) and GND through some resistors. When a leak is detected, the signal is pulled high to VCC and bright red LED (D3) shines. The circuit that reads from the SOS Leak Sensor is borrowed from Blue Robotics. [2]

- **LEDs**: The LED1(D1) is used to indicate the signal when we burn a bootloader to the chip. The LED2(D2) is used to indicate the status of the analog voltage, and the LED3(D3) is used to indicate the signal of the SOS Leak Sensor.

- **Signals**: The digital signal is connected to pin PD6 on the chip to send the message to the main CPU when there is a leak via using digital data. In addition, the analog signal can also be used and more accurate than the digital signal to detect a leak and send the message to the CPU. The analog signal is connected to pin PA7 on the chip and it will be required of using ADC for analog signal.

Many considerations were made in the design process for PCB (Print Circuit Board) layout. These considerations include the dimensions of each component (footprints), dimension of the board (it needs to fit within the actual dimensions on the sub), connections between each component on the PCB, and much more. Many custom footprints were made with accurate dimensions according to the actual component and space on the PCB. The physical dimension of the PCB is 45.70 mm x 46.00 mm which meets the requirement from the Robosub club. The requirement of dimension for the PCB is 56.20 mm x 50.00 mm. The front-copper layer was used for placing all components and connection tracks between them. The front copper layer was used for all components and the back-copper layer was used for the names of our clients, professors, mentors and faculty volunteer. A logo of Robosub club and our team member's names are placed on the front-copper layer. The PCB layout of our onboard system is shown in Figure 6.

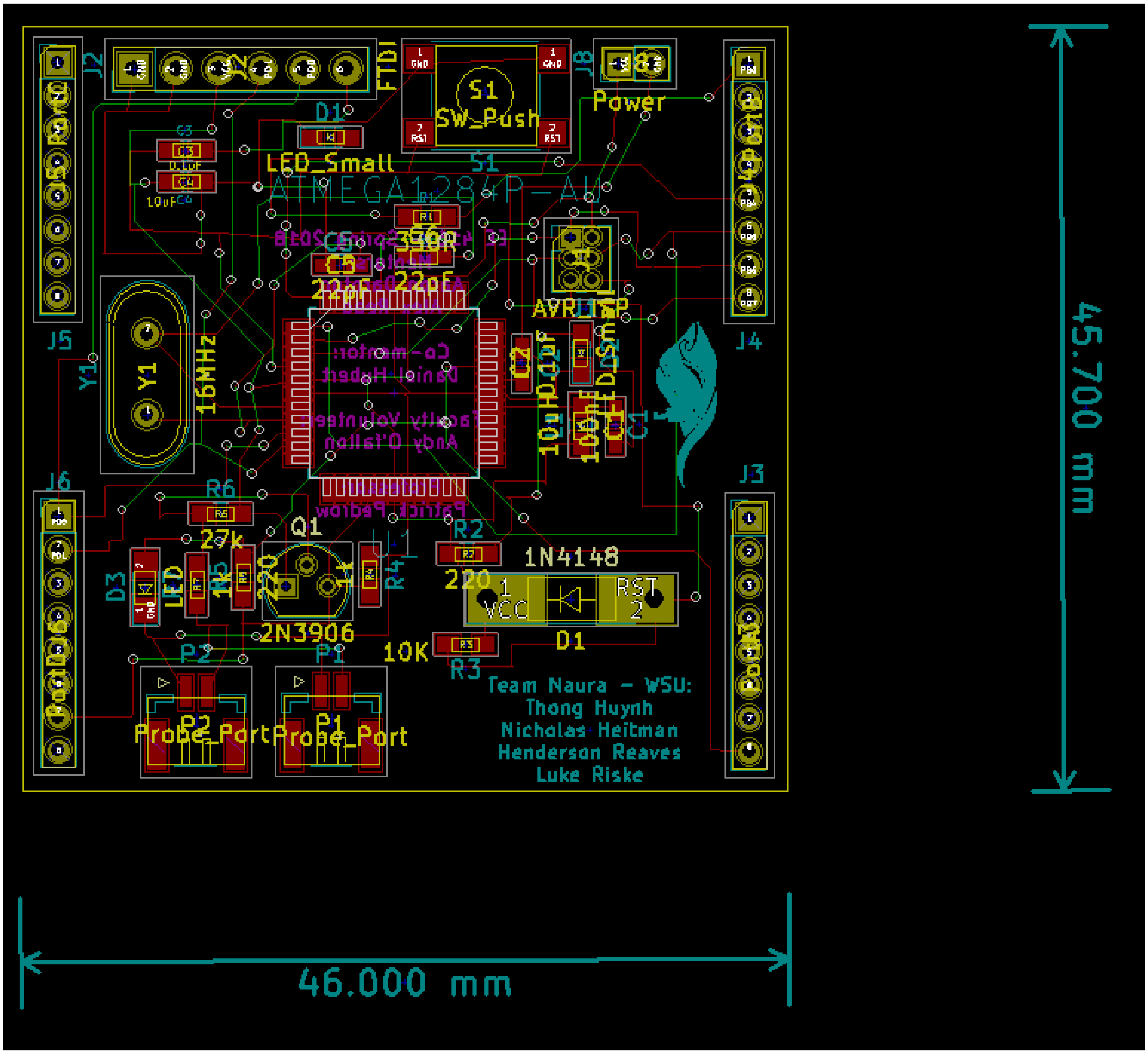

Fig 6. PCB Layout of the Onboard System

The KiCad software package also provides a 3D viewer that can be used to view our potential PCB with 3D model formats supported by available 3D plugins. The 3D model of the onboard PCB is shown with different views in Figure 7 and Figure 8.

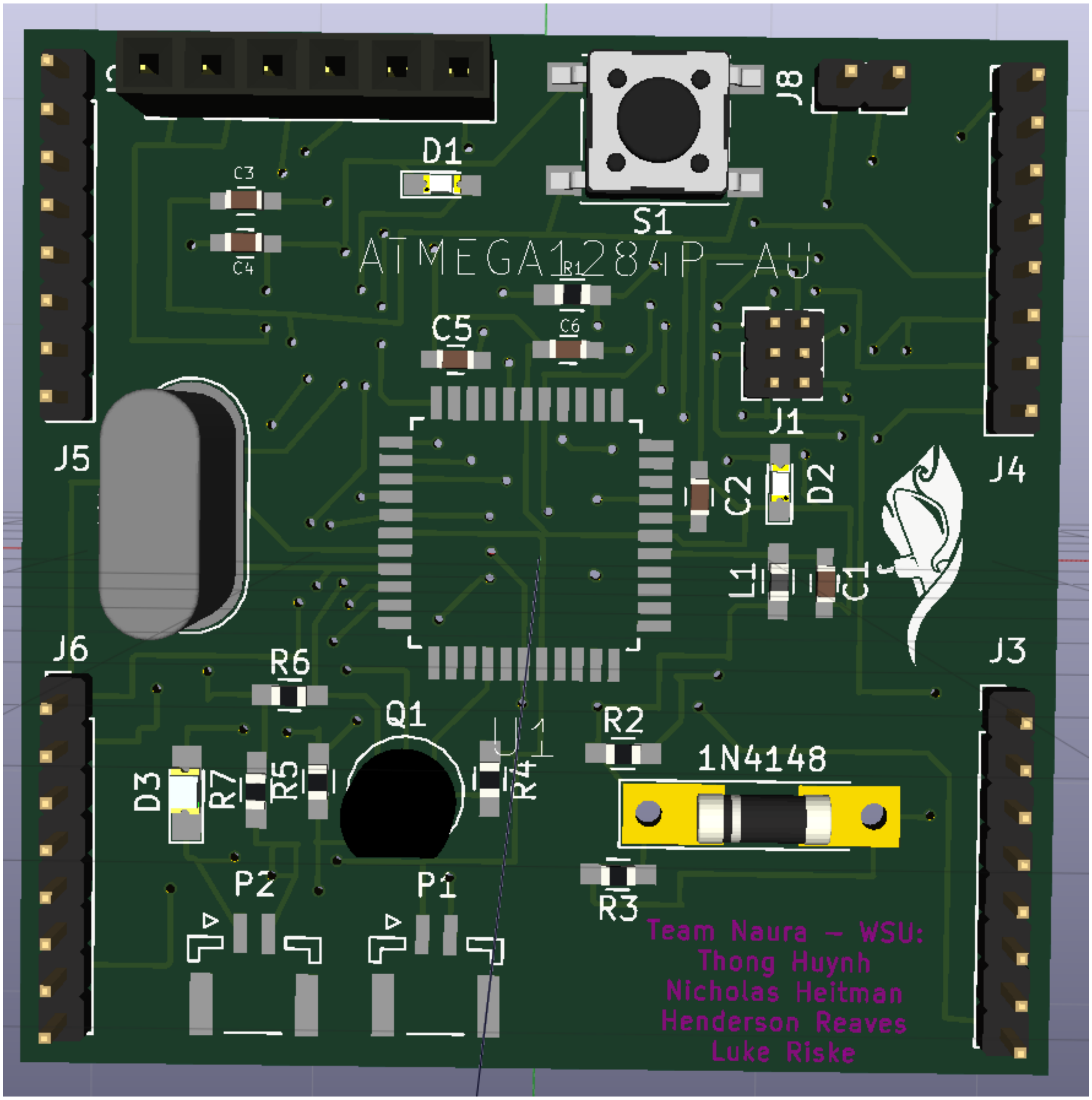

Fig 7. 3D Model Top View Onboard System PCB

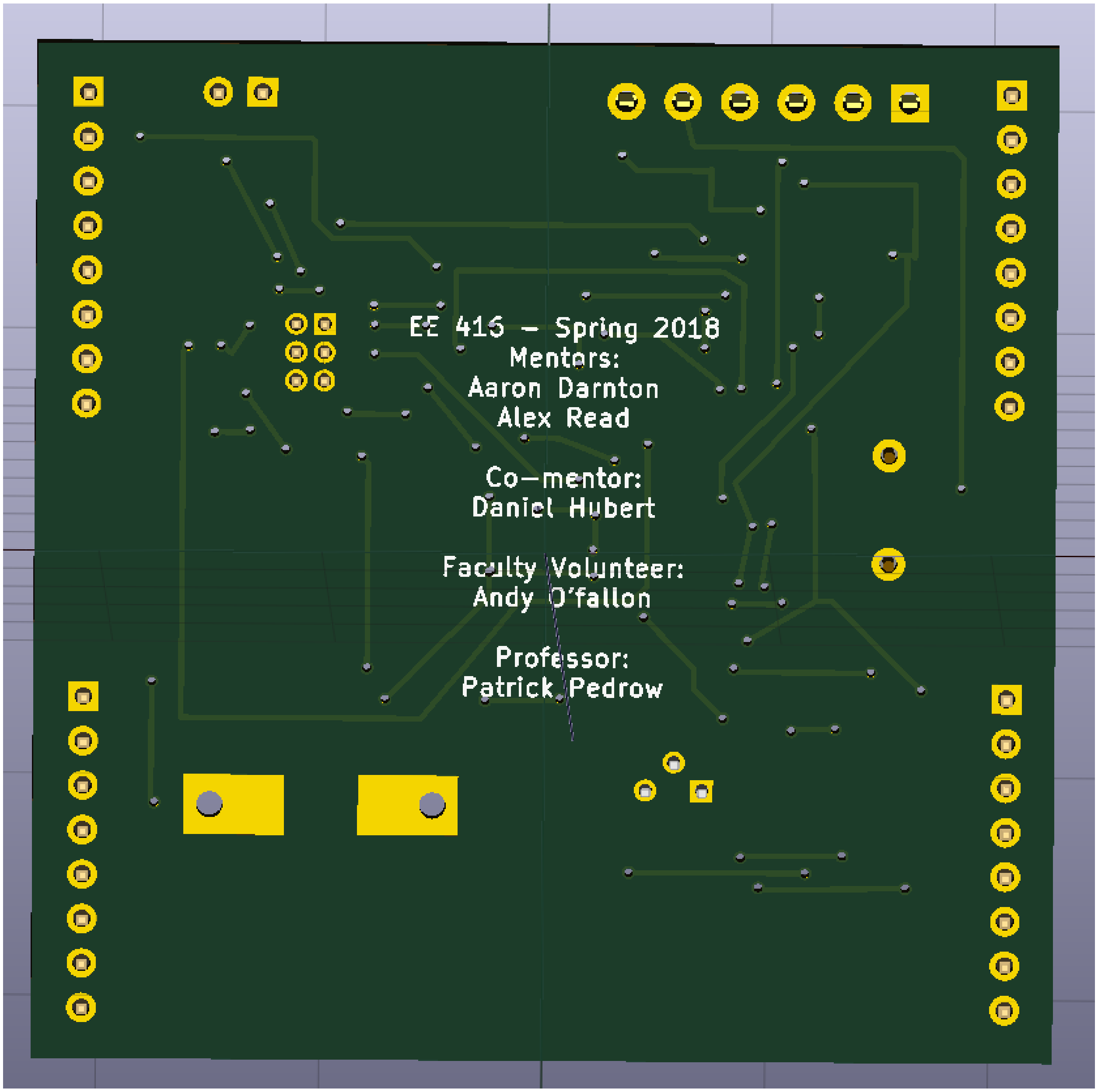

Fig 8. 3D Model Bottom View Onboard System PCB

In addition, the board is designed with the chip placed in the middle and all components around it for signal quality purpose. A reset button is added to the board to reset the system if needed. The probe ports are placed at the end of the board for easy access when the PCB is integrated on the sub. The JST_GH connection ports with 1.25 mm pitch are used for the probe ports. Since we use OSH Park as our manufacturer for PCB layouts, we need to follow their design rules for minimum trace widths, trace spacing, drill diameter, and annular ring diameter from OSH Park. Our PCBs layout meets all of these requirements.

Simulation Results:

Several simulation tests were performed for each schematic and PCB design during the design process to ensure our design meets all client's requirements with no errors. When the schematic of the onboard system was designed, the electrical rules check (ERC) application was performed to make sure all the connections on the schematic were correct. There were no errors or warnings found during the process. The record of the testing process is shown in Figure 9. In addition, the design rules check (DRC) was performed for the PCB design to ensure all the design rules were satisfied. There were no problems or unconnected errors found during the process. The record of this process is shown in Figure 10.

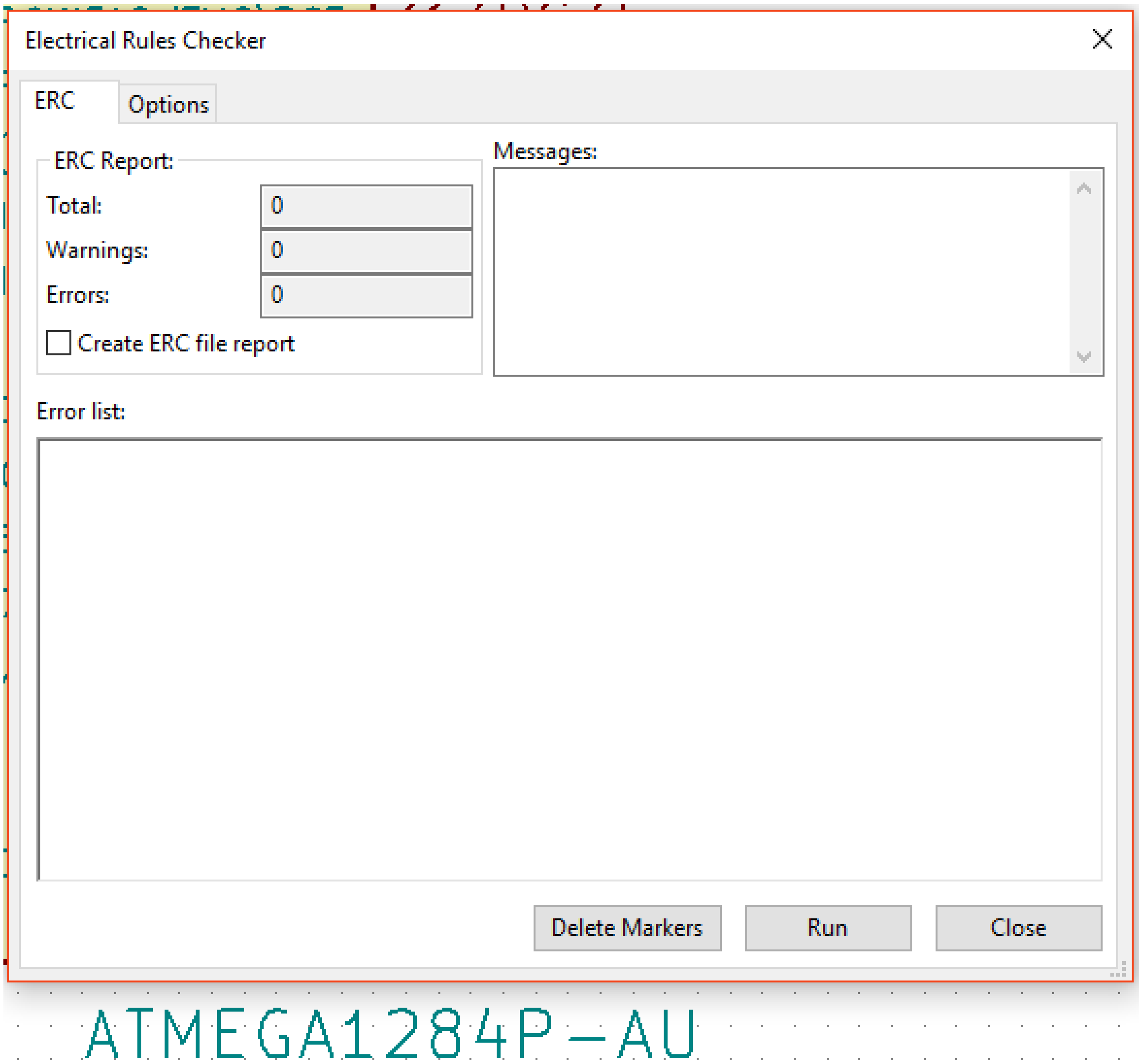

Fig 9. ERC Testing Process Onboard System PCB

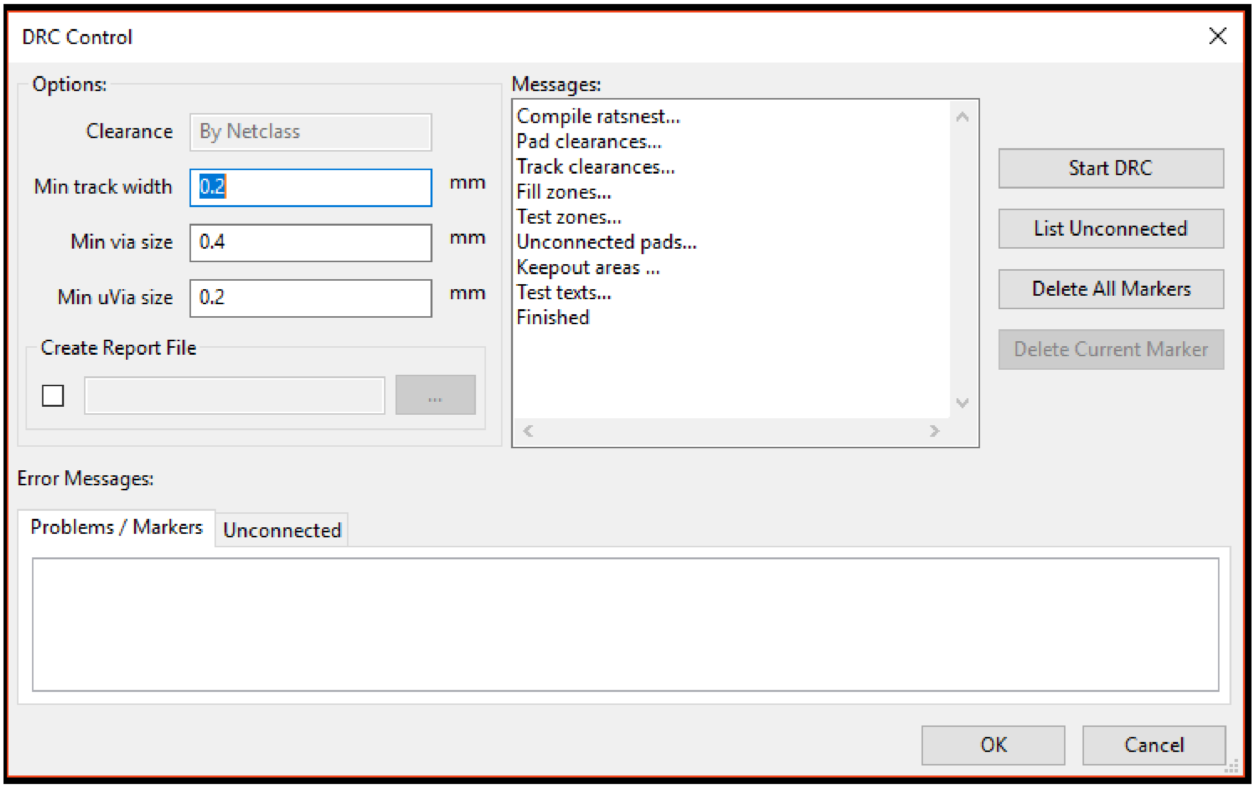

Fig 10. DRC Check Onboard System PCB

Since the actual board for the PCB design did not arrive in time, the testing process was constructed on a breadboard with the SOS leak detector, and with Arduino Nano. The Arduino Nano uses a similar microcontroller to our onboard system. It uses an atmega328P, which has a smaller amount of memory than our actual microcontroller (atmega1284P). The memory comparison table for both microcontrollers is shown in Table 2.

Table 2 Memory Comparison Table

Features	Atmega328P	Atmega1284P
Flash (Bytes)	32K	128K
SRAM (Bytes)	2K	16K
EEFROM (Bytes)	1K	4K

However, for this project, we do not need a lot of memory from the chip. Therefore, it will not affect our testing results. The probe was connected to the Arduino Nano board, and an LED on the breadboard. The code was written and uploaded to the Arduino Nano via Arduino IDE. When the probe is dry, the LED will not turn on and a “Dry!” message will be sent to the CPU. When the probe is wet, the LED will turn on and a “Leak!” messages will be displayed.

The record of the testing process is provided in Figure 11, Figure 12, Figure 13, and Figure 14, The test was constructed successfully. The analog signal was used to detect the leak and send warning messages to the CPU. The SOS Leak Sensor was able to detect the leak with one drop of water and sent the warning message to the CPU. The LED which is used to indicate the sensor status was turned on when a leak occurs. In addition, when there is no leak, the signal is not pulled high to the VCC, and the LED will not be turned on. The system also sends a “safe” message to the CPU in this case.

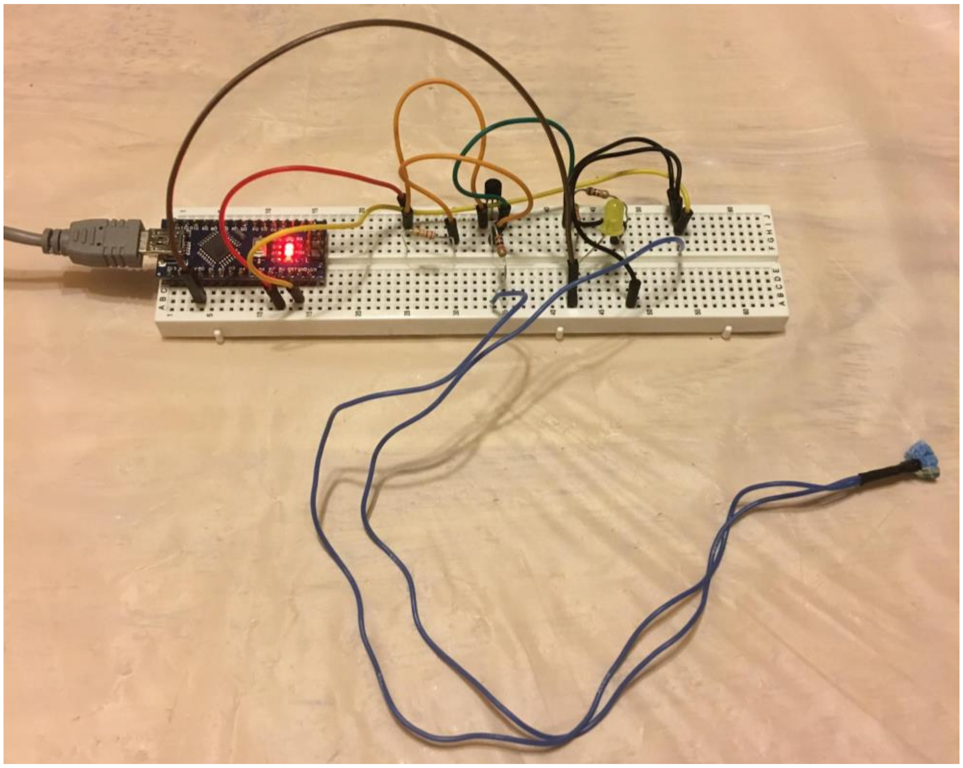

Fig 11. The Dry Probe With LED Off

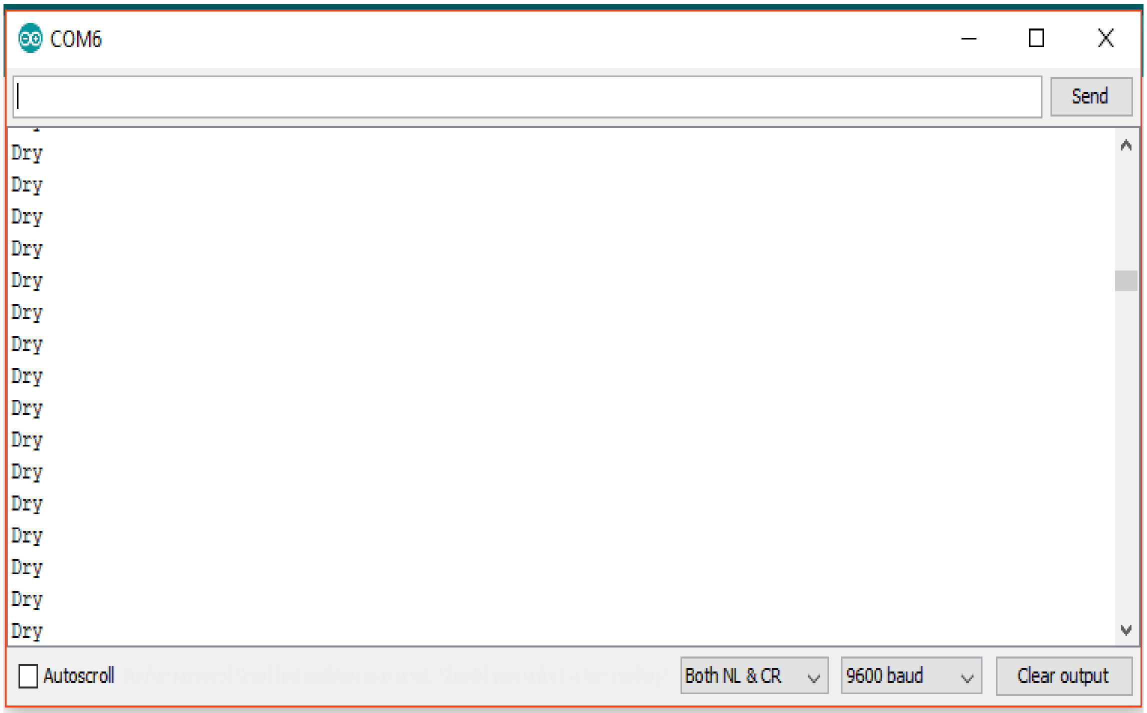

Fig 12. The “Dry” message.

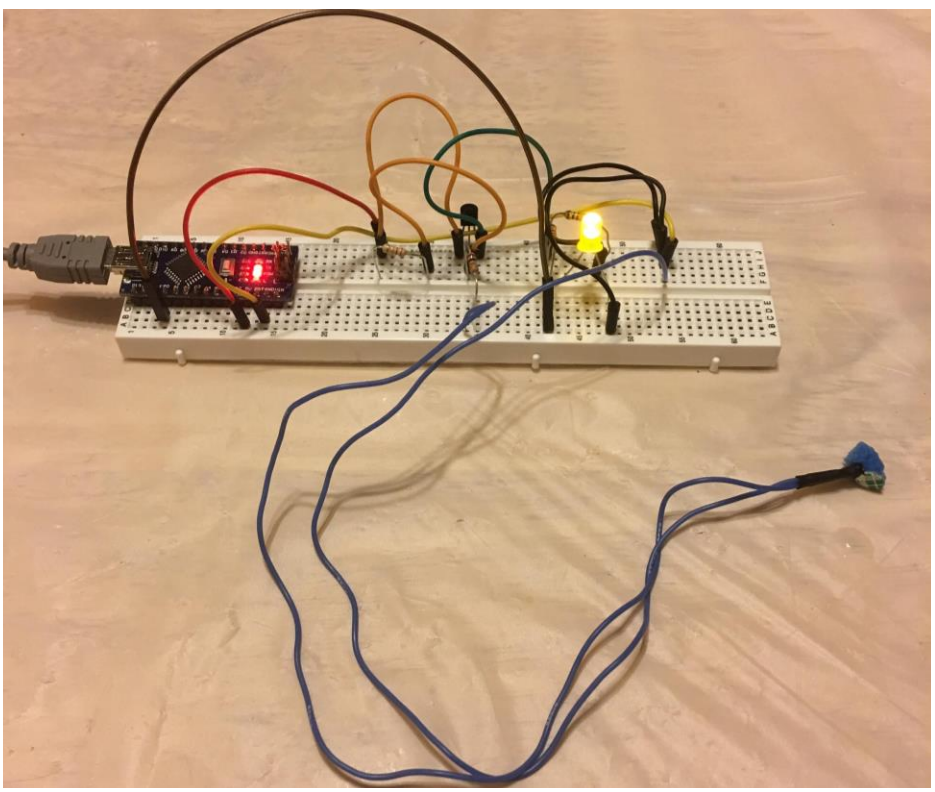

Fig 13. The Wet Probe with LED On

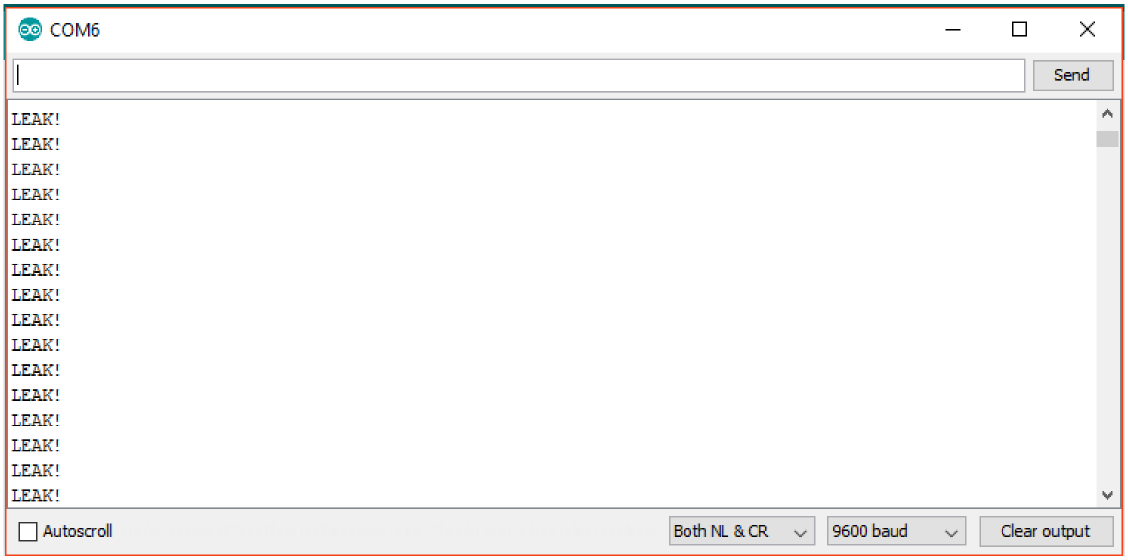

Fig 14. The “Leaking” Message

A back up plan was designed in case the onboard system does not work as we expected. The Arduino Nano Shield was built with the SOS Leak Sensor as the backup plan. Another schematic and PCB were designed for the Arduino Nano Shield, with the SOS leak sensor. The schematic of Arduino Nano Shield is designed based on the requirements of this project. The SOS Leak Sensor is added to the schematic as well as indicator LEDs. The schematic of our backup plan is shown in Figure 15.

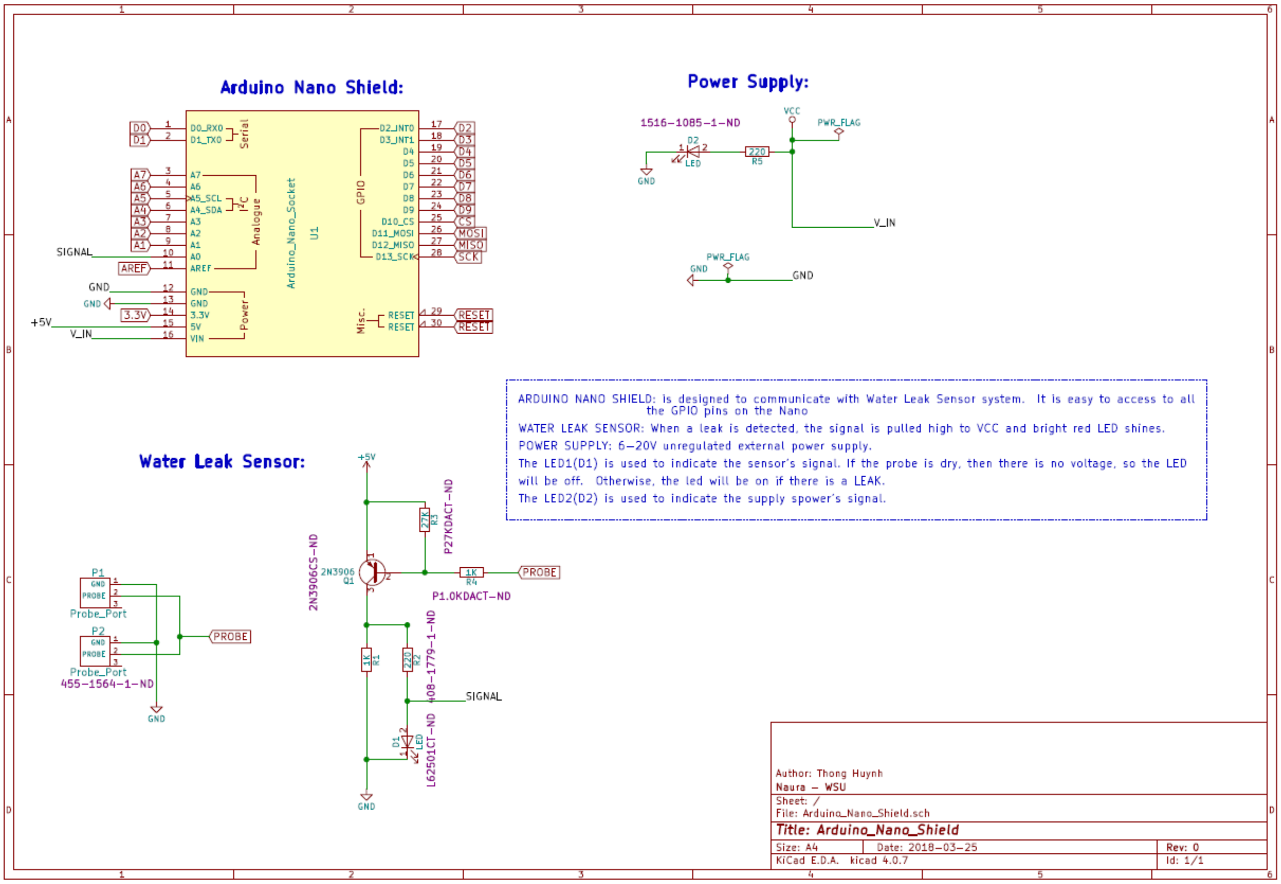

Fig 15. Arduino Nano Shield with SOS Leak Sensor Schematic

The method used to design the Arduino Nano Shield is more simple than the onboard system. There are three main components on the design, which include: the Arduino Nano shield, SOS Leak Sensor, and Power Supply. The SOS Leak Sensor is designed the same as the onboard system. The Power Supply will come from the actual Arduino Nano, and an indicator LED is used to check the power's signal. The Arduino Nano Shield is designed with thirty pins, 15 pins on each side and the dimension of each pin have to match with the pin of actual Arduino Nano which is 0.1 inch. The dimension of the shield needs to be 1.9 inch x 0.8 inch according to the physical dimension of the Arduino Nano.

Moreover, all the testing processes, electrical rules check, and design rules check were performed for this design as well. A Robosub club logo is placed on the front-copper layer of the PCB and our team member names are placed on the back-copper layer of the PCB. layout of Arduino Nano Shield is shown in Figure 15. The testing results are shown in Figure 17, and Figure 18. No errors were found during this testing process which means all the connections on the schematic are correct.

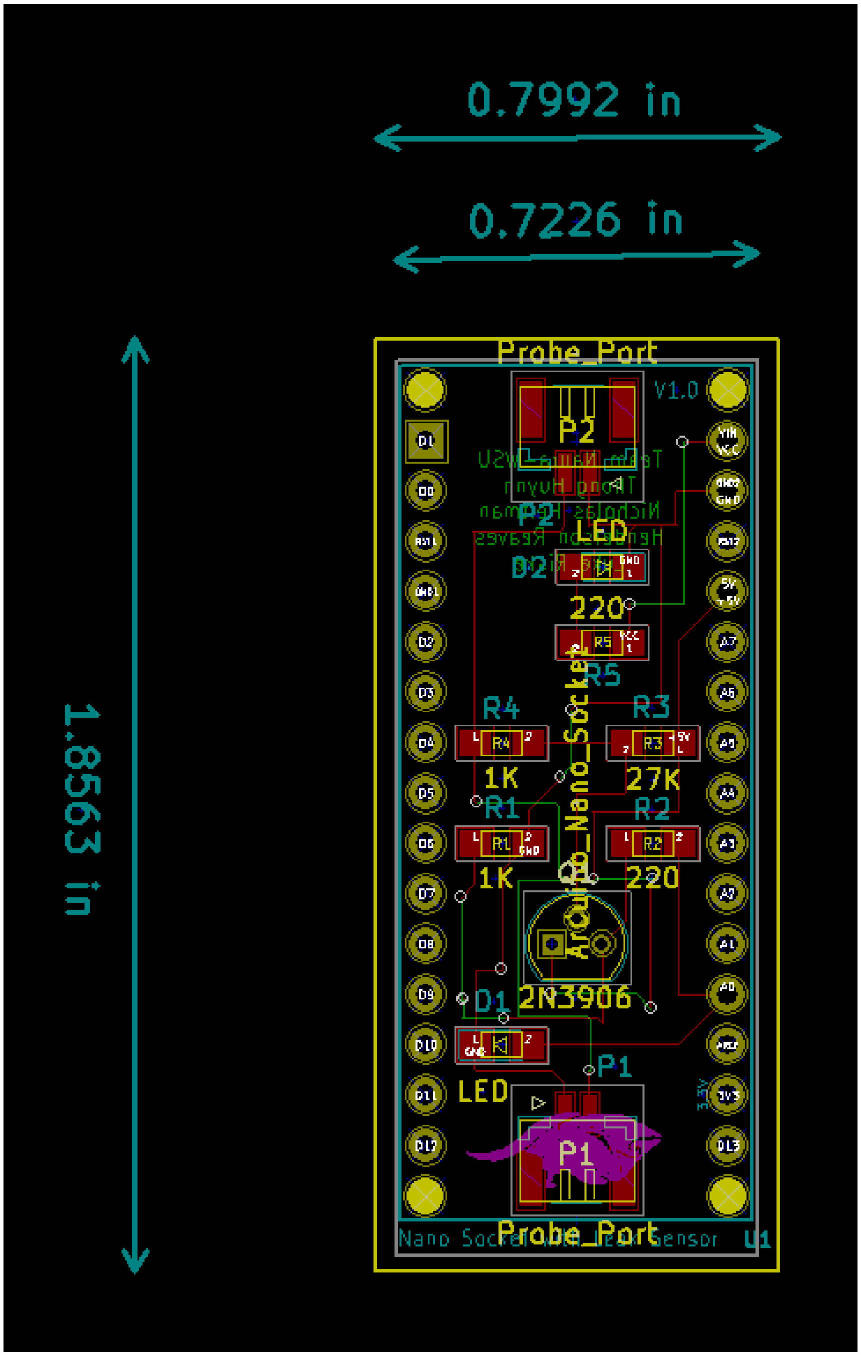

Fig 16. The PCB layout of Arduino Nano Shield with SOS Leak Sensor

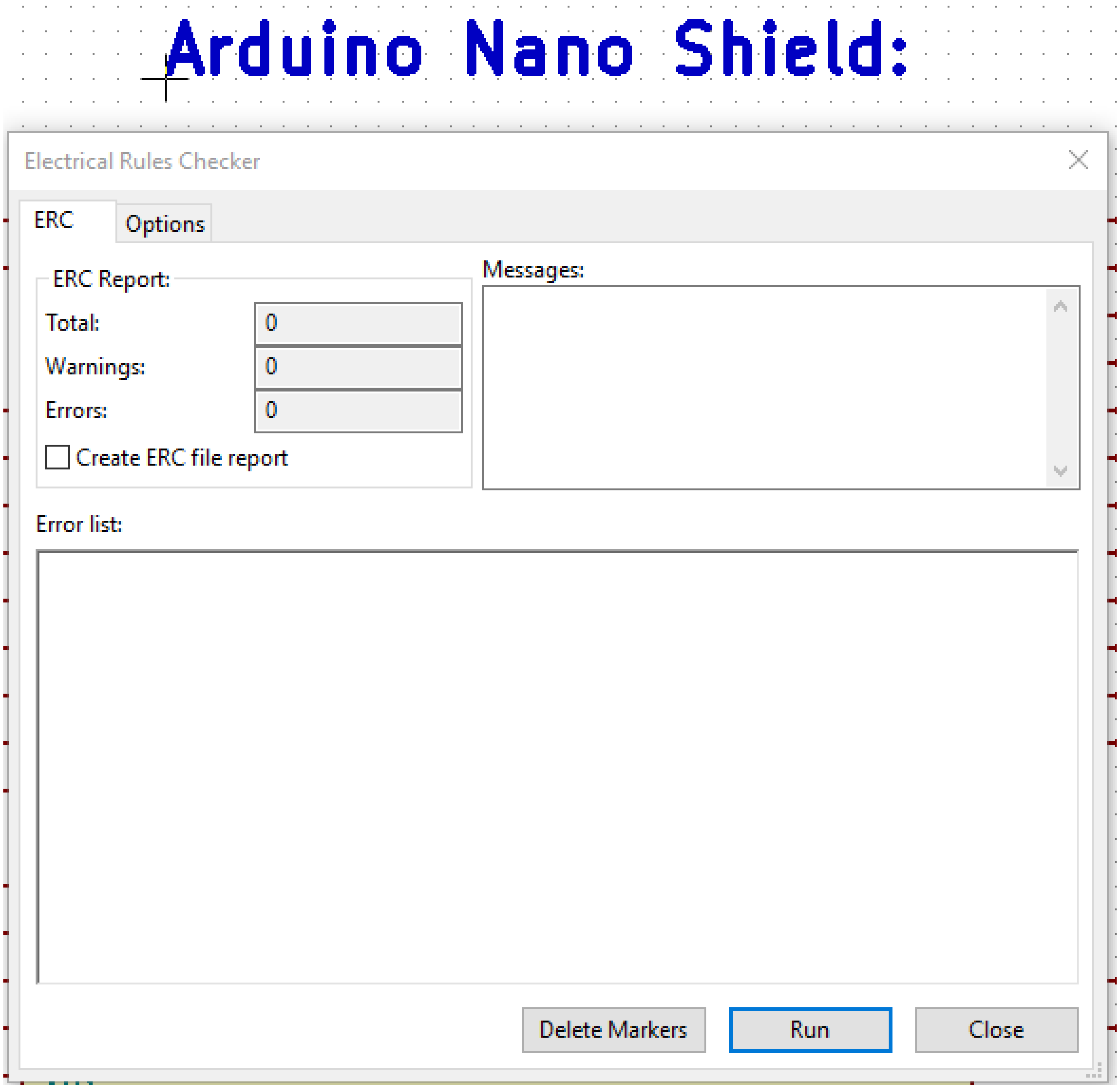

Fig 17. ERC testing process Arduino Nano Shield

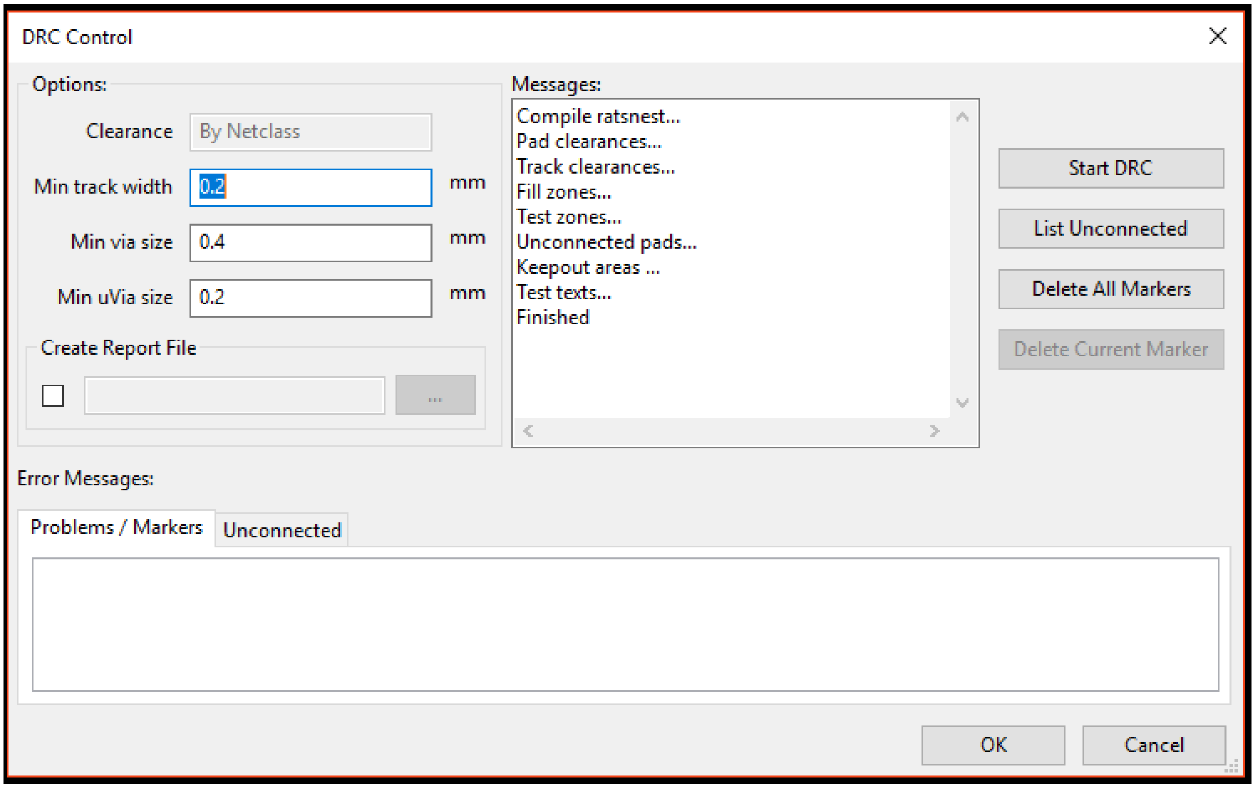

Fig 18. DRC Testing Process Arduino Nano Shield

In addition, an Arduino Nano was used in the breadboard model with SOS Leak Sensors and an indicator LED to test for prototype. The results satisfy our client's requirements. Thus, our backup plan is successfully designed and tested.

Broader Impacts and Contemporary Issues

Underwater vehicles are currently providing strong opportunities on the WSU campus. Current development of these vehicles is directed towards exploration on Earth and outer space. In the article, "WSU Researchers Build -300ºF Alien Ocean to Test NASA Outer Space Submarine," Tina Hilding describes the current research towards creating a testing chamber to emulate a submarine exploring the seas of Saturn's moon "Titan." [3] Having a submarine in this environment would impact our methods of leak detection immensely. The variable temperatures and pressure levels of Titan would require our design to be reconsidered from both software and hardware standpoints. The article "A new generation of Titanic exploration," by Randy Bolerjack explains another project currently being pursued on the WSU campus. The article explains WSU electrical contributions to a five-person submarine with hopes of descending to view the wreckage of the Titanic in the near future. [4] This project could integrate with similar methods of leak detection we developed throughout this course. Reconsiderations would have to be made to account for size of the submarine, and level of pressures experienced at the depths of the Titanic.

The future for autonomous vehicles is promising. Autonomous vehicles have already been introduced to society in the form of drones and driverless cars, where innovation is still taking place. However, Autonomous Underwater Vehicles (AUVs) are still in the early stages because they face a big barrier, water. The underwater environment that these vehicles operate in blocks all electromagnetic radiation waves which is what all other conventional communication systems use, hence the need for new innovations. Despite this fact there are a lot of commercial and military applications for these vehicles. The article titled “Infographic: The Future of Autonomous Underwater Vehicles” by Stephen Cass provides some details on how AUVs have adapted over the past 10 years to overcome some of the design challenges posed by the aquatic environment. For example, when inspecting underwater infrastructure such as pipelines, they could use a combination of sonar and camera systems to identify landmarks on the seafloor for reference. [5]

In recent years, the concept of networking has become popular between underwater autonomous vehicles. The article “Low Cost Autonomous Underwater Vehicles for New Concepts of Coastal Field Studies,” by L. Madureiraf, A. Sousaf, J. Sousa and G. Goncalves provides benefits to networking vehicles for environmental studies. When referring to acquisition of data during the event of a natural disaster they write, “With the current technologies, tools, and models, it is simply not possible to inter-operate vehicles, sensors and communication networks with different vendors/institutions” (Madureiraf, 2009). They infer that networking autonomous vehicles can spread information more effectively, but this function in autonomous vehicle manufacturing is limited. The authors also explain that networking provides the opportunity for better planning, and supervision of underwater missions from land. [6]

In their current state Autonomous Underwater Vehicles are widely used throughout the Oceanography field to gather data and perform certain tasks for researchers. However, some suggest that they are not as effective as they could be. The article titled “Adaptive Autonomous Underwater Vehicles: An Assessment of Their Effectiveness for Oceanographic Applications” by Mario Paulo Brito and other contributors, explains how AUVs are behaving more automatic than autonomous, meaning their behavior isn’t as adaptive as it could be which leaves more exciting data ungathered. The main difference here is that adaptive mission planning (AMP) isn’t being utilized by the AUVs in the field. Of all the researchers surveyed agree that the scarcity of demonstration trials for AMP on AUVs is a primary cause for this difference in operation. If these trials could be conducted the possibilities would greatly increase. [7]

Limitations and Recommendations

There are three major limitations that have been assessed with the pre-submersion beta prototype system. These limitations deal with component reposition on the PCB, and space constraints of the portable case.

One of the limitations of the pre-submersion leak detection system is the current orientation of the LCD screen. The portable case was designed with the LCD screen mounted upside down when propped in the upright position, which makes it difficult for the user to determine the state of the test. The current orientation of the LCD screen when the case is in the upright position is shown in Figure 18. Our team tried to mitigate this problem with software revisions by printing characters to the LCD upside down, but only 8 custom characters are available to be produced out of 32 total. This has since been fixed in the PCB layout, and it is recommended that the Robosub club uses the revised layout if it is ever reprinted. This could also be fixed by reprinting the portable case with the mounting position in the opposite direction. It is still possible to easily visualize the state of the test when the case is placed with the window facing upward.

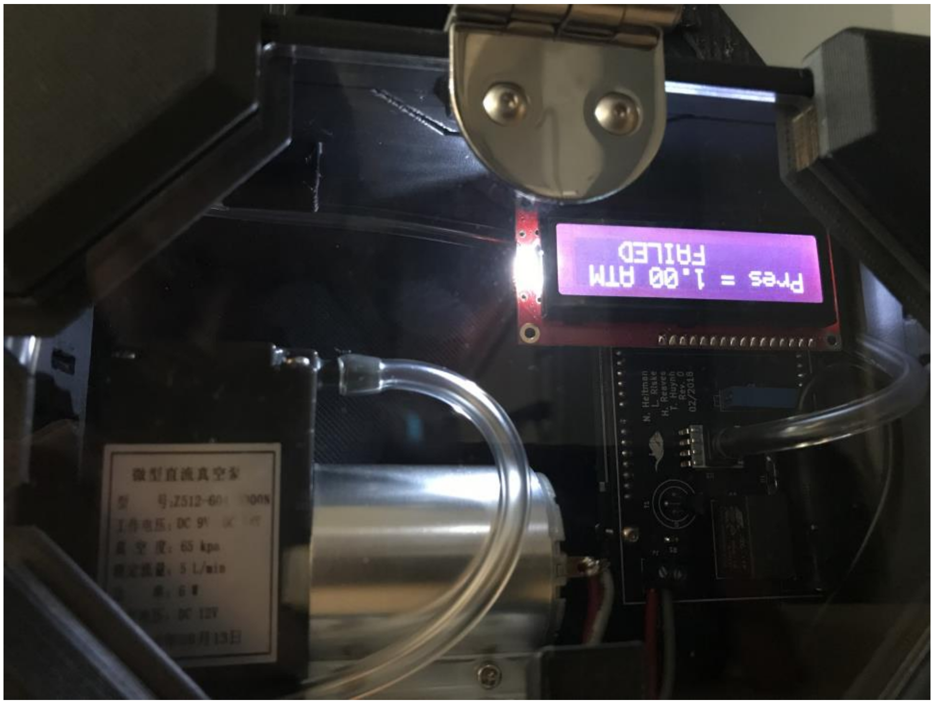

Fig. 18 LCD Screen with Upside Down Orientation

In addition, the layout of the pre-submersion PCB was made with the barrel jack port facing inward by mistake. Luckily, the port still plugs in, but it would be convenient to be plugged in from the outward position. The picture in Figure 19 shows the barrel jack port facing inward to the PCB. This limitation has been revised in the PCB layout, which is recommended if the PCB needs to be reprinted in the future.

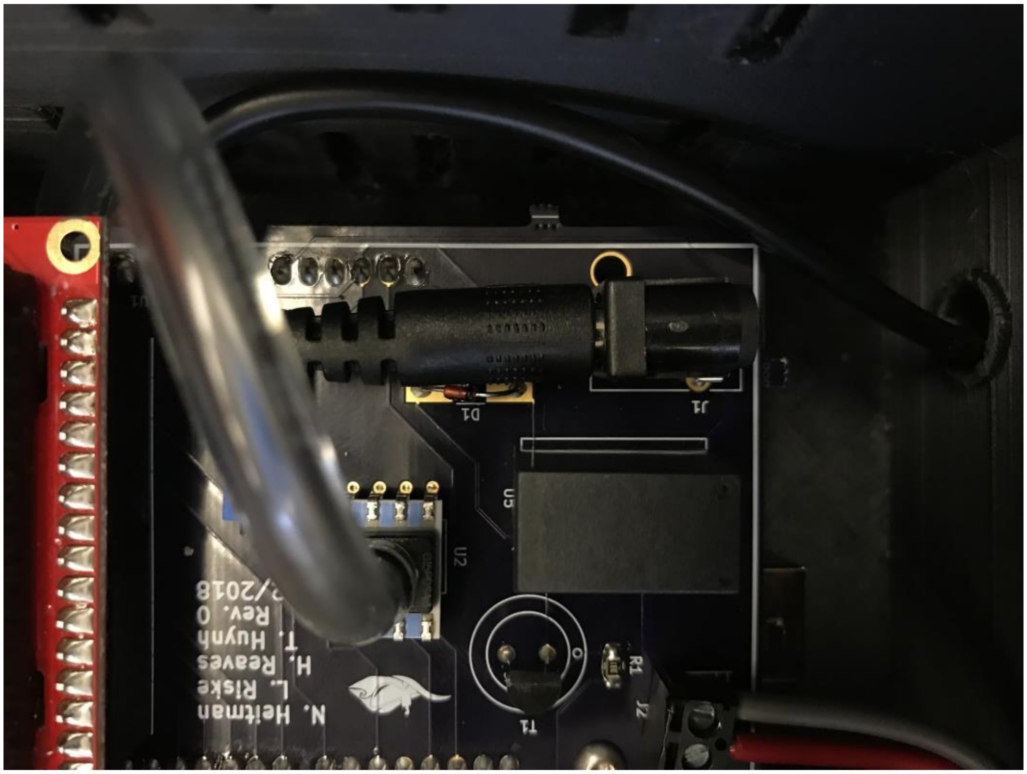

Fig. 19 Inward Orientation of the Barrel Jack Adapter

The biggest limitation of our pre-submersion system is the strength of the vacuum generator. From our testing results, it takes an average of 46.1s to reach the threshold of 0.9ATM when used with the Robosub autonomous submarine. If the current testing time is undesirable, this vacuum operation time could be decreased substantially with a more powerful vacuum. Although, if replaced, the size of the portable case must be considered. The portable case only supports the footprint of the current vacuum generator, and we recommend that it is revised if the vacuum is ever substituted.

Conclusions and Future Work

Overall, the current state of the pre-submersion system is a functional beta prototype. Our test results conclude that the system is capable of testing airtightness on a closed vessel. Over the course of this semester the pre-submersion system has been developed into a simplistic standalone unit that can be used to test multiple vessels. To further enhance the system will require layout revisions to be reprinted, and modifications to the portable case. These limitations will require extra time, and budgeting moving forward. The system functions as desired in the current state, and it is up to the client if future work needs to be poured into these revisions.

From our test results, the onboard system performs as intended. The system still requires integration with the Robosub autonomous submarine. This will be considered as future work for the final weeks of the semester.

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The following people provided us with help, and guidance throughout the course of the semester:

I. Aaron Darnton and Alex Reed - NAVSEA Mentors
II. Professor Andrew O’fallon - Faculty Mentor
III. Ben Songras - WSU Robosub Club Electrical Engineer Leader
IV. Ryan Summers - Robosub Club Leader
V. Alex Lanphere - Portable Case Designer for Pre-Submersion System
VI. Rustom Jehangir - Employee at Blue Robotics (permitted use of the circuit to read SOS probes)

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Appendix

Appendix A. Team Photo

Left to Right: Thong Huynh, Henderson Reaves, Nick Heitman, Luke Riske

Appendix B. Description of EE415 Senior Design Algorithm

In EE415 we were asked to design a leak detection system for the WSU Robosub club. After labeling the customer needs, we began our pursuit of target specifications. We were informed that the club wanted the system to be: a standalone system that operated on its own power source, simple in design so that it could be removed during maintenance work, arduino compatible, and able to check the pressure of the system pre submersion. Moving forward we began to develop concepts.

The concepts we came up with included: building a small robot to patch leaks if they occurred, a moisture detection system similar to those in commercial optical fiber cables, and using a pressure sensor to detect deviations in pressure that would indicate a leak. Originally, we had decided to pursue the pressure sensor method, and began brainstorming for that particular design. After being advised by our mentor Aaron Darnton that pressure deviations would not be great enough to signify a leak, we decided to go with the moisture detection method. At this point in time it was brought to our attention that this project should consist of two separate designs: the onboard system to detect water infiltration, and an off board pre-submersion pressure system that would be automated.

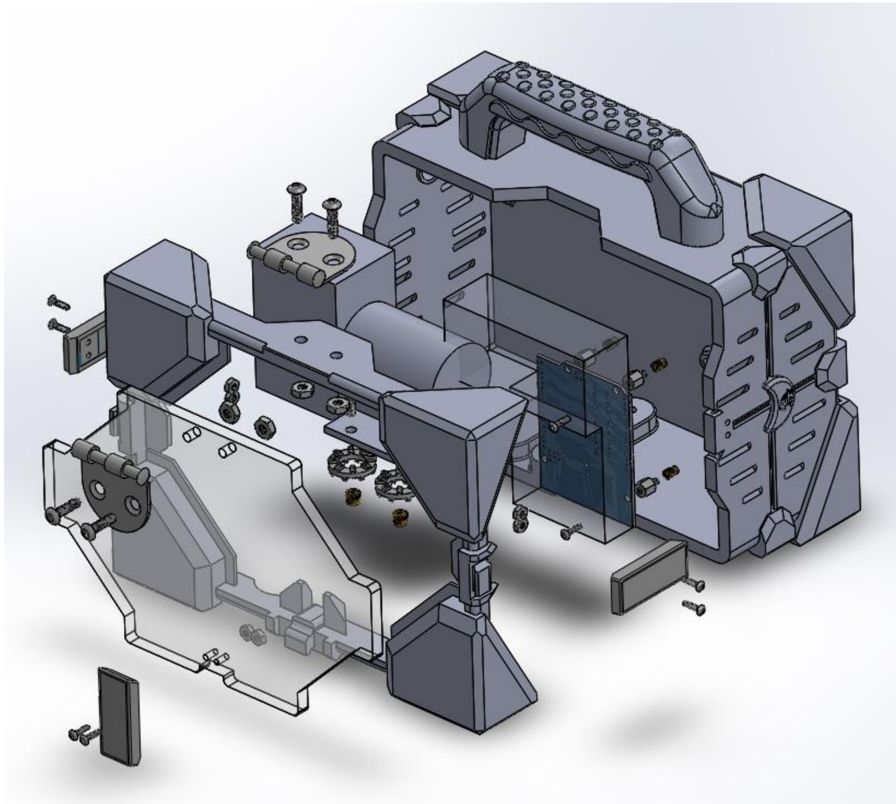
Putting the onboard system on hold, we started the iterative design process over, and began to work on the automated vacuum system. We knew what the club wanted so we got started on establishing target specifications. The club said that they wanted the internal pressure to be brought down to 0.9ATM, and that it should hold this pressure over a substantial amount of time. Knowing the target specifications we began the concept generation process.

To simplify our concept generation process we started by making sure we did not encroach on any designs that have been patented, so we researched the Thomas register, and patents in this field of work. A vacuum generator, a pressure sensor, an arduino compatible chip were the baseline for the project. We were informed by our mentor Aaron Darnton that the vacuum generator could be an air mattress pump, but the club had already come into contact with a vacuum generator. We decided to utilize the one that the Robosub club provided. We then began brainstorming the functional process for the system, and determined which concepts we would actually select.

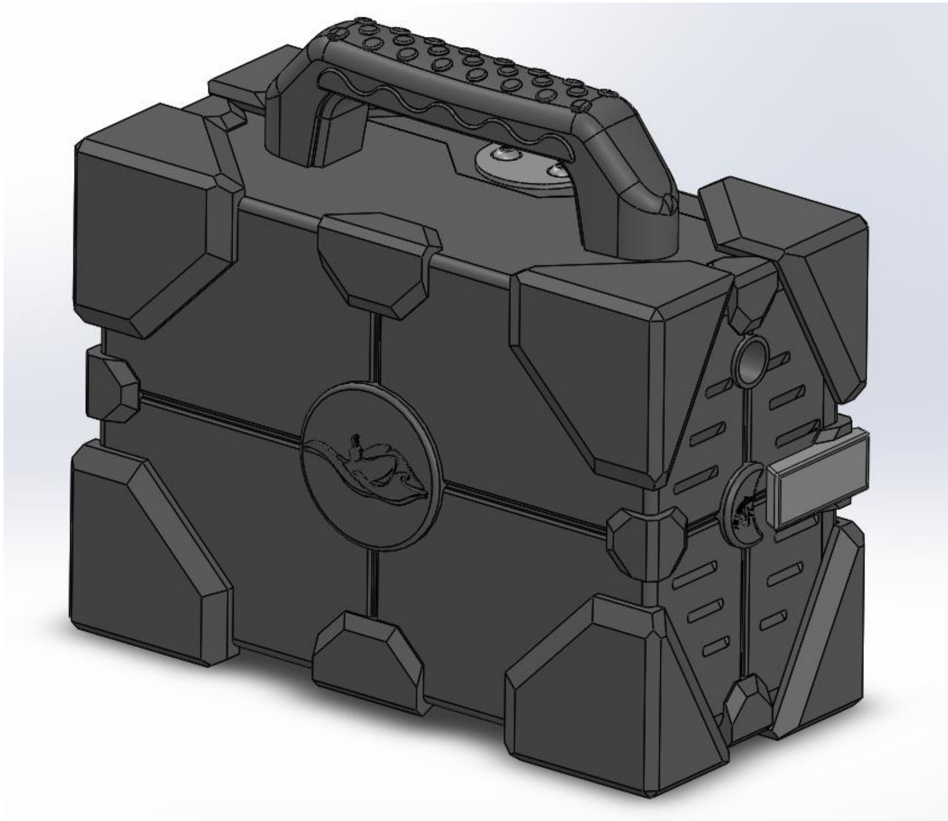
Utilizing a concept selection table we broke down every area that our system would need to cover in order to function, and began researching components that fit the target specifications. After assembling a list for all of the component that would be required for the project to function correctly, we began designing multiple layout configurations, for which the project could be built. Next we selected, and constructed the project on a breadboard. Then we tested its functionality, and began to plan for the future Beta Prototype development, and how we could potentially improve the system we had just created.

At the end of EE415 we had a fully functional alpha prototype for the pre-submersion system of leak detection. Moving into EE416 we knew that we still needed to develop the onboard system to fully satisfy the clients needs. Our team also wanted to simultaneously shift our pre-submersion alpha prototype to a PCB, and simplify the mass of wires we had in its the breadboard circuit. We also wanted to provide a portable carrying case so that all of the pre-submersion components were contained, and easily transportable.

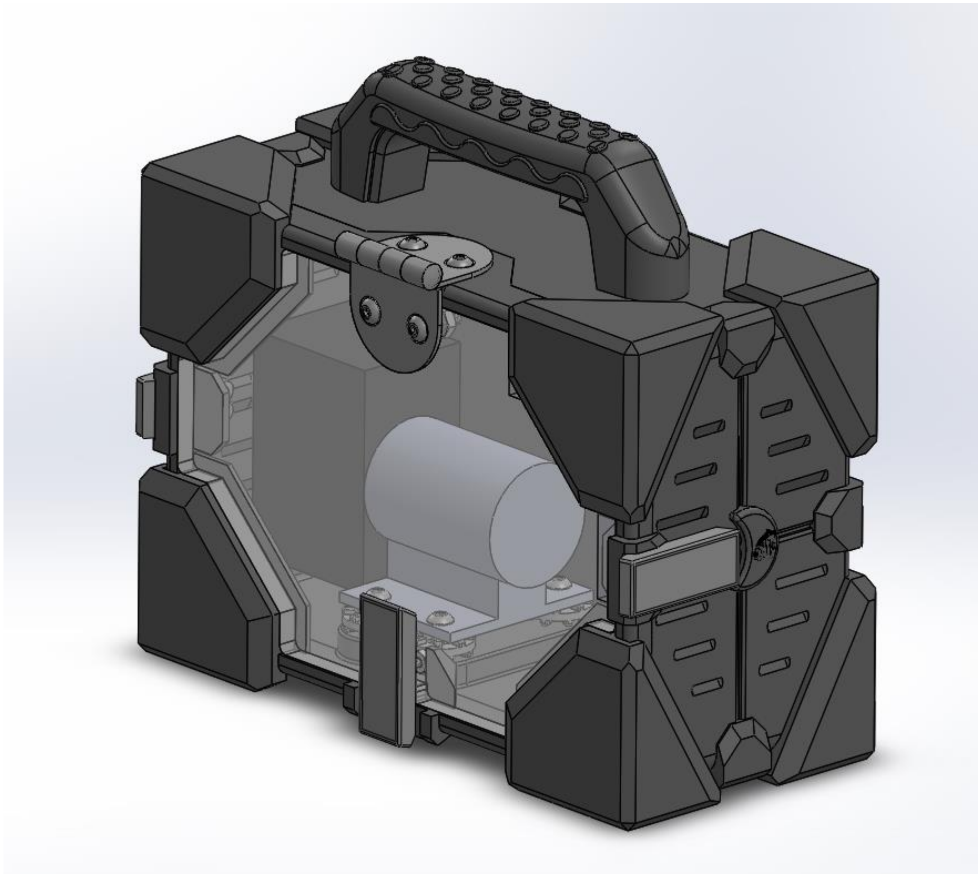
Appendix C. Images of Portable Case for Pre-Submersion System (Accredited to Alex Lanphere)



C-1: 3-D Model Exploded View of Portable Case for Pre-Submersion System



C-2: Back View of Portable Case for Pre-Submersion System



C-3: Front View of Portable Case for Pre-Submersion System