Wireless Data Acquisition (wDAQ) System for High Frequency Ultrasound Signals

Design Document

sddec25-06
Avishek Das
Prof. Manojit Pramanik
Merrick Czaplewski
Samuel Foster
Jerry Liu
Rocco Yassini
sddec25-06@iastate.edu
https://sddec25-06.sd.ece.iastate.edu

Revised: 5/4/25 /1.1

Executive Summary

The wireless data acquisition system is being designed and made for the purpose of gathering data in the ultrasound lab used by BioMedical students. The original design was made with BNC cables attaching the oscilloscope to the multiple sensors to gather 2D data at many different angles as the device spins similar to that of an MRI machine. The major problem for this system is that the cables to transmit the data from the probes to the display get tangled up as the testing device spins, not allowing for easy use. The solution to this problem is to have the oscilloscope spin with the testing device and transmit the data through wifi or bluetooth to another device to display.

The main requirements for this design are wireless data transmission, real life data transmission, the input should be amplified onboard, a sample rate 20-25 M S/sec, a max input voltage of ± 2 volts, a resolution of 12 bits, a record length of 50-100 µsec, the transmission chip being the ESP32 and the interface program being LabView. The main part that is being focused in this project is the wireless data transfer and the design used is a combination of 2 chips, and a computer with it's monitor for the display. The two main chips are the STM32H750 and the ESP32 as per required above. The ESP's internal clock can not sample the data at a fast enough rate to match the required so the STM BlackPill (32H750) is being used to meet the sampling rate requirement with its internal clock running up to 480 MHz and will also act as the ADC in the system. The initial tests are being done on the less powerful STM BluePill, and once those are complete, the BlackPill will be used in the tests.

The progress on the project has reached a point where the next steps will be for the team to connect the STM BluePill to the ESP32 to attempt to transmit the data over the wifi. The data is showing up on the display with the majority of the coding for the BluePill being finalized. This does not meet the main requirements, specifically with the sampling rate, the display and the transmission not corrupting the data. This is due to the internal clock of the BluePill being at 48 MHz but the transition to the STM BlackPill chip will allow for us to meet the sampling requirements to have us move onto the display requirements. The next steps will be to finalize the code for the BluePill, test out the code with a wired display and then move on to work on the code for the ESP32 chip for it to transmit over the wifi.

Learning Summary

Development Standards & Practices Used

- IEEE 802.11ac - Wireless Communication Standard
- IEEE 1657-2009 - Battery Management Standard
- IEEE 11073 - Medical Device Communication Standard
- ISO 9001 - Quality Management Standard
- ISO/IEC 27001 - Information Security Management Standard

Summary of Requirements

- Wireless System to allow for flexibility and mobile data collection
- Real-time transmission and immediate analysis
- Input needs to be amplified and filter with onboard low-noise amplifiers
- ADC conversion rate is 20-25 M S/sec
- Record length is 50-100 µsec
- Maximum Input voltage of ± 2 volts
- Input Impedance of 50 - 1M ohms
- Two channels pers module
- Resolution is 12 bits
- Interface program LabView
- The transmission chip being the ESP32

Applicable Courses from Iowa State University Curriculum

- CPRE 2810
- CPRE 2880
- EE 2300
- EE 3300
- SE 3090
- SE 3190
- SE 4390

New Skills/Knowledge acquired that was not taught in courses

- Data collection and transfer over bluetooth and wifi
- Programing in C
- STM32Cube IDE to program the Blue and Black Pills
- Data capture and storage on microchip devices

Table of Contents

1. Introduction 5

1.1. Problem Statement 5

1.2. Intended Users 5

2. Requirements, Constraints, And Standards 5

2.1. Requirements & Constraints 5

2.2. Engineering Standards 5

3 Project Plan 6

3.1 Project Management/Tracking Procedures 6

3.2 Task Decomposition 6

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria 6

3.4 Project Timeline/Schedule 6

3.5 Risks And Risk Management/Mitigation 7

3.6 Personnel Effort Requirements 7

3.7 Other Resource Requirements 7

4 Design 7

4.1 Design Context 7

4.1.1 Broader Context 7

4.1.2 Prior Work/Solutions 8

4.1.3 Technical Complexity 8

4.2 Design Exploration 9

4.2.1 Design Decisions 9

4.2.2 Ideation 9

4.2.3 Decision-Making and Trade-Off 9

4.3 Proposed Design 9

4.3.1 Overview 9

4.3.2 Detailed Design and Visual(s) 9

4.3.3 Functionality 10

4.3.4 Areas of Concern and Development 10

4.4 Technology Considerations 10

4.5 Design Analysis 10

5 Testing 10
5.1 Unit Testing 11
5.2 Interface Testing 11
5.3 Integration Testing 11
5.4 System Testing 11
5.5 Regression Testing 11
5.6 Acceptance Testing 11
5.7 Security Testing (if applicable) 11
5.8 Results 11
6 Implementation 12
7 Professional Responsibility 12
7.1 Areas of Responsibility 12
7.2 Project Specific Professional Responsibility Areas 12
7.3 Most Applicable Professional Responsibility Area 12
8 Closing Material 12
8.1 Discussion 12
8.2 Conclusion 12
8.3 References 13
8.4 Appendices 13
9 Team 13
9.1 Team Members 13
9.2 Required Skill Sets for Your Project 13
(if feasible – tie them to the requirements) 13
9.3 Skill Sets covered by the Team 13
(for each skill, state which team member(s) cover it) 13
9.4 Project Management Style Adopted by the team 13
Typically Waterfall or Agile for project management. 13
9.5 Initial Project Management Roles 13
9.6 Team Contract 13

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

- Figure 1: wDAQ Gantt Chart
- Figure 2: Reported Hours Table
- Figure 3: Context Table
- Figure 4: Detailed Design
- Figure 5: Picture of ADC output waveform
- Figure 6: Areas of Responsibility Table
- Figure 7: Four Principles Table

1. Introduction

1.1. Problem Statement

Many labs across the country analyze signals and display them almost daily to understand their experiments better. This causes them to extensively use oscilloscopes (devices that display signals/waveforms) that have large BNC cables in order to transmit the data that is gathered at their probes. In certain applications the devices the oscilloscopes are attached to are rotating or moving which causes the BNC cables to become tangled. This prevents people from conducting tests with these kinds of setups without hassle. Furthermore, these cables take up a lot of room, take time to untangle from each other and need to be replaced every so often. It would be very beneficial to the scientific community if these devices were able to be utilized without cables. This project directly addresses all of these problems, by creating a device that can do everything a conventional oscilloscope can without the cables, transmitting the data over wifi. Such an invention would revitalize labs across the world, by freeing up immense amounts of storage and laboratory space; it would also allow for new experiments to be conducted by freeing them from the constraints of wired oscilloscopes. This also allows for the oscilloscope to be moved and can allow for the device to be used in other experiments.

1.2. Intended Users

Some people that may use the wDAQ include lab technicians, students, and faculty. The lab technicians using the wDAQ will be taking multiple measurements in quick succession, so they need a device capable of rapid use, such as in the specific situation the client provided with the rotating arm to acquire 2D data, similar to MRI scanning. They would benefit from the wDAQ because it would enable them to take measurements from devices that are spinning that would otherwise not be as useful or time efficient. The students will be using labs once a week and don't want to be present longer than necessary to complete other work, school and home related. This causes them to want a device with an easy to use interface to minimize difficulties during lab sessions. They would also benefit from the wDAQ because they would be able to project results directly to their personal devices which remove a considerable amount of hassle during lab sessions trying to find a way to gather the information from the oscilloscope. Lastly, the faculty use multiple different oscilloscope devices in multiple different locations, so they need an oscilloscope that is portable and easy to take to and from different locations. This allows for their specific settings to stay from location to location also allowing for quicker use.

2. Requirements, Constraints, And Standards

2.1. Requirements & Constraints

Functional requirements:

The system needs to display signals like a regular oscilloscope, showing voltage and current. To ensure the correctness of data acquisition, it needs to support a high-speed internal clock of at least 20MHz to ensure that data can be read on demand and with enough precision for the use of the lab specific environment.

Resource requirements:
The STM32 microcontroller chip and ESP32 Bluetooth and Wifi transmission chip provided by the client must be used.

Physical requirements:
The system needs to be small and lightweight, similar to that of a calculator, easy to install on the lab specific machine and have mobility. Data transmission must be wireless and cannot rely on any external connection cables.

User experience requirements:
The system needs to be easy to disassemble and install, easy to move, and stable when rotating at most speeds. Users should be able to easily connect to the computer program for the display and view the data.

Environmental requirements:
The system needs to effectively shield most electromagnetic interference (EMI) to ensure clear and accurate data.

Standards and constraints (supplementary notes):
Physical standards: Since the project requires increased mobility and flexibility, it is necessary to ensure that the equipment is small and lightweight. This is especially important for users who need to move equipment frequently or work in different environments.

Wireless standards: Wireless transmission must comply with existing Wi-Fi standards (IEEE 802.11) and have high anti-interference capabilities to ensure stable and secure data transmission in operation.

Electromagnetic interference (EMI) standards: The project needs to comply with appropriate electromagnetic compatibility standards to ensure that the device will not be subject to excessive interference during wireless transmission and will not affect surrounding equipment.

Safety standards: The system must meet basic electrical safety requirements during design and use to avoid potential risks such as overheating and short circuits.

2.2. Engineering Standards

Importance of Engineering Standards:
Engineering standards play a vital role in ensuring the quality, consistency and safety of design and technical implementation. Engineering standards ensure that different devices, technologies and systems can be seamlessly connected and that products can meet the expected functional requirements. For example, standardized communication protocols (such as Wi-Fi and Bluetooth standards) ensure interoperability between wireless devices, while electrical safety standards ensure the safety of equipment when in use.

Related Standard Selection:
According to the needs of the project, the following standards were selected from IEEE and other relevant standards:
IEEE 802.11ac - Wireless Communication Standard
This standard defines a high-speed transmission protocol for Wi-Fi communication, supporting high-throughput wireless network transmission. For wireless data acquisition systems (wDAQ), it is critical to ensure that data can be transmitted to computers stably and efficiently, especially when high-frequency ultrasonic signals need to be transmitted in real time. This standard ensures that the system has sufficient bandwidth and stability during wireless transmission.

IEEE 1657-2009 - Battery Management Standard
This standard specifies the design requirements, management and test specifications of battery systems to ensure the safety and reliability of batteries during use. Considering that the system will rely on battery power, understanding and complying with this standard is fundamental to ensure long-term stable operation of the system.

IEEE 11073 - Medical Device Communication Standard
This standard deals with data transmission protocols between medical devices and computer systems. Since the project system involves data acquisition of high-frequency ultrasound signals, the applicable medical device communication standard is essential to ensure compatibility between devices and accurate data transmission. This standard can help the team better design the interface and data transmission parts of the system.

Relevance of the standard to the project:
IEEE 802.11ac: This standard is closely related to the project because it ensures efficient and stable wireless data transmission. Considering the high frequency and large amount of data of ultrasound signals, this standard provides the required bandwidth and speed support.

IEEE 1657-2009: Battery management and safety are key elements of the project design, especially in terms of mobile and wireless operation. Following this standard will help the team ensure safe use of batteries under high load conditions and extend the system's operating time.

IEEE 11073: The project will be integrated with medical devices, so following this communication standard is essential to ensure reliable data transmission between different devices.

Other standards selected by team members:
After team discussion, the following standards were considered:
ISO 9001 - Quality Management Standard: This standard helps ensure that the team's design and manufacturing processes meet quality management requirements, thereby providing a reliable and efficient system.

ISO/IEC 27001 - Information Security Management Standard: For sensitive data in the system, especially in the field of medical and high-frequency data acquisition, the information security standard ensures that the team's data transmission and storage meet security requirements.

Modifications to the project design:
In order to meet these standards, the team will make the following modifications:

In the system design, ensure that the wireless transmission module complies with the IEEE 802.11ac standard to provide high-speed and stable data transmission.

The battery management part will be designed according to the IEEE 1657-2009 standard, select the appropriate battery and management system, and ensure safety during battery charging and discharging.

In the medical device interface part, the IEEE 11073 standard will be followed to ensure data compatibility and transmission stability.

The team will also introduce quality management and information security management standards to ensure that the quality and data security of the entire system meet high standards.

3 Project Plan

3.1 Project Management/Tracking Procedures

This project has a combination of waterfall and agile management style. Since the project has some necessary components, pre-defined development checkpoints come about through those components. These checkpoints follow a more waterfall approach, however teams are able to pursue these checkpoints with whatever strategy most effectively achieves them, which is more in line with the agile approach.

To track system progress, photo and written documentation of team work will be taken as the team goes, so that the system has evidence of what the team has done to refer back to.

3.2 Task Decomposition

The final product breaks down into a few key functions/components: Analog to digital conversion (ADC) of data, wi-fi transmission of data, and data visualization via a display. Of these, the most complicated and first component that must be developed is the ADC. The STM needs to receive the analog input, run a fast enough clock for itself, the amplifier and the wi-fi microcontroller and also convert the input to a displayable digital signal. For testing purposes, it is more beneficial to use a temporary display like a serial plotter, and develop it more so later down the line. This way, the team can tell if the ADC is successfully operating over a wired connection. The wi-fi connection comes next, configuring a separate microcontroller with wi-fi capabilities to receive and transmit the output of the ADC. Finally, the team will set up a display so that the transmitted digital signal generated by the ADC is readable by humans in a user-friendly interface. This will likely be done using LABVIEW.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

The major milestones for this project are:

- First the ADC code for the (BluePill) STM microcontroller must be finalized. Then a sinusoidal signal will be passed into the BluePill's analog to digital converter, and the digital waveform will be plotted on a serial plotter to ensure that the data is being converted accurately. A number of different inputs will be passed into it to further verify it works properly and observe that the output waveform changes with the input. Code that captures and stores the data will also be written, so that it can be displayed later. This part will be considered done when it can be verified that the data is being converted and stored properly.

-Then the code will be altered so that it is compatible with the STM 32H750 (BlackPill) which has a faster internal clock which can reach 200 MHz, meeting the sampling rate required by the client. This part will be considered done when it can be verified that the data is being converted and stored properly.

-Then code will be written for the ESP32 microcontroller which has wifi capabilities that will be used to transmit the digital data to the final display. The ESP32 must also be connected to the clock of the BlackPill since it must also have a sampling rate of 200 MHz. Testing scripts will be used to ensure the ESP32 is working properly, these will likely involve transmitting typed characters onto a test display (like the terminal of a computer). This milestone will be considered achieved when it can be verified that the data is being transmitted at 200 MHz at which point the data shows up on a screen when no cable is used and that it is consistent, with a 80% rate for the data being displayed and the connection made.

-Then using LABVIEW or MATLAB this stored data will be displayed onto a plot. This part will be verified by ensuring the plotted data matches the input it corresponds to.

-Next it must be verified that the STM and ESP microcontrollers can work together properly in unison. They will be connected together to ensure that the data is being converted properly, stored and then transmitted. Then this data will be placed onto the final display (most likely LABVIEW) to verify the output. This will be tested and cleared when the team can see the system outputs the signal controlled at the time input with the correct frequency.

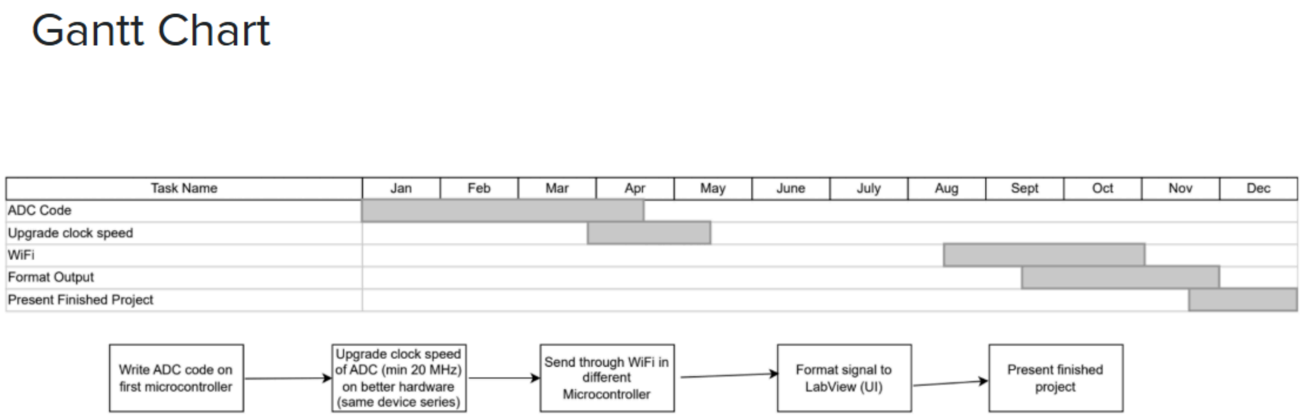
-Finally, all the parts of the system will be integrated together. This will consist of the input signal, amplifier, STM, ESP and display. It will be verified that each part connects together properly and yields the output it should. The amplifier should output an amplified version of the input signal. The STM should output a digitized version of the amplified input signal. The waveform on the display should match the observed digitized amplified input signal, which will be thanks to the ESP32 functioning properly. When all these can be verified the system is functioning as intended and the design is ready to be tested.

- The team will deem the implementation of this project a success when the system shows the data/waveform being displayed matches the waveform being produced by the source and the graph is able to show the full, detailed and accurate picture.

3.4 Project Timeline/Schedule

This Gantt chart outlines the timeline for completing this project, it includes ADC code development, clock speed upgrades, Wi-Fi integration, and LabView data formatting. The tasks are scheduled throughout the year, with the main phases starting with writing the ADC code and then upgrading the clock speed in April-May. Wi-Fi setup will take place in August-October while formatting the output signal in LabView is scheduled for September-December. A final presentation of the completed project is scheduled for December. Each task is linked to the next to ensure smooth project completion. Testing is implemented at the end of each phase which is elaborated further in the description and break down of each step.

Figure 1: wDAQ Gantt Chart:



3.5 Risks and Risk Management/Mitigation

In the project, potential risks include hardware component compatibility issues, insufficient Wi-Fi transmission stability, and substandard ADC system performance.

Hardware component compatibility issues: The project can mitigate these risks by selecting higher-quality components, optimizing coding, and performing multiple tests. Given the fact that the client specified the use of the STM and ESP microcontrollers they are most likely compatible. The only hardware component where issues may arise is the amplifier since it's being designed by another project group. As long as coding mistakes aren't made and the amplifier group does not make many mistakes no hardware issues should arise.

Substandard ADC system performance and insufficient Wi-Fi transmission stability: Both these issues would arise from inadequacy from the STM and ESP microcontrollers respectively, since the circuits used to perform these tasks are inside them. Agile methods will help us evaluate and manage risks in each sprint to ensure that the project proceeds as planned. For the wireless data acquisition (wDAQ) system project, agile methods mean gradually developing and testing the system's functions (such as ADC acquisition, Wi-Fi communication, etc.) through each sprint cycle and making timely adjustments based on test results and team feedback during the process, thereby reducing the risk of project failure and improving the quality of the final delivery.

3.6 Personnel Effort Requirements

Figure 2: Reported Hours Table

Task	Hours
Learning STM Syntax and becoming familiar with IDE	1-5

Coding STM microcontroller	15-20
Troubleshooting STM code issues	20-30
Coding ESP Microcontroller	10-20
Connecting ESP microcontroller to STM clock	1-5
PCB board design, improving amplifier and other potential tasks	15-20
Prototyping/integrating system	20-30
Testing system	10-20

Coding the STM is the most difficult and time consuming part of this project. Learning the syntax and other differences of the STM takes a decent amount of time. Additionally, troubleshooting more rare and smaller problems has also proven quite troublesome. The ESP microcontroller coding will likely be significantly easier as it's just being used to transmit the signal, although getting it to use the STM's clock could prove difficult. Other tasks like designing the PCB board for the final design should not be too time consuming. Integrating all the different parts and performing comprehensive testing will likely be a time consuming ordeal. The team needs to make sure the waveform is accurate. It's essential for us to do this part right, as the whole project is centered around moving and displaying data. It needs to be ensured each part of the system works and adding another component onto it does not disrupt it at all. The system must work for a wide range of inputs and be able to respond to and plot them accordingly.

3.7 Other Resource Requirements

The major resource needed to complete the project will be the aid of an advisor and the help of github and other websites on the coding portion. That is a difficult task and the team will need to learn a lot for them to complete this project. Other resources are the boards themselves along with access to the lab so the team can run tests, both of which are being provided by the advisor. The last resource is just time to work on the project and be able to complete the steps in a timely manner.

4 Design

4.1 Design Context

4.1.1 Broader Context

This table gives insight into the context, effects and implications of the wDAQ.

Figure 3: Context Table

Area	**Description**
Public health, safety and welfare	The wDAQ could help achieve breakthroughs in ultrasound technology which would benefit the medical field and public health.
Global, cultural and social	Companies who produce BNC cables and their employees could suffer significantly from a successful and mass produced wDAQ. Those that produce wired oscilloscopes could also be negatively affected.
Environmental	The wDAQ could potentially reduce electronic waste and production-related emissions by reducing the number of BNC wires being produced and discarded.
Economic	The wDAQ is much less expensive than most other wireless measurement devices. This makes it much more accessible than other products.

4.1.2 Prior Work/Solutions

There are many available products in industry that perform similar functions as the wDAQ, although most of them are missing one or two requirements that are required by the client. For example, many available devices may be handheld but have wires and not a fast enough sample speed, they might be bluetooth but have no display to accompany it. On top of that, they are either extremely expensive, usually selling for well over a thousand dollars, or are very cheap and don't provide the necessary requirements. The wDAQ will be one of the first of its kind to meet all the specifications of the client as well as not being overly expensive.

Two prior groups have worked on this project before us, however, the first had too much on their plate which caused the whole project to not meet standards, and the second group is purely focused on designing the amplifier. They did not do any work on the coding end of things which is what this team's work has mainly centered around.

4.1.3 Technical Complexity

This project requires circuit theory and analysis to be applied to develop the amplifier. It requires knowledge of embedded systems and microcontrollers to understand how to convert the amplified data and transmit it. It requires knowledge of coding to code the aforementioned microcontrollers and the display their outputted data will be placed on. It also requires the team to know how these different modules interconnect and how they should be expected to interact with each other. This project draws upon a large amount of EE technical knowledge and requires the team to understand how these different subjects relate.

4.2 Design Exploration

4.2.1 Design Decisions

The first key decision the team had to make was figuring out what components are needed to achieve the functionality the client desires. A component capable of amplifying the signal was needed, an analog to digital converter was needed and a device with the ability to transmit data was needed. An input signal and display were also needed but these were very minor considerations. The client has another group developing the amplifier and already made the decision to utilize the STM and ESP microcontroller for the ADC and transmission respectively.

The second key decision the team had to make was how to code the STM and ESP microcontrollers to get them to perform the functions required of them. Microcontrollers have many capabilities, so figuring out how to get them to perform the tasks the wDAQ needs them to is essential for the success of the project.

The final consideration the team will have to make is how to interconnect everything in a compact fashion. The final device needs to be small enough to mount onto ultrasound lab equipment, which means its final size should be no larger than a calculator. The layout of the final PCB board and the packaging that surrounds it must be compact but, without risking any loss in functionality or interference between chips and devices.

4.2.2 Ideation

The potential options that the project team came up with for the interconnection of components were:

-Utilizing a small breadboard and connecting the devices together by placing them on and using jumper cables.

-Creating a printed circuit board (PCB) design and getting it produced by a third party. Then soldering the microcontrollers onto it. This is the most promising and logical option.

-Buying a premade circuit from the internet. The chances that a premade circuit would have all the capabilities and specifications the wDAQ needs is low though.

4.2.3 Decision-Making and Trade-Off

Making a PCB board using CAD software and then sending that schematic to a PCB board manufacturer is definitely the best option. PCB boards have more secure connections than breadboard circuits as well as less noise interference from other devices on the board. Since this device will be attached to a rotating device, it is very important that the final build be secure and not break easily. PCB boards can also be optimized to be as small as possible which is important since the wDAQ needs to be mobile and light. A premade circuit would likely be much more expensive and hard to find, as well as not meeting the specific requirements necessary for this project. The breadboard circuit would be very fragile and would be difficult to attach to surfaces and could cause a tangle of wires in the device defeating the purpose of the entire project. So, for those reasons designing a PCB board appears to be the best option and allows for certain freedoms to be taken later on if needed.

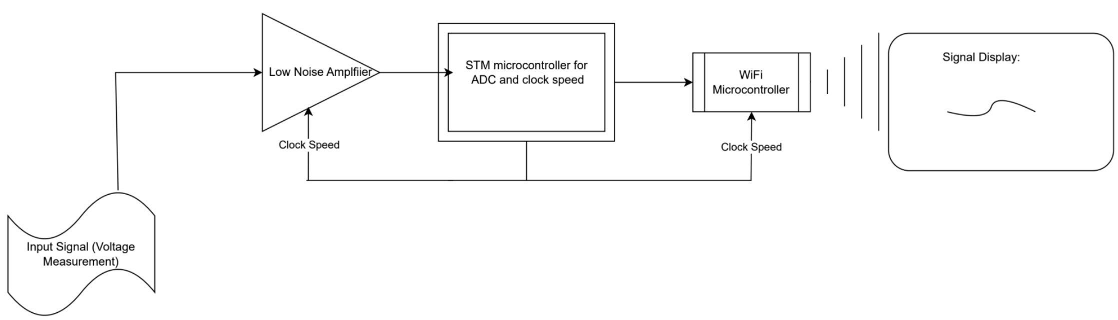
4.3 Proposed Design

4.3.1 Overview

The proposed design is separated into 3 large parts. The first part is the data gathering part, the next is the data transmission and finally ending with the receiver and display. The data gathering portion of the project is what is connected to the testing equipment, which is the part of the project that involves gathering the data. The next section of the project is the data transmission, which is cleaned up by an amplifier and sent through microchips to be changed from an analog signal to digital data to then be transmitted over wifi or bluetooth. The final subset of the project is the receiving end and the way the data is shown on the receiving device. That device is connected to the transmitter through the same wifi or bluetooth and the display is going to show in the form of a graph that one can interact with.

4.3.2 Detailed Design and Visual(s)

Figure 4: Detailed Design



The design of the project can be separated into 5 different interconnecting sections. The first is the input signal which will be emitted from an ultrasound device in the applied science complex (ASC) ultrasound lab. This signal is then passed through a low noise amplifier, which amplifies the signal so it can be transmitted easier without losing clarity.

The transmission process can be broken down into 2 separate parts, the ADC and the wifi transmitter. The ADC microcontroller will be the STM BluePill initially for testing purposes so that it can be verified that the system's code is accurate and the data is ready for transmission. Then change to the STM 32H750 for the upgraded clock speed for the final product. This upgraded clock speed will allow for more data samples to be collected and allow for the client request to be met. The clock of the STM 32H750 will also be used for the amplifier and ESP32 since a clock speed of 200 MHz is needed.

The digital data will be sent into the ESP32 microchip so it can be used as an antenna to transmit said data in real time over the wifi. This chip will only be used to transmit the data and will not cause any of the information to be corrupted or changed as it will not change the data in any way. These two will work together, with a simple cable connection, to make it so the data gathered can be seen at a different point in the room. The power for both of these products will be supplied with the power for the amplifier and the main system.

The third subpart of the project is the receiver. This part of the project is just the process of displaying the data that is transferred over the wifi using a general user interface (GUI). The GUI will be programmed with a focus on user-friendliness and ease of use in lab settings. This will be done using LABVIEW.

4.3.3 Functionality

The wDAQ will be used within a biomedical laboratory, with a machine that outputs ultrasonic frequencies while spinning at different speeds for different scenarios. Users would attach the wDAQ to this machine to measure these frequencies and EM noise in the testing environment to create a 2D picture. Normal oscilloscopes would not be usable in this scenario because of the rotating machine which prevents the use of cables. The wDAQ will operate the same as a normal oscilloscope otherwise, providing a visual graph of its input over wi-fi to a display on a separate device. The user will grab a new waveform by using a UI in LABVIEW.

4.3.4 Areas of Concern and Development

The design will be optimized to best satisfy the wireless and portability needs of the users. Using a wi-fi microcontroller to connect to a display wirelessly will ensure no cables are necessary to use the wDAQ. The design has also been made very simple so that hardware components are minimized, creating a small and very mobile device. The design has been approved by the client and logically makes sense.

The current design may fall short of other products in terms of accuracy of signal readings, which may require more powerful microcontrollers to get better readings. The accuracy of readings falls upon the sampling rate and internal capabilities of the chips, so it is crucial to make sure that both of those fall within the requested specifications.

For now, the team will proceed with the current design. Since the potential issue outlined above won't be observable until user testing is complete (since the current design is likely to be accurate enough to satisfy users), no hardware upgrades will be made for this version of the product.

4.4 Technology Considerations

On the hardware side of things, the project has been utilizing the STM 32H750 microcontroller. The main appeal of these microcontrollers is that they can produce a 200 MHz clock, so the data's shape can be maintained and the data presented will be more accurate. The team will also utilize a ESP microcontroller to transmit the data to the final display, this microcontroller will also utilize the STM's clock speed to avoid any data being cut off. The STM likely could be swapped out for any microcontroller that also is capable of producing a 200 MHz clock speed.

On the software side of things, the first step of the project has utilized the STM IDE which is necessary to interface with the microcontroller. Within the IDE, C is the programming language that is used. This is a very accessible programming language and all group members are familiar with it.

While this team has not specifically worked on it, an amplifier is also an essential part of this project. This takes the smaller noise produced in the tests and amplifies it so that the users can read it and understand it better allowing for them to notice any discrepancies or changes needed on the device that is being tested. This also allows for the user to get a good understanding of the signal being read which allows for them to move forward with their tests and experiments.

4.5 Design Analysis

So far, the team has managed to code the STM to perform a conventional ADC conversion using UART. The team also has coded it to perform an ADC using direct memory access (DMA) which improves operation speed and allows for the data to be temporarily saved to be shown on a display. The project team has verified that the STM microcontrollers can take an analog signal and convert it to a digital one, and have researched how the chips work and their capabilities. Previous groups have also worked on the amplifier, so significant progress has been made on that end.

5 Testing

5.1 Unit Testing

In this senior design project, the ADC, display, and wi-fi transmission are being tested. Since all of the above are exclusively software, the "testing" falls more along the lines of "does it work?". If yes, then the component has been successfully tested and can be potentially improved upon, depending on any issues with the present version. The section of the project that this team is working on focuses on the ADC and the wifi chip, which if the two chips were to work properly, it would show the analog data converted to a digital data format and able to be displayed as well as the data being properly transferred over the wifi or bluetooth to another device. The ADC being slightly more involved uses a sinusoidal voltage wave input with a DC offset, with the only thing really being tested is its ability to perform its job properly. The team's next step would be to see if the ADC's primitive form of the display is showing the input data correctly, within a 5% margin of error and then if the ADC is receiving a signal and converting it to a graphable form. The display will be developed in more depth once the wi-fi is able to successfully pass the signal to a separate monitor. The wifi chip will be tested by seeing if the display receives the signal transmission and displays it in the proper format and connects with a 98% success rate.

5.2 Interface Testing

The interfacing with the current team's section of the project is mainly two sections. The first is the interface display that comes over the wifi and into the user's computer. This interface testing will be moved between the group, focusing on ease of use, user friendliness and ability to display properly. Since the team will be working with a known input to be displayed upon the device in the graphing format, the person who is using the interface will try to graph the data with the proper units, axis title names, and show the input data in the form which is expected from the controlled input. They will also confirm that it is easy for the user to read and comprehend. Another person will switch the input to see if the data correctly shows up on the interface. Another way that the team is going to test the interface is to have the person utilizing the interface not know the input. This will be able to see if they can accurately describe the input into the system. A multimeter and a voltage source will be used to give data into the system and then a computer to receive the data and display it. The second part of the interface testing will be near the end of the project as a whole. This is the interaction testing between each team that has taken up the project. It is unclear how this testing will go exactly, but some thoughts and ideas would be to test each section individually to meet the standards placed for those parts and then combine them piece by piece. Start with the low-noise amplifier and combine with the ADC wired directly to a display. Follow the parameters established above to verify that the outcome is what is wanted with the display, amplification and conversion rate for the data. Once that works within the parameters, add on the wifi chip and run a similar test just with the addition of making sure the chip connects to the correct computer and displays the input accurately.

5.3 Integration Testing

The critical integration paths in this design are between the ADC and the display, and between the wi-fi and the monitoring device. Since the ADC has no explicit evidence of functionality, with its primary functionality being that of converting the analog input data to a digital form, it is critical that it must be integrated with the display. This integration will be tested in the same way that the ADC and the display will be tested- does the signal get displayed? Is the signal what is to be expected from the input? Connecting the ADC to a test signal and doing some quick testing with another oscilloscope, the tester will determine what the display signal should look like. If the ADC is not working there won't be a visible signal or it will not be shown as what is expected, and if the display is not working there won't be anything to show the signal. The other major integration path is the wi-fi and the monitoring device. In this case, the wi-fi must be able to be connected to some form of monitor with a compatible graphing function (in the case of this project, LabView will suffice as the function). No wi-fi chip means nothing to transmit, and no monitor means nothing to view the transmission on. Once the wifi chip is functional, the next step is to test the data communication speed, and verify it matches the client's requests. The test will be done in real time, with multiple people to communicate back and forth, verifying and live troubleshooting to find the problem and come up with a solution.

5.4 System Testing

The team has multiple test units that are being used prior to using the devices that will be placed within the circuit. Each device will be tested individually, specifically using the STM BluePill before using the STM 32H750 chip so that any issues can be caught before using the more expensive and unique device to prevent damage to the chip. Each chip will be tested in order of how they would connect within the system, checking each chip before moving onto the next. This portion of the project consists of 2 chips connected to each other, with the team using 3 chips in total. The first chip is the STM BluePill, this is the testing chip for the team to learn and focus on the process of coding for an ADC. The next is the STM BlackPill, the main focus on the project and the main ADC used for its proper sampling speed and internal clock. The final is the ESP32 which is the wifi chip which should have minimal programming to be done, but the chip that transmits the data for the display to read without wires. There will be breaks implemented within the system when connecting the devices together to make sure the system isn't overridden with power or data. Focusing on this part of the project, each of the three chips will be verified to work alone before connecting the parts together. Starting with the STM BluePill, then transferring to the STM BlackPill and finally adding the ESP32 wifi chip in at the end. Two chips will be tested together, specifically the STM BlackPill and ESP32 before moving into adding other parts of the project.

5.5 Regression Testing

Physically, the design is pretty well thought out and likely won't need to be changed for this first prototype. Also considering the fact that the main purpose of this project is to maintain the ability to take a signal, amplify it, convert it and then transmit it, removing any of the components is likely not possible. If any future team needs to switch or change the main chips, a large part of the programming is being made for any STM chip. One thing that is likely to be revised frequently that is needed to not break is the code for the STM. It is necessary to ensure that the code is still sampling at a specific rate and then placing that data into a file. So, ensuring that the code still accomplishes all of this will have to be something the team checks on frequently when making changes to the code. Looking into the future of the project, past the first prototype, with the addition of people wanting to maybe export data, have multiple displays connected, have different file formats and be given more freedom with the display and connectivity. To ensure this can be implemented in the future, the team is focusing on making sure the basics work and not adding too many bells and whistles. Focusing on basics first allows for further steps to build upon the design without having to edit the foundations.

5.6 Acceptance Testing

The final display shows the input signal, and since the signal that is being inputted is known, the team can just look at the display to see if the shape and magnitude of the waveform is accurate within a 5% margin of error based on the controlled input. If the team wants to look at a specific part to see if the amplifier or another part was functioning properly, then they could just use a normal oscilloscope to analyze the signal at a certain point in the system. Since the input is controlled, a user can tell if/where an issue is occurring by tracking it across the device. The team would involve the project's client in the acceptance testing by first testing basic signals from a waveform generator (or similar device) to prove that it is in fact accurately depicting signals. Then this signal would be replaced with the ones that come from the ultrasound devices they use in the ultrasound lab to ensure it is compatible with what it will actually be used for.

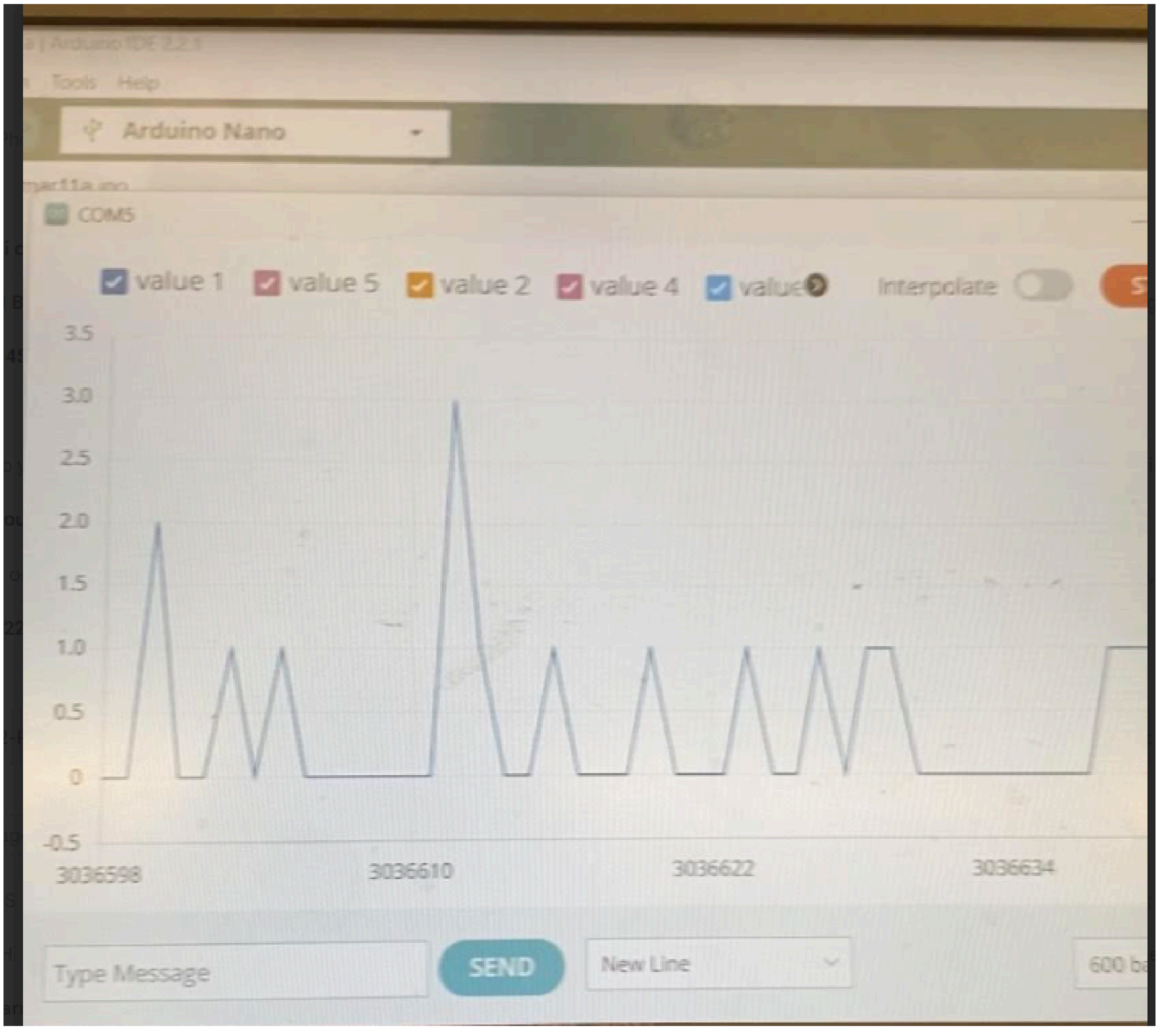
5.7 User Testing

The real users of this product happen to also be the project's clients and advisors. The way the team would get user testing would be through a person using the device and then filling out a feedback survey so that the changes and improvements can be sent to the team to fix. This survey would consist of open ended and multiple choice questions designed for the user to be able to give feedback on a range of topics including installation, ease of use, user friendliness, and satisfaction with the final open ended questions about improvement for the product. The survey is designed to take less than 10 minutes to complete which allows for more responses from users and more data being collected for the team to put to use as a lengthy or extensive survey can make people not want to take it. This survey would most likely be in a place where results can be collected easily and anonymously so the users do not feel pressured to be nice or compliment if the product is not to their liking.

5.8 Results

At present, the ADC and a primitive version of the display have been tested. The display shows that the ADC is functioning, and the display needs to be adjusted to show more data and give a more useful image of the ADC output signal. The axes on the graph of the display are too short right now, so the output signal only appears to be a straight line while updating the range of the vertical output rapidly. This shows the ADC is detecting and outputting a sinusoidal voltage signal, but the limited axes prevent this information from being shown in any useful manner. The next steps for the team would be to fix the code so it displays the data correctly with the appropriate axes by gathering data into a saved file and then displaying it from there. The display should show a perfect sinusoidal wave which can be easily seen once displayed and can be compared to the display of another oscilloscope to verify. Once that is finished, the team will move onto running tests for the rest of the chips such as transmitting to an external display, verifying the sampling rate is correct with a plugged in display, combining the two with a known input and verifying it works on the other end.

Figure 5: Picture of ADC output waveform



6 Implementation

As of right now, the project has not yet had any implementation. The closest thing to it is the testing stage of the ADC to verify if it works. The first stage of implementation will occur after both the wi-fi and remote display have been created, which will enable the project to be used for its intended purpose. After an initial implementation attempt has been made, the project can then be analyzed for any weaknesses present, for which the project will undergo adaptations to either erase or reduce these weaknesses.

7 Ethics and Professional Responsibility

7.1 Areas of Professional Responsibility/Codes of Ethics

Figure 6: Areas of Responsibility Table

Area of Responsibility	**Definition**	**Relevant Item from IEEE Code of Ethics**
Work Competence	Completing work at high levels of quality, punctuality, and professionalism	To maintain and improve the team's technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations
Financial Responsibility	Keeping costs of work within allotted budget; minimizing costs while avoided sacrificing quality	To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist
Communication Honesty	Reporting work to the highest level of accuracy possible	To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others
Health, Safety, Well-being	Minimize or eliminate all risks posed to any possible affected parties	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment
Property Ownership	Respecting and acknowledging the owners of property, ideas, and information	To avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses
Sustainability	Acknowledge and minimize the negative impacts of work on the environment	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment
Social Responsibility	Create products for the	To improve the understanding by

	betterment of society and the public	individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems

The team is succeeding in adhering to financial responsibility. The project is being designed with cost as a significant factor in mind, since existing similar products are commercially priced considerably higher than the anticipated cost of the current design.

One area that the team is struggling to excel in is work competence. The majority of this project is programming, but the entire team lacks extensive experience in that field to yield high quality results. The team is exploring online resources to improve its programming abilities and will continue to do so in order to improve the final product as much as possible.

7.2 Four Principles

Figure 7: Four Principles Table

Area	**Beneficence**	**Non-maleficence**	**Respect for Autonomy**	**Justice**
Public health, safety, and welfare	Reducing safety risks	Avoiding creating more safety risks	Avoiding impeding on stakeholder activities	Stopping and preventing maleficent activities of the stakeholders
Global, cultural, and social	Improve the ease of work completion	Avoiding impeding on work completion	Avoiding forcing workers to use new facilities	Stopping and preventing maleficent activities of workers
Environmental	Cleaning pollution	Avoiding the creation of more pollution	Avoiding taking away from the existing environment	Stopping and preventing the creation of pollution
Economic	Spending less money	Avoiding spending more money	Avoiding a change in budget	Stopping and preventing irresponsible spending of money

One broader context-principle pair that this project is excelling in is the ease of work completion. The purpose of this project is to take measurements from a machine that has not been previously measurable, and this direct method is very beneficial to easing the completion of work.

One broader context-principle pair that this project is lagging in is the avoiding of spending more money. Technically speaking, the purpose of this project is to improve the work experience of lab technicians but its completion isn't mandatory for their research. Therefore, in order to create and implement the wDAQ the spending of more money is inevitable.

7.3 Virtues

Three virtues that this team values include punctuality, communication, and adaptability. Punctuality is supported by all members by showing on time to all meetings to ensure that work is completed by the expected times. Communication is supported by all team members by informing other members on progress, changes in plans, and coordinating how the project should move forward. Adaptability is supported by all team members by coming up with viable and alternative strategies for moving forward whenever unforeseen circumstances significantly impact current plans.

Merrick Czaplewski-

A virtue I have demonstrated is a consistent level of communication with the team and outside of the team. I value communication in team projects because it allows for me and the entire team to be on the same track and make getting tasks done easier. Communicating regularly, keeping my team members in the loop of developments as well as asking questions, keeping an open line with the facility and TA's as well as taking the criticism given and applying it to the next week has shown my skills and abilities in this project.
One of the values I lack is innovation and creativity. I struggle with these tasks in particular with relation to this project due to lack of experience and knowledge. This is not my wheelhouse nor does this fall under my abilities so I focus on the tasks I can do properly. This does lead to the whole of the team falling into ruts as we are unable to come up with viable solutions for the issues we run into. I plan to continue to find ways to contribute to the team in the ways I can, as well as look for outside help and direction so the team as a whole can get the knowledge we need to succeed.

Samuel Foster-

One virtue that I have demonstrated in my senior design work thus far would be communication. I find this virtue important because when working in a team, it is very important to make sure that all team members are on the same page at all times. I've demonstrated communication skills by informing team members on plans for when we meet up to work on the project, as well as by reaching out to our client to ascertain information required to continue progress.

One virtue that I have not demonstrated yet in this project is creativity. I find creativity to be important because it allows me to add some personality into any products I work on, and it changes *a* project into *my* project. In order to demonstrate this virtue, I should find any opportunities where I can implement my skills in a place that my teammates cannot.

Jerry Liu-

One virtue that I have demonstrated is coordinating teams. For example, When we try to work together, we have to separate our tasks fairly, like 25% for each one. And when we are facing the problems we can help each other to talk about what issue we have, and how to fix it then make our project better.

One virtue that I have not demonstrated is time management, because everyone in our team does not only have senior design tasks, we still have other classes and follow tasks that need to be done, so I was aware that our team cannot make a stable time schedule to do the senior project. For this demonstration, I will try to make a timeline for each task period in senior design, and make sure everyone can work on senior projects on time by following the time schedule.

Rocco Yassini-

I have demonstrated a commitment to learning and applying the knowledge I already know. I utilized the knowledge I learned in CPRE 288 about microcontrollers and the ADC circuits on board them to code the ADC on the STM microcontroller. I also continued to learn new things by acclimating myself to the STM IDE (the program used to upload code to the STM) and learning the syntax used by this program.

One virtue I have not demonstrated in this project is innovation. Since the design of this project was mostly pre-determined and made logical sense I have not thought much about alternative ways to do this project. I've just been sticking to the path that has been laid out for us. Bringing in alternative methods to solve problems that have arisen in the project could have been helpful.

8 Closing Material

8.1 Conclusion

As of right now, the project stands at a completed analog-digital converter on the STM BluePill, with a prototype display. The STM BluePill is being used to create a framework of code to use with the BlackPill, only needing to change the values of the clock speed to accommodate the more powerful hardware. The prototype display is done through arduino for now, only so that the ADC can be verified as functional. This project still needs to upgrade the microcontroller for better clock speed, enable wi-fi, and create a more refined display.

These changes will be made by upgrading the microcontroller to the BlackPill, integrating the ESP32, and developing a display through LabView. The original timeline of having upgraded the clock speed with the BlackPill by the end of the spring semester fell through due to the primary contact having to go on leave. Because of this, the team had to search for other resources to continue working on the ADC. This resulted in a slowdown in the timeline, pushing the hardware upgrade to this fall.

8.2 References

STM32H750 Microcontroller datasheet:
https://www.mouser.com/datasheet/2/389/stm32h750ib-1505386.pdf

ESP32 Microcontroller datasheet:

https://www.esp32.dk/esp32_datasheet_en.pdf

ADC on STM tutorial:

https://www.youtube.com/watch?v=deMF2xu_ASQ

9 Team

9.1 Team Members

1) _____Rocco Yassini______________
2) _____Jerry Liu___________________
3) _____Merrick Czaplewski__________
4) _____Samuel Foster_______________

9.2 Required Skill Sets for Your Project

Knowledge of Embedded systems and how to code them. How to use on board ADC's on microcontrollers.

9.3 Skill Sets covered by the Team

Merrick Czaplewski - Understanding of basic code and how to iterate ideas, how to use LabView and work with display systems similar to it. Has the ability to communicate well through writing and talk.

Rocco Yassini - Knowledge of embedded systems and how to program them. How to program ADC's that are on board microcontrollers.

Samuel Foster- Knowledge of C and MATLAB coding, porting of data/files between development softwares

Jerry Liu – Knowledge of embedded systems, including designing and programming microcontroller-based solutions. Experienced with circuit simulation tools such as MATLAB, Simulink, and Verilog. Strong understanding of digital VLSI design and capable of applying these skills to complex engineering projects.

9.4 Project Management Style Adopted by the team

Typically, Waterfall or Agile for project management.

9.5 Initial Project Management Roles

Merrick Czaplewski: Final checks documents and reports to verify accuracy of information and grammar, focuses on communicate with client and advisor to set up meetings with the team

Rocco Yassini: Ensure technical progress is being made, especially on the ADC side of things.

Samuel Foster: Ensure technical progress is being made

Jerry Liu – Manage project integration and ensure timely progress across all subsystems, focusing on system reliability and providing technical support.

9.6 Team Contract

Team Members:

1) _____Rocco Yassini_________ 2) ____Samuel Foster_____________

3) _____Merrick Czaplewski___ 4) ____Jerry Liu_________________

Team Procedures

Day, time, and location (face-to-face or virtual) for regular team meetings:

Fridays every other week at 3:30 in the senior design lab or TLA

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

Discord/email

3. Decision-making policy (e.g., consensus, majority vote):

Majority vote

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

Use google drive to share documents

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:

Every person is expected to attend at 3:30, if that is not possible team members must communicate that they will be late. If they cannot attend at all (within 15 mins of 3:30) they must propose an alternate meeting time. Share updates on project progress, share any problems that may have arisen and plan any collaborations that need to happen before the next meeting.

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

We will divvy up the project in as close to equal parts as possible to each team member. If specific steps of the project must be done in a shorter timeline or before other parts, multiple team members may work on those parts together. Each member will be responsible for ensuring that their respective parts of the project are done by each deadline.

3. Expected level of communication with other team members:

Team members are expected to communicate any problems they discover while working on their respective part(s) of the project that they feel they cannot solve on their own as early as possible. If all team members still feel they cannot find a solution, they should contact the project advisor for guidance. Team members should also communicate progress as well at the regular meetings.

4. Expected level of commitment to team decisions and tasks:

All team members are expected to show complete commitment to team decisions once they have been made. If they have an issue they should bring that up while the decision is being made to prevent any potential problems.

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction,

individual component design, testing, etc.):

Samuel Foster + Rocco Yassini - Main programers
Merrick Czaplewski - Client Interaction and Documentation
Jerry Liu - Testing and Innovation

2. Strategies for supporting and guiding the work of all team members:

Since the work will be divided amongst team members, when members reach a roadblock they can reach out to other teammates to find the most qualified to help proceed. If teammates are not able to resolve the roadblock they should come up with a question to ask the advisor.

3. Strategies for recognizing the contributions of all team members:

Team members are expected to keep track of what they did between meetings, which will then be recorded into a progress record at the regular meetings noting who did what, who helped who, and what got done.

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the

team.

Rocco Yassini: Circuit design/analysis, modelsim, embedded systems, attention to detail, soldering
Samuel Foster: Circuit design/analysis, C-programming, MATLAB, communication, quick study
Merrick Czaplewski:Circuit and PCB board design, semiconductors and EM, soldering, and layout design, Data Acquisition and Analysis
Jerry Liu: Circuit design/analysis, MATLAB, Related project information search, Data Integration

2. Strategies for encouraging and support contributions and ideas from all team members:

Compile ideas in a google doc and decide on one after brainstorming

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will

a team member inform the team that the team environment is obstructing their

opportunity or ability to contribute?)

Team members will acknowledge the gaps in their knowledge/experience and will share this with the team so that we can either work around this gap by reassigning project parts or help fill the gap in knowledge.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

Create a detailed plan of progression, complete code for ADC and signal acquisition, interface with wifi, complete a prototype PCB design, test a prototype

2. Strategies for planning and assigning individual and team work:

Assign parts of the project to team members who have strengths associated with that area, assign team work when there is integration between parts, or if a part has a shorter timeline, or if it needs multiple heads put together to proceed.

3. Strategies for keeping on task:

Each team member will be expected to set aside a minimum of 3 hours each week to work on the project (effectively one lab or three lecture lengths)

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?

Assign another team member to work with the infracting member so that they can stay on track and progress can be monitored.

2. What will your team do if the infractions continue?

Notify either the advisor or one of the 4910 professors.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) ______Samuel Foster_______________________________ DATE ____2/9/25_________
2) ______Jiarui Liu________________________________ DATE ____2/11/25________
3) ______Rocco Yassini_______________________________ DATE ____2/11/25________
4) ____Merrick Czaplewsk_____________________________ DATE ____2/11/25________