# System Design for Mechatronics Engineering

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# 1 Revision History

| Date | Version | Notes |
| --- | --- | --- |
| 18 January 2023 | 1.0 | Revision 0 for System Design |

# 2 Reference Material

This section records information for easy reference.

## 2.1 Abbreviations and Acronyms

Please refer to the System Requirements Specification at this link for a list of abbreviations and acronyms.

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# 3 Introduction

This document provides a detailed description of the system design for the EMAnator; the system currently under development by the Back End Developers which aims to assist researchers in performing Ecological Momentary Assessment for older adults. The goal of this design is to construct a system which fulfills all the requirements specified in the System Requirements Specification, and that meets the needs of EMA researchers.

This document provides the big-picture goals of the system, an overview of the project, a comprehensive list of system variables, and details regarding the user interfaces of the system. It also lists the various hardware and electrical components involved in the design of the system. Finally, it includes a high-level timeline for the development of the system.

The design presented in this document is the result of collaboration between the Dr. Luciana Macedo of the School of Rehabilitative Sciences and the Back End Developers development team. We have discussed the project requirements and identified the best approach to meet them. This is covered in detail in the document titled Problem Statement and Goals.

The Back End Developers hope this document serves as a useful guide for anyone involved in the development or deployment of the system.

# 4 Purpose

In general, engineering design documentation is a set of documents that outline the detailed specifications for an engineering project. It describes the design of the project, including its requirements, the materials to be used, the processes involved, the safety and environmental considerations, and the estimated costs. The purpose of engineering design documentation is to provide a comprehensive record of the project that can be consulted by engineers, oversight bodies, and other stakeholders throughout the project's life cycle.

This documentation includes technical drawings, process diagrams, system and component specifications, and relevant schematics and images. It also provides a basis for quality control and assurance, as well as a way to track progress and identify potential areas of improvement. It is an essential part of any engineering project, as it ensures that all stakeholders have a clear understanding of the project and the necessary steps for its successful completion.

This project currently has the current pieces of design documentation available:

- Problem Statment and Goals

- Development Plan
- System Requirements Specification
- Hazard Analysis
- VnV Plan
- Module Guide
- Module Interface Specification
- System Design Document

# 5 Scope

This system in theory is very simple. An array of sensors grabs info regarding the position, speed, orientation, etc. and uses that information to understand the current state of the user. This data is then used to generate prompts that the user will answer and all the collected data is compiled, processed and stored within the system. Finally, researchers will analyze the collected data and generate observations.

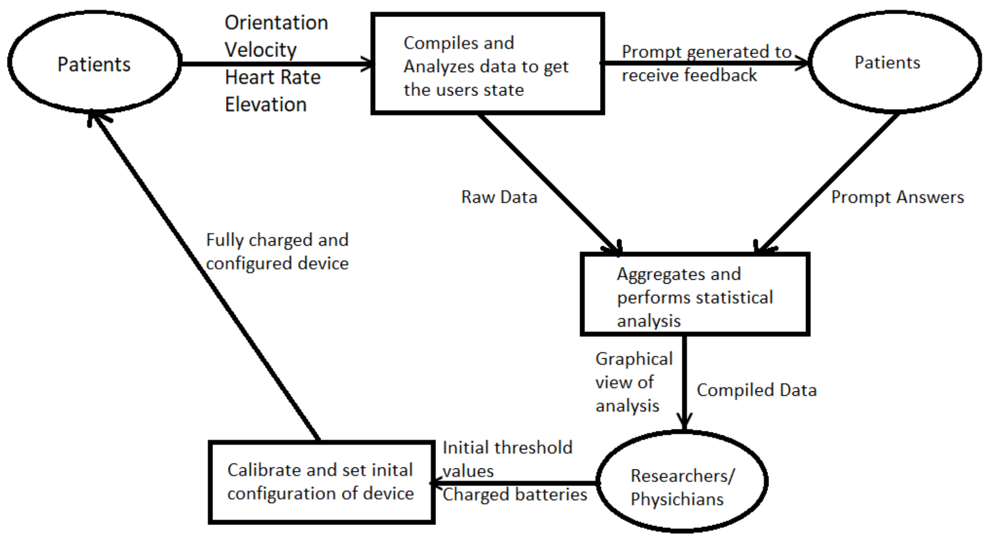


Figure 1: System Context

[Include a figure that show the System Context (showing the boundary between your system and the environment around it.) —SS]

# 6 Project Overview

## 6.1 Normal Behaviour

## 6.2 Undesired Event Handling

[How you will approach undesired events —SS]

## 6.3 Component Diagram

## 6.4 Connection Between Requirements and Design

[The intention of this section is to document decisions that are made "between" the requirements and the design. To satisfy some requirements, design decisions need to be made. Rather than make these decisions implicit, they are explicitly recorded here. For instance, if a program has security requirements, a specific design decision may be made to satisfy those requirements with a password. —SS]

# 7 System Variables

[Include this section for Mechatronics projects —SS]

## 7.1 Monitored Variables

## 7.2 Controlled Variables

## 7.3 Constants Variables

# 8 User Interfaces

## 8.1 Hardware User Interface

The device is worn by a participant on the wrist for measuring activity and generating prompts. The following items will be shown on the display of the activity tracker:

| **Description** | **Behaviour of TFT Display** |
|---|---|
| Power up of activity tracker. | Displays Back End Developers on startup. |
| Default behaviour, no activity tracked. | Displays date and time. |
| Activity tracked. | Prompt generated on screen, for example: Are you in pain? |
| Answering prompts using touch sensor (bezel). | Toggle between different options on screen. For example: (Yes/No). |

Table 1: Components of Hardware User Interface

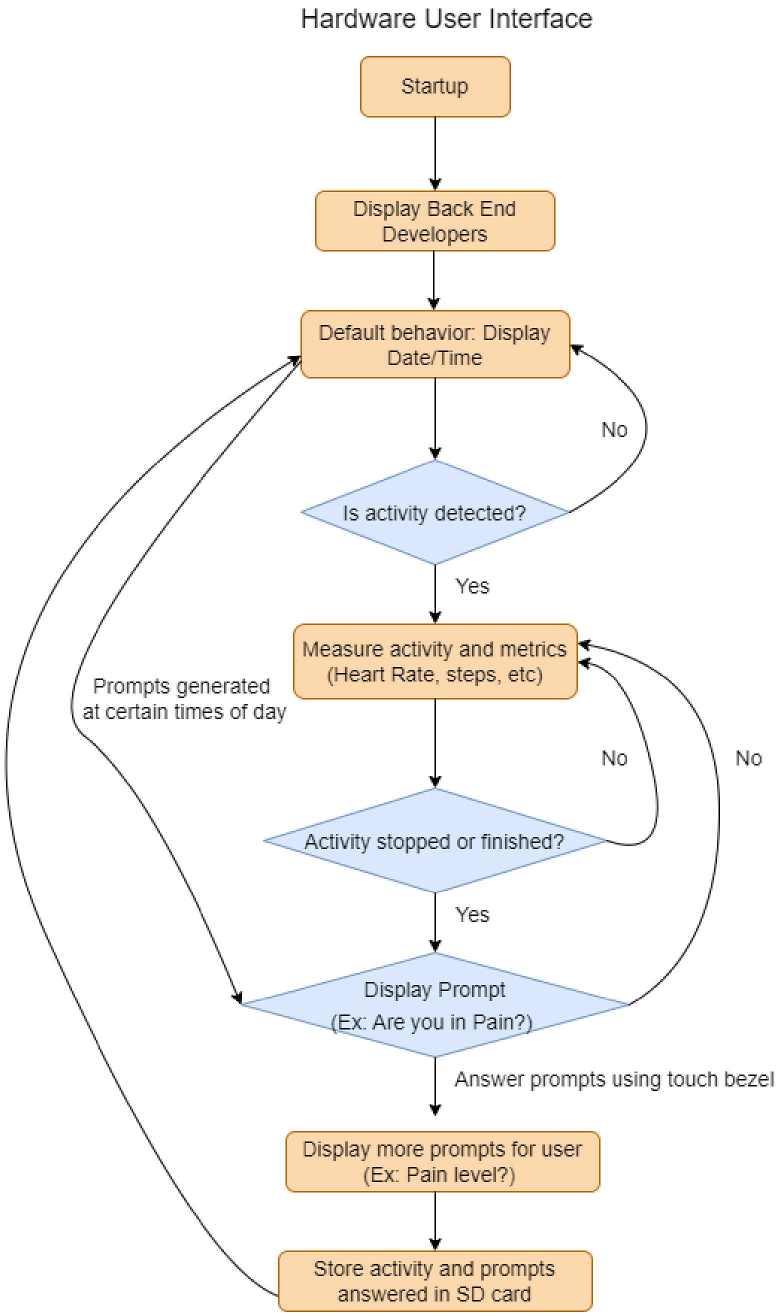


Figure 2: Finite State Machine for Hardware User Interface


Figure 3: Display on activity tracker at startup

Figure 4: Display with custom 3D printed case


Figure 5: Display of Date/time on activity tracker.

## 8.2 Software User Interface

The Software User Interface will be used by the Researcher for configuring the activity tracker according to the participant. The interface will be on the Host Computer and will be able to store participant data, create new data and view records using encryption. The interface will also have authentication, and only the Researcher will be able to log in. The following features are available on the Software User Interface:

| Options on UI | Description |
|---|---|
| Main window | Main menu that leads to different windows when clicked. |
| Connect to tracker | Connects to SD card for device and shows status of connection. |
| Create Records Window | Creates new record for particpant and stores it in a database. A record can only be created if the correct username and password is provided. |
| Records Window | Participant records can be viewed in a tabular format and can be searched/filtered. |
| Data View Window | Data stored on SD card can be viewed and filtered. Data can also be plotted using Graph button. For example: Heart Rate vs Time. |

Table 2: Components of Software User Interface

Below is an example of the Software User Interface for the Main window.

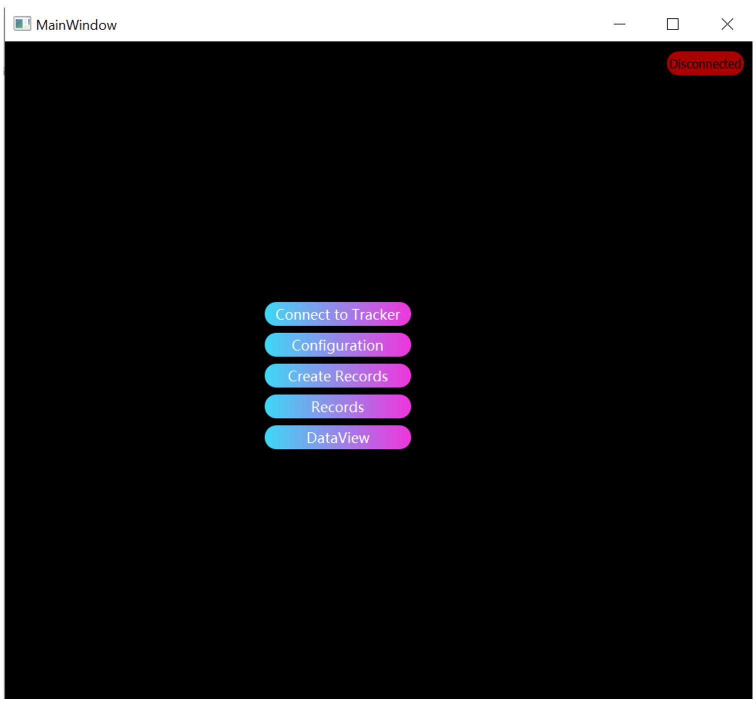


Figure 6: Main Window for Software User Interface

For more examples of Software User Unterface, refer to Appendix.

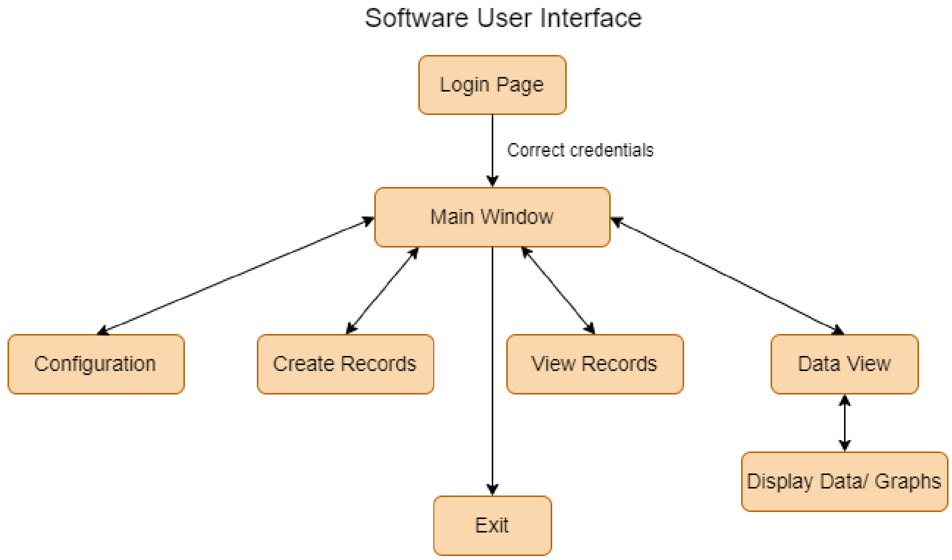


Figure 7: Finite State Machine for Software User Interface

[Design of user interface for software and hardware. Attach an appendix if needed. Drawings, Sketches, Figma —SS]

# 9 Design of Hardware

The table below shows hardware components that will be used in the activity tracker.

| **Hardware Component** | **Description** |
|---|---|
| Custom PCB | Custom PCB designed to fit in activity tracker. |
| MPU 6050 | Accelrometer/Gyroscope, off-shelf component. |
| seeeduino xiao samd21 | off-shelf microcontroller for activity tracker. |
| DS1307 RTC | Real time clock, off-shelf component. |
| TFT Display | Off-shelf display used in activity tracker. |
| Outer casing for TFT Display | Designed using Autodesk Inventor and 3D printed |
| Pulse sensor | Plug and play Heart Rate sensor for Arduino (off-shelf component) |
| Li-Po Battery | Generic off-shelf lipo battery used for smart watches. |
| USB Type-B charger | Generic off-shelf usb to Type-B charger to charge device. |
| MicroSD card | Standard off-shelf SD card. |
| SDCARD connector 473521001 | MicroSD connector (off-shelf component) |
| Watch straps | Generic watch-straps for strapping device onto the wrist. |

Table 3: Components of Hardware Design

[Most relevant for mechatronics projects —SS] [Show what will be acquired —SS] [Show what will be built, with detail on fabrication and materials —SS] [Include appendices as appropriate, possibly with sketches, drawings, CAD, etc —SS]

# 10 Design of Electrical Components

The schematic/circuit diagrams shown below are used to generate the PCB layout.

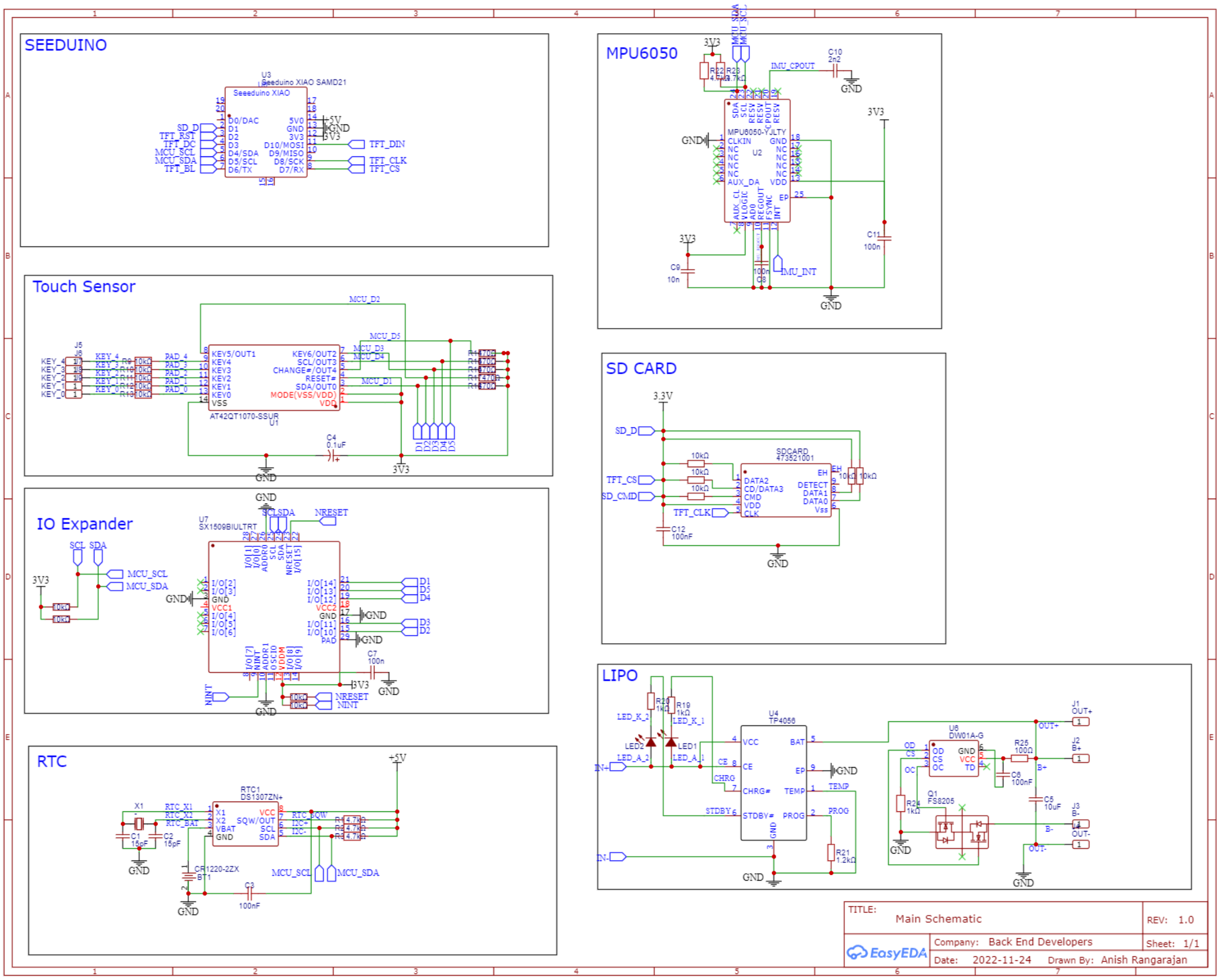


Figure 8: Schematic for PCB

The custom PCB designed is shown below.

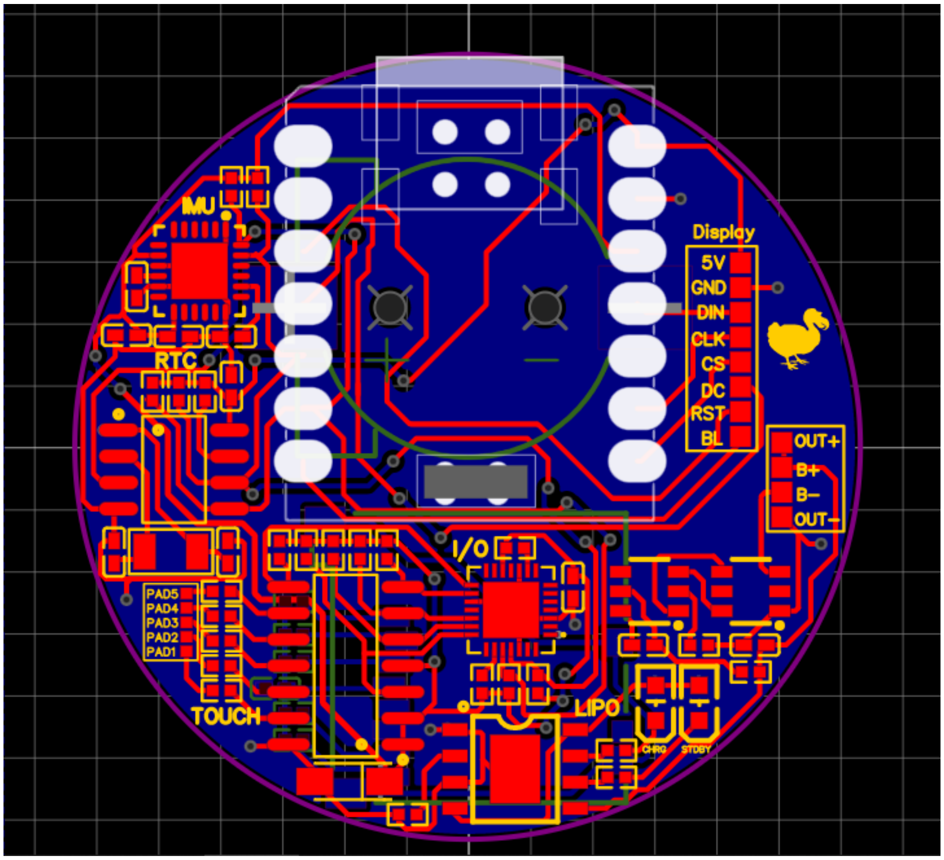


Figure 9: Layout of PCB design

The table below shows Electrical components built into the activity tracker.

| Electrical Component | Description |
|---|---|
| IO Expander SX1509BIULTRT | off-shelf IO Expander used in PCB. |
| Resistors | Resistors built into hardware components (1k ohms, 10k ohms). |
| Capacitors | Capacitors built into hardware components (15pF, 100nF). |
| LEDs | Various LEDs in device used to identify status of operation. |

Table 4: Electrical Components

[Most relevant for mechatronics projects —SS] [Show what will be acquired —SS] [Show what will be built, with detail on fabrication and materials —SS] [Include appendices as appropriate, possibly with sketches, drawings, circuit diagrams, etc —SS]

## 11 Design of Communication Protocols

[If appropriate —SS]

## 12 Timeline

[Schedule of tasks and who is responsible —SS]

# A Software Interface

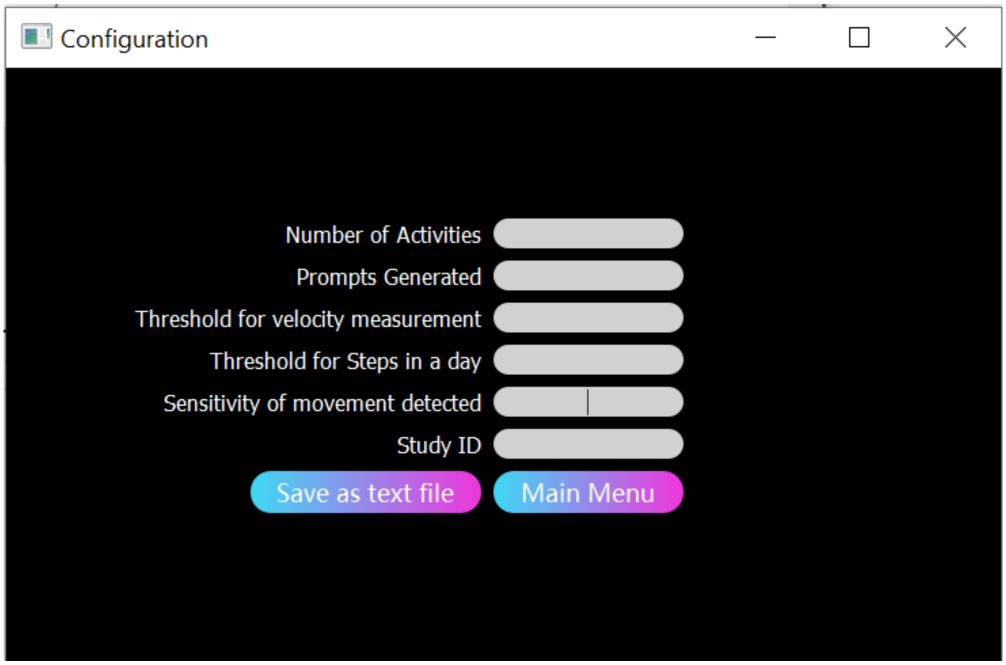


Figure 10: Configuration Window

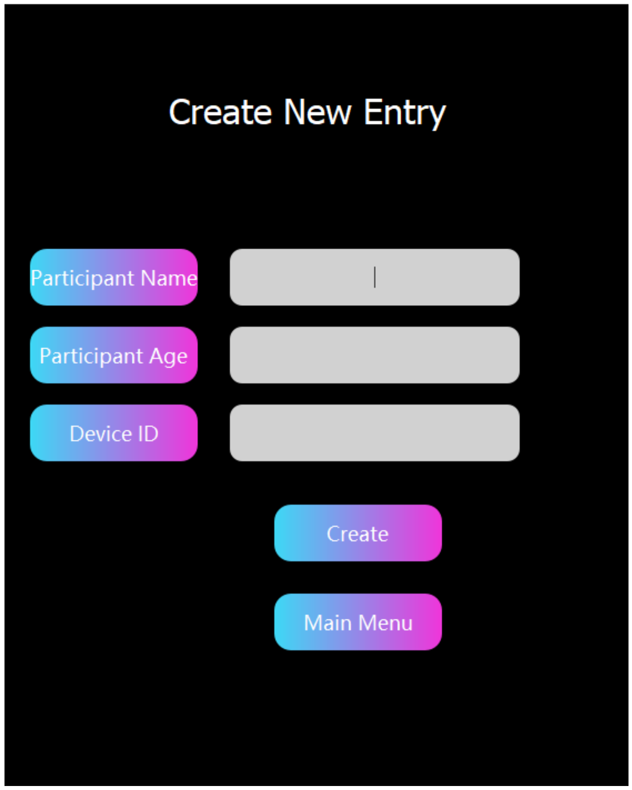


Figure 11: Create Record Window


Figure 12: Record Window

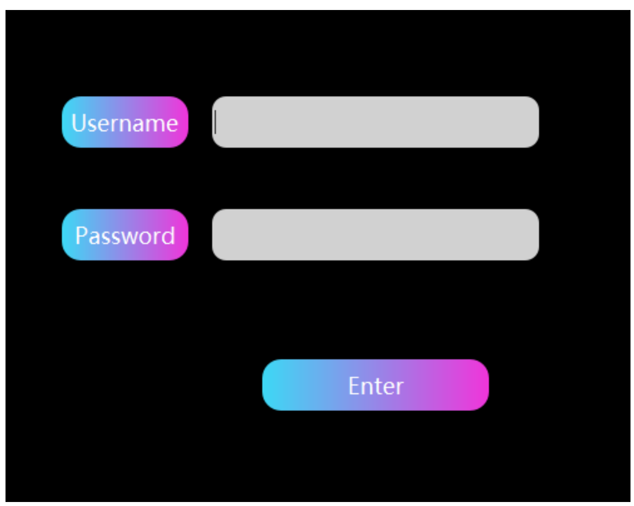


Figure 13: Login Dialogue box

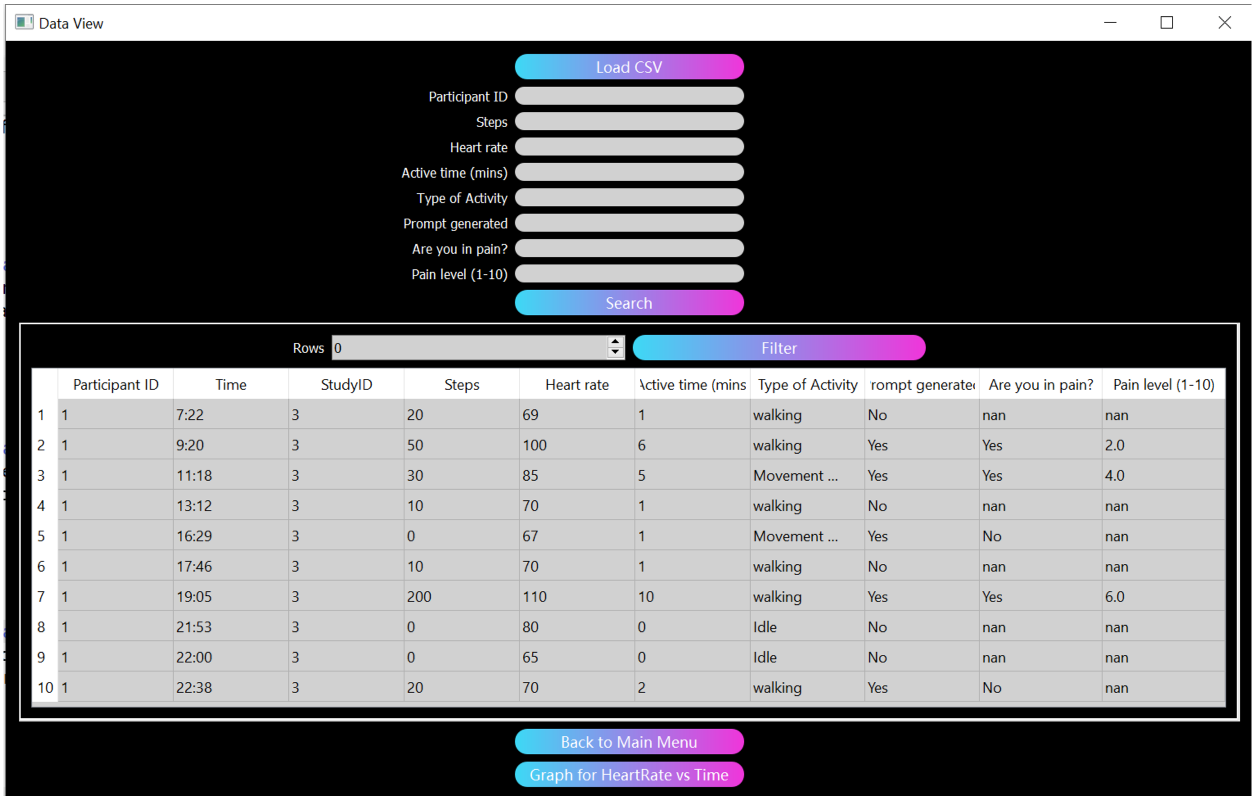


Figure 14: Data View Window

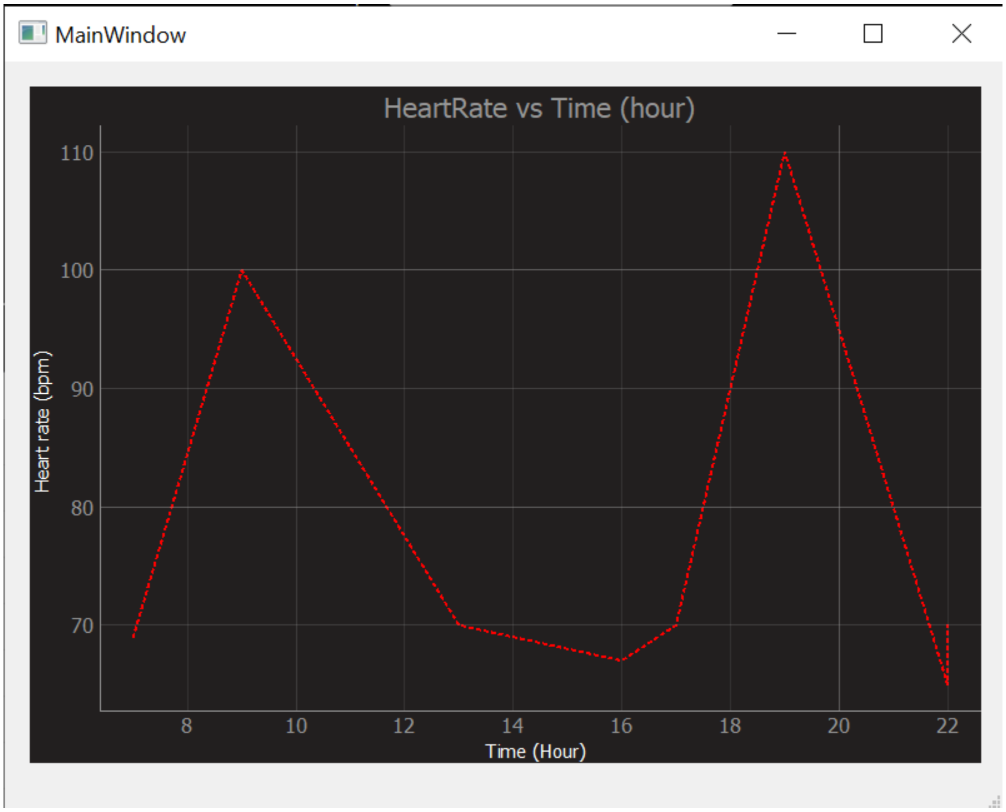


Figure 15: Generated Graph for Heart Rate vs Time

# B Mechanical Hardware

# C Electrical Components

# D Communication Protocols

# E Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Problem Analysis and Design. Please answer the following questions:

1. *What are the limitations of your solution? Put another way, given unlimited resources, what could you do to make the project better?* (LO_ProbSolutions)

   This is a difficult question to answer. Given unlimited resources, the Back End Developers would have many more options available in fundamental design, and may have pursued a different design altogether — however going forward with this question it is assumed that this question refers to the current design on hand.

There are many forms of ”resources” that have to be managed during an engineering project. Cost, time, testing opportunities, and many more constraining factors can be considered resources. Let us consider cost and time, as those have the largest and most obvious impacts on the project.

Given an unlimited budget, the face of the EMAnator likely would have been a touchscreen, as the cost of a touchscreen was prohibitively high and we had to find a workaround using nearby capacitive touch sensors instead. In addition, the we would have kept ordering test PCBs of our designs as we iterated through different version. This would have allowed us to test individual components and wiring routes as we constructed the final design. As cost was limited, we have to finish the whole design first, and proceed to order a very limited number of test PCBs on which we must test all aspects of our design. We will then revise the design to compensate for issues found on the test boards, order the final set, and pray that they work as intended. We would also consider added an operating system to the device to make it ”smart”. Currently our device has a very limited number of functions that fit tightly into our requirements. An OS would enable us to expand the functionality of our device beyond its current borders.

If the design could have taken place over an infinite amount of time, there are additional possibilities that we could consider. Primarily, we could investigate using and shrinking down a more powerful microcontroller. Currently, the type of microcontroller that we can use is extremely limited in its capabilities. However if we wish to upgrade to a more powerful one (e.g. a Raspberry Pi), we would have to place a large number of auxiliary components necessary for the functioning of the more powerful (and more needy) processor. This would have taken a large amount of time; as finding reasonable space on a PCB and routing components like these is notoriously time consuming.

Obviously there are many new and exciting possibilities for this project should certain resources be unlimited. But overall, we are satisfied with the design that we have made given the constraints that have been placed on us. Should we decide to continue developing this device past the capstone course, we may return to these options at a certain point.

2. *Give a brief overview of other design solutions you considered. What are the benefits and tradeoffs of those other designs compared with the chosen design? From all the potential options, why did you select documented design?* (LO_Explores)

During the initial phases of the design process, we encouraged each other to throw around as many design ideas as we could. Here is a short list of a few we considered, along with a few of their pros and cons:

- Anklet Activity Tracker
  Pros:
  - Discreet and unobstructive to daily activities.
  - High-quality data available regarding motion of legs (steps, jumps, falls, etc.).

  Cons:
  - Difficult to reach for people with difficulty bending over.
  - If designed poorly, can potentially look like a prison ankle monitor.
  - Difficult for a user to read any data displayed on a screen on the anklet.
- Waist-Mounted Activity Tracker Pros:
  - Being close to the core of the user, the maximum weight weight of the device can be greatly increased.
  - Easy access to those with difficulty bending over, or with other movement related issues.

  Cons:
  - Located in a hard-to-hide location, and may get in the way of reaching below the waist.
  - Incompatible with certain clothing.
- Bracelet Activity Tracker Pros:
  - Extremely discreet.
  - High-quality data available regarding motion of arms (walker use, exercise, etc.).
  - Not obstructive to daily activities.

  Cons:
  - Interacting with a small-surface area bracelet may be difficult for those with movement issues.
  - Small size reduces battery capacity options.
- Full Body Suit Tracker Pros:
  - Highest fidelity data possible, collecting data from every point on the body.
  - Difficult to misplace.

  Cons:
  - Prohibitively expensive.
  - Easy to damage.

  - Many people would be uncomfortable wearing a full sized-body suit during all their daily activities.

- Mobile App Pros:
  - Inexpensive.
  - Soft; meaning we can modify it according to new requirements whenever necessary.
  - Many are already extremely familiar with activity tracking apps; onboarding process will not be difficult.
  - Can be linked to off-the-shelf smartwatches with fantastic activity collecting technology.

  Cons:
  - Not a mechatronics solution.

Why did we pursue the smart-watch solution? For two very important reasons; end-user familiarity and end-user acceptability.

The other solutions that we could have proceeded with may have met all the functional requirements and many of the nonfunctional requirements that we specified, but many of them are unfamiliar and possibly confusing to the end user. For example, having to wear a box around one's waist is likely a novel and strange experience to any user, and could make them uncomfortable with using the device in general. In addition, most people have worn a watch before, and are very familiar with their operations. This makes the process of learning how to use the watch simpler and more intuitive.

A smart-watch was also deemed the most acceptable solution to an end user. It would be difficult to convince anyone to wear a sensor covered spandex suit everywhere they went in their daily life, for a period of up to 14 days. A watch is familiar, socially acceptable, and much less embarrassing than wearing a full bodied suit.