EE/CprE/SE 491
wDAQ System (sddec24-19)
Design Document: Project Plan

March 26, 2024
Client: Manojit Pramanik and Avishek Das
Faculty Advisor: Manojit Pramanik

TEAM MEMBERS

Adam Shoberg [EE] - Circuit Design & Simulation, PCB Design, Team Communications Leader

Henry Chamberlain [EE] - PCB Design & Construction

Lisa Tordai [SE] - Software Development, Wireless Data Sharing

Vaughn Miller [CprE] - Computer Engineering

3.1. PROJECT MANAGEMENT/TRACKING PROCEDURES

Our team has adopted an agile project management style. We are trying to complete tasks and milestones for our project in a timely manner in order to satisfy our client's expectations, but are not restricted to a firm timeline for the most part. Our client would like the project to be completed a couple of months ahead of the December deadline, because he is hoping to publish an academic paper with us about our project after it is completed. We are currently meeting weekly with our client to discuss our progress, ask questions, and formulate tasks and deliverables for the project as we go, so our timeline is flexible and adaptive to new ideas and design changes. We typically complete design tasks relatively quickly and delegate electrical and software/computer portions of the design to the respective team members.

This project management style has worked well for our team so far, because with the wireless data acquisition system we are designing, many of the software and computer-related portions of the device (e.g., Wi-Fi communication, user interface, microcontroller and analog-to-digital converter) can be designed independently of the electrical parts of the device (e.g., the amplifier, signal filtering and processing, and battery power supply), which makes it more practical to split up most tasks, while working together as a team to bring the components of the device together in the top-level design. Additionally, some tasks and design sprints end up taking significantly more or less time than originally anticipated, making it more sensible to adapt to new timelines as needed. Lastly, our client likes to be closely involved with our work and communicate with us regularly, as well as alter the design and timeline for the project occasionally, which makes the agile working style a much more logical choice overall.

In terms of tracking progress, the majority of our communication and progress updates within our team and client occur through a shared Microsoft Teams channel. We use our Teams channel to communicate regarding weekly meetings and progress, ask questions, and post updates, documents, and deliverables. These posts include weekly progress report Powerpoints, Schematic documents and PCB files, and code files for software items, posted under the “Files” section of our Teams channel. Eventually, most of these deliverables will also be shared on our team website. Aside from Teams, our team has a Snapchat group chat for casual communication, and we use Outlook and Zoom for communication with our faculty advisor. We have been able to work successfully so far without using Git, Trello, Slack, and related project management tools, but we may end up using these to some extent in the future.

3.2. TASK DECOMPOSITION

Even though we are using mainly an agile project management style, our project can be split into three major “targets”: project planning and design, prototyping, and building the final product. As for specific tasks that must be completed to create the wDAQ device, we need to amplify and filter analog signals (physical signals from test subjects), digitize the signals, send the signals to a computer software user program via Wi-Fi, and display the signals to the user interface. The figure below shows the design plan and flow that our team created using Figma.

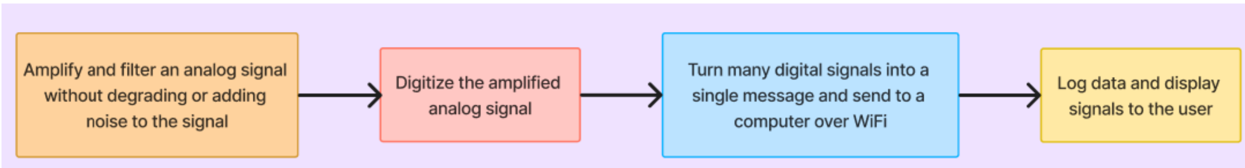


Figure 1: Design Task Decomposition Flowchart

Our team will reference this flowchart throughout the year for a high-level overview of the requirements and deliverables we want to create, but on a smaller scale, we can divide the major phases and targets of the project into smaller tasks. The list below describes the subtasks for each target associated with our design.

Target I: Project Planning and Design

- Understand the requirements and needs of the client and users
- Gather inspiration and ideas by exploring related products on the market
- Create a flexible initial plan of work
- Break the design steps from the flowchart into smaller milestones and tasks
- Delegate individual tasks and responsibilities to team members on a weekly basis
- Design the device in small steps or “sprints”

Target II: Prototyping

- Order parts and electrical components to create a prototype PCB for the device
- Solder PCBs for individual components of the device and connect them with header pins
- Test the PCB to ensure proper electrical connections and functionality
- Develop user software to a functional level and connect software with the device

- Observe and analyze the results of the prototype
- Discuss shortcomings, design errors, and areas of improvement

Target III: Final Buildout

- Host an evaluation & feedback session with the client and users of the product
- Analyze user and client feedback to recognize key areas of improvement
- Brainstorm and make decisions as a team on changes needed for the final product
- Gather new materials or parts for the device as needed
- Work out software bugs and ensure the program is working up to a high standard
- Rebuild the device or parts of the device as needed to meet requirements
- Test the final product and ensure accuracy and satisfaction of requirements

As mentioned in the previous section, many aspects of the project will be delegated specifically to electrical, computer, or software team members, as this will enable team members to work in the areas where they are the most comfortable and skilled. Creating a schematic and PCB for the amplification and filtering stages of the circuit, as well as the battery and battery protection system for the power supply, and parts of the analog-to-digital converter (ADC) will be assigned to electrical team members, while the design and testing of the microcontroller and parts of the ADC circuit will be assigned to the computer and software members, and the design of the user interface and Wi-Fi connection will be almost entirely the responsibility of the software team member. When building the device and combining individual parts, all four team members will come together to ensure the device meets all requirements.

3.3. PROPOSED MILESTONES, METRICS, AND EVALUATION CRITERIA

The milestones, metrics, and performance targets we will be aiming toward with our project are listed below. We separated these targets by steps from our initial design plan, because this plan has more concrete metrics and objectives than the “targets” plan from above. Our client will be designing the battery, so we do not have milestones or metrics for this currently.

Amplifying and Filtering the Input Signal:

- Milestone A1: The amplifier has a Bandwidth of 100 kHz ~ 1 GHz
- Milestone A2: System Gain of up to 60 dB with low signal degradation
    - Milestone A2.1: The amplifiers produce 2 dB of noise at 300 MHz
- Milestone A3: The system draws a current of 70 mA or less (corresponding to a power draw of 864 mW or less with a 12 V power supply)
- Milestone A4: The system has an input impedance of 50 Ω
    - Milestone A4.1: The amplifier is connected by SMA cables with impedance of 50 Ω
- Milestone A5: The PCB contains two single-rail IC amplifiers (cascaded together)
    - Milestone A5.1: The IC amplifiers are powered by a single 12 V DC supply
    - Cascading of amplifiers will occur later when building the full device’s circuit

Digitizing the Amplified Signal:

- Milestone B1: Suitable ADC has 12 Bits of resolution with sampling rate of 120 M samples/sec to avoid the effects of aliasing
- Milestone B2: The ADC takes differential (positive and negative) signal inputs.
    - Milestone B2.1: Differential inputs are sourced from the output signals of the LNA
- Milestone B3: The ADC is supplied by 5 volts, fed from our single 12 V DC supply.

- Milestone B3.1: The ADC supply voltage is adjusted to 5 V using a voltage regulator such as the LM7805 from TI (implemented in ADC driving circuit).

Wirelessly Sending Digital Signals to Computer:

- Milestone C1: Obtain communication module parts compatible with the needs of our project
    - Milestone C1.1: Research and decide one Bluetooth and one WiFi device that fit the needs of our project
- Milestone C2: Testing capabilities of Bluetooth vs. WIFI
    - Milestone C2.1: Using Arduino to program Bluetooth module to successfully send and receive data from laptop
    - Milestone C2.2: Using ESP32 to program WiFi module to successfully send and receive data from laptop
- Milestone C3: Programming device to send data over server for LabVIEW to be able to receive data
- Milestone C4: Program project microcontroller to send data through the WiFi Module

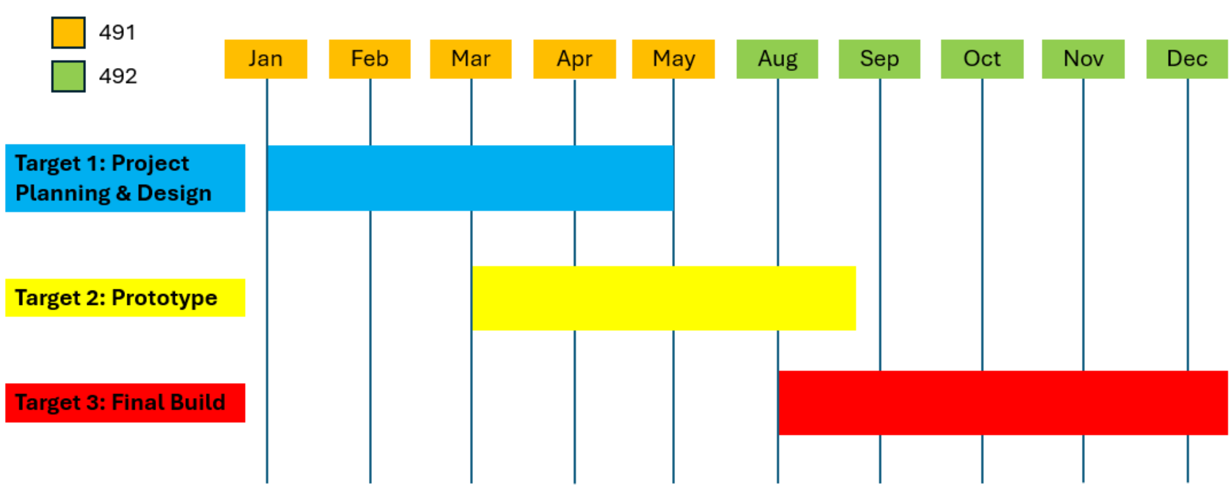
Logging and Displaying Data in User Interface:

- Milestone D1: Discover capabilities of LabVIEW tools to connect with Bluetooth and Wifi
- Milestone D2: Create LabVIEW VI to create a connection with WiFi Module
- Milestone D3: LabVIEW reads in data from LabVIEW server
    - Milestone D3.1: Read in values from WiFi Module
    - Milestone D3.2: Display data in a graph for the user to be able to analyze
    - Milestone D3.3: Allow user to log and export data

3.4. PROJECT TIMELINE/SCHEDULE

The timeline for our project does not line up with the proposed calendar for projects given in the 491 course, because our client is pushing us to jump ahead of the recommended schedule and complete the planning & designing quickly, reserving the remaining time in the Spring & Fall for prototyping, revising, building and implementing the final device, and writing an academic paper about the project. This is quite a bit different from the suggested calendar, which recommends using the entire spring semester for designing, planning, and research, and completing the entire implementation and buildout of the project in the Fall semester.

The simplified Gantt chart for our project, split into our three main “targets” described in Section 3.2, is shown below. Please note that January schedule begins January 23; May schedule ends May 10; August schedule begins August 26; and December schedule ends December 13.



A more detailed monthly schedule for our project that elaborates upon and follows the targets and dates from the Gantt chart is given in the table below. The schedule also incorporates the estimated completion dates of specific milestones and metrics from Section 3.3. The tasks and objectives for January through March are finished, but they are included for reference.

Month	Tasks and Objectives
Month 0 (January) **Target 1**	- Project Overview - Team Introductions

Month 1 (February)
Target 1
	- Market Research
	- Low-noise-amplifier (LNA) simulation in LTSpice and NI Multisim
	- Acquisition & testing of prebuilt LNA
	- Extraction of LNA voltage & current characteristics with client
	    - Checking to see if the marketplace LNA follows the metrics/milestones we want for our LNA
	- Bluetooth and Wi-Fi simulations
	    - **Milestones C1, C1.1, C2, C2.1, C2.2**
	- Microcontroller product exploration

Month 2 (March)
Targets 1 & 2
	- Microcontroller selection, ordering, and testing of eval board
	- Battery Protection System exploration
	- Microcontroller to Wi-Fi communication testing in LabVIEW
	    - **Milestones C3, C4**
	- Develop GUI in LabVIEW
	    - **Milestones D1, D2**
	- Sourcing suitable ADC chip
	    - **Milestones B1, B2**
	- Schematic and PCB for LNA and ADC driving circuit in EasyEDA
	    - **Milestones A1, A2, A2.1, A3, A4, A4.1, A5.1, B3, B3.1**
	- Configuration of microcontroller clocks

Month 3 (April) **Targets 1 & 2**	- Test and evaluate performance of PCBs for LNA & ADC circuits - Revise LNA and ADC circuits if needed - Continue developing GUI in LabVIEW - **Milestones D3, D3.1, D3.2, D3.3** - Design and order PCBs for microcontroller and Wi-Fi circuit
Month 4 (May) **Target 2**	- Develop and order (?) battery and battery protection system - Connect individual circuits together to form a prototype for the device (exclude battery/battery protection system if unfinished) - **Milestones A5, B2.1** - Test and evaluate prototype board - Present findings and progress to faculty and industry panels
Month 5 (August) **Targets 2 & 3**	- Complete battery module and protection system (if not already) - Perform power management study and optimization of circuit - Revise circuit based on observations and feedback - Design PCB (front and back) for final version of the device
Month 6 (September) **Target 3**	- Order complete PCB (front and back) for the device - Test final build and troubleshoot

Month 7 (October) **Target 3**	- Implement the design in PAT system at ISU BILab - Begin writing an academic paper on the device
Month 8 (November) **Target 3 (complete)**	- Continue writing academic paper - Complete final design document
Month 9 (December) **Target 3 (complete)**	- Complete and publish academic paper - Present completed project (?)

This schedule incorporates the estimated timelines for work and completion of each of our three main "targets", as well as for each of the milestones given in Section 3.3. Although the schedule mentions presenting our project to industry and faculty panels, writing our final design document, and creating & publishing an academic paper on our project, we chose not to classify these as specific targets or milestones, because they are technically not part of our actual project, and we are unsure whether or not we will decide to publish an academic paper.

3.5. RISKS AND RISK MANAGEMENT/MITIGATION

The potential risks associated with each task or "sprint" of our project are given in the table below, with a severity level and estimated probability assigned to each risk. For risks classified with "high" severity or an estimated probability greater than 0.5, a risk mitigation plan is also given beneath the table.

Task/Sprint	**Risk**	**Severity**	**Probability**
Amplifier & Filter Design	Bandwidth of system is narrower than expected	Mid	0.4
Amplifier & Filter Design	System gain is less than expected (1)	Low	0.6
Wi-Fi Communication Design	Having latency in data from machine to GUI (2)	High	0.6
GUI (Graphical User Interface) Design	Having an unstable connection with the Wi-Fi module (3)	High	0.3

Amplifier & Filter Prototype & Buildout	Some components ordered have incorrect nominal values, tolerances, etc. (4)	Low/Mid	0.6
Amplifier & Filter Prototype & Buildout	Specific components or parts out of stock (5)	Low/Mid	0.6
Wi-Fi Communication Prototype & Buildout	WiFi module is not compatible to communicate effectively between microprocessor and GUI (6)	High	0.7
GUI Prototype & Buildout	Missing necessary data and functionality of the user (7)	High	0.4
Battery Module	Battery protection system doesn't properly protect from overcurrent/overheating (8)	High	0.2
Combined Design & Buildout	Full design doesn't fit on PCB (front & back) (9)	High	0.3
Implementation in BILab	Device doesn't fit in the PAT System (10)	High	0.2

The list below describes the risk mitigation strategies for the risks from the table with high severity or probability above 0.5, which are referenced by (1), (2), etc. in the table.

1) System gain is less than expected: The first risk is that the system does not have enough gain to amplify the signal to the required magnitude of the ADC. We have discussed steps to add female header pins so we can add more IC modules in the future to give the system more dynamic and user selected functionality. This would in turn address any problems with system gain.
2) Having latency in data from machine to GUI: The device is only useful if the user can see realtime data like a regular oscilloscope would provide. We will need to send over the server a large quantity of data continuously so we have to ensure that the WiFi module we use is capable of this. We also need to ensure the interface we program in LabView will process the data and display it as efficiently as possible.

3) Having an unstable connection with the Wi-Fi module: One migration strategy we have currently enacted is the use of high-end Wi-Fi modules that allow for stable connection within a 20 foot radius. Given the condition this device will operate under, it can be assumed that it will give us the needed stability for consistent connection.
4) Some components ordered have incorrect nominal values, tolerances, etc.: This is a common mistake when ordering parts that can easily be fixed by verifying the correct values, component properties, etc. with the circuit schematic and placing another order with the corrected parts.
5) Specific components or parts are out of stock: Typically, having parts in a design or order that are out of stock can be fixed or worked around fairly easily by substituting parts or components with similar values and characteristics, ordering from another supplier, or purchasing an identical or similar component from a different manufacturer.
6) WiFi module is not compatible to communicate between microprocessor and GUI: Proper research using online documentation and product help services will be conducted before the purchase of the device to ensure its compatibility with all components.
7) GUI missing necessary data and functionality of the user: The product's main purpose is to serve the user with important information and data analysis. We need to ensure that we are producing the needs of the user in the GUI and that it is easy to collect data.
8) Battery protection system doesn't properly protect from overcurrent/overheating: Our client will be handling most issues related to the battery and battery protection system. If the battery is not properly protected from overcurrent or overheating, the consequences could be severe, such as the battery catching fire or exploding. One way these risks could be mitigated is through the use of a voltage regulator in the battery pack (such as the TI LM7805) that keeps the voltage within a safe operating range at all times.

9) Full design doesn’t fit on PCB (front & back): If this problem becomes apparent, we will have strategies to remove redundant components and switch footprint sizes of devices.

10) Device doesn’t fit in the PAT System: In order to mitigate the risk that the overall device doesn't fit in the designated brackets, we have sectionalized the design into phases and parts while selecting the smallest components that do not reduce overall performance. WIth that, we have taken steps to reduce the use of redundant components that didn't have a large effect on the overall systems specification requirements.

3.6. PERSONNEL EFFORT REQUIREMENTS

Task/Sprint	**Hours: Adam**	**Hours: Henry**	**Hours: Lisa**	**Hours: Vaughn**
Planning & Design: Amplifier & Filter	20	20	0	0
Planning & Design: ADC	10	5	0	5
Planning & Design: Wireless Communication	0	0	20	0
Planning & Design: User Interface	0	0	4	0
Prototyping: Amplifier & Filter	20	20	0	0
Prototyping: ADC	20	20	0	20
Prototyping: Wi-Fi Communication	0	0	12	5
Prototyping: User Interface	0	0	15	0
Prototyping: 3D Model Case	0	0	15	0
Final Build: Amplifier & Filter	15	15	0	0
Final Build: ADC	15	15	0	15
Final Build: Wi-Fi Communication	0	0	15	15
Final Build: User Interface	0	0	15	15
Final Build: 3D Printing Case	0	0	5	0
Design & Implement Battery Module	10	10	0	0

Implement Device in ISU BILab	5	5	5	5
Write & Publish Academic Paper for Client	5	5	5	5
Presentations for Client & Advisor Meetings	20	20	20	20
Weekly Client Meetings	28	28	28	28
Biweekly Joint Client & Advisor Meetings	14	14	14	14
Team Website Maintenance	0	0	5	0
Prepare Lightning Talks	15	15	15	15
Write & Revise Design Document	20	20	20	20
Faculty & Industry Panels	4	4	4	4
TOTAL PERSONNEL HOURS REQUIRED	**221**	**216**	**217**	**181**

The table above is an estimate for the total number of person-hours that will be required for this project. The table does not include 491 class time, because this time is not considered “hours” where the team is working on the project. However, it does incorporate the time that will be spent outside of class working on presentations and design documents for the course, as well as preparing an academic paper and presentations for our client, meeting with our client and faculty advisor, implementing our device after it is completed, and other tasks and requirements that fall outside of the targets, milestones, and metrics given for the project. Tasks corresponding to the three targets are bolded in the table and milestones are included within these tasks (see schedule from Section 3.4 for explanation of where milestones and metrics fall within each task).

Since our team members have agreed that we do not want to spend more than 10 hours per week on average working on Senior Design, the total available time for each member should be no more than 290 hours (since there will be 29 “working” weeks across the two semesters). As the table shows, the projected hours per member is within this limit, with most members anticipating to spend an average of about 7.5 hours per week working on the project.

3.7. OTHER RESOURCE REQUIREMENTS

Aside from the obvious financial resources that will be required to fund our project, we will require tools and equipment, parts and materials, training and instruction, and some amount of labor. A breakdown of our needs associated with each of these resources is given below.

- **Tools and Equipment:**
    - Soldering equipment (iron, tin, desoldering wick, flux, wire cutters, clamp)
    - Personal protective equipment (safety goggles and gloves for soldering)
    - Electrical measuring tools & lab equipment (multimeter, oscilloscope, wavegen)
    - Software (Arduino IDE, LabVIEW, MATLAB, EasyEDA, NI Multisim, etc.)
    - 3D Printer & 3D modeling software
- **Parts and Materials:**
    - Resistors, capacitors, and inductors (surface-mount and through-hole)
    - Miscellaneous surface-mount and through-hole components
    - STM32 Microcontroller IC
    - ESP Wi-Fi Module
    - Analog-to-Digital Converter (ADC) IC
    - Amplifier ICs (Aside from RF Amplifier)
    - Arduino Board
    - Printed Circuit Boards (PCBs)
    - Breadboards
    - Jumper Wires
    - SMA Cables
    - RF connectors

- **<u>Training and Instruction:</u>**
    - EasyEDA and NI Multisim (circuit simulation & design software) tutorials
    - LabVIEW training and assistance (as needed)
    - Soldering training (as needed)
    - General electrical/software questions for client
- **<u>Labor:</u>**
    - ETG Parts Orders
    - PCB soldering & assembly (from ETG or JLCPCB)
    - Programming microcontroller and LabVIEW
    - 3D printing case for assembly