# Executive Summary

Wearable Cardiac Monitor

*Design Document*

Team 24

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## Engineering Standards & Design Practices

- IEEE Standards
- Circuit and Block Diagrams
- Agile practice & values
- Commenting on Code

## Summary of Requirements

- Wearable
- 48+ hour battery
- Bluetooth phone connection
- Data storage
- Easy to use Android Application

## Applicable Courses from Iowa State University Curriculum

1. CprE 185 - Introduction to C Programing
2. CprE 288 - Embedded Systems in C
3. CprE 388 - Android studios development
4. E E 224 - Signals & Systems I
5. E E 230 - Electronic Circuits & Systems
6. E E 303 - Energy Systems and Power Electronics
7. E E 324 - Signals & Systems II
8. E E 330 - Integrated Electronics
9. E E 475 - Automatic Control Systems
10. ComS 227 - Introduction to Java
11. ComS 228 - Java data structures
12. ComS 309 - Java app development

## New Skills/Knowledge acquired that was not taught in courses

- Bluetooth Communication was something we hadn't really worked on in any of our classes so we need to learn how that worked in order to effectively finish the project.
- We also became better at communicating with a group and effectively managing our time while we are all meeting together.
- We got a better understanding of reading technical diagrams in order to understand how our devices work.
- We more efficiently learned to use existing libraries in order to reduce the amount of work needed and increase quality in development.

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# 1. INTRODUCTION

## 1.1 ACKNOWLEDGEMENT

Thank you to Dr. Cheng Huang, our client and advisor, for providing guidance throughout the project. He has been very helpful with providing us with a clear focus for the project as well as ensuring we have the resources we need to complete the project. Dr. Huang has lots of great recommendations and suggestions which have been greatly appreciated as we work to ensure our device works properly.

We would also like to thank Cosette Scallon, MD from Thielen Student Health Center for taking time out of her day to help us get a better understanding of a heart beat. During this time, we were also able to get a reading from one of our teammates in order to compare our data to throughout our project.

## 1.2 PROBLEM AND PROJECT STATEMENT

On the market right now, wearable heart monitors that last 48 hours are scarce and very expensive. Not to mention, in searching for one online, most of the products are watches. This form of monitoring is less useful than those with ECG electrodes so we are wanting to combine the size of the watch with the functionality of heart rate monitors that have the ECG electrodes for our project.

With these issues in mind, we are making a heart monitor that will be cheap and easy to use for our client that may be used for future clients as well. This heart rate monitor will be smaller than a normal heart rate monitor in order to make it more portable. By making it smaller, the client will not be limited to sitting in a doctor’s office all day and can still go about their daily activities.

This heart rate monitor will be a compact, have low power consumption, and user friendly. We will still have the three typical ECG electrodes that will connect to the clients torso in order to get a signal which will be sent to the Android application. From there, the Android application will provide the client with their heart rate. Once the application has the data, it will store the data in order for someone (typically a professional) to read. We are hoping that it will also help point out any irregularities that might occur in someone’s heart such as a heart murmur or other irregularities.

## 1.3 OPERATIONAL ENVIRONMENT

Our product attaches to the human body, ideally, this should be worn all day long for up to two days or 48 hours. Therefore, it will follow people's daily actions such as walking, running, showering, etcetera. Shaking and hitting against the body could potentially happen. It may be exposed to water during a shower or rain.

## 1.4 REQUIREMENTS

- Wearable
- Smartphone (Android) connectivity
- 48+ hour battery life
- Motion calibration
- Data logging/storage

## 1.5 INTENDED USERS AND USES

The heart rate monitor will be intended for anybody that feels as though something is not working properly with their heart. Most of these clients will typically consist of someone coming from a doctor's office or a pharmacy. The client will wear this heart rate monitor for up to 48 hours with the gathered data being stored to a smartphone application via bluetooth connection.

## 1.6 ASSUMPTIONS AND LIMITATIONS

Assumptions

- 48+ hours battery duration
- 48+ hours worth of stored data
- Bluetooth connectivity - this is how data is sent
- Pocket size or smaller
- Wearable and comfortable
- Limit to one user per heart rate monitor
- The device will need to detect when it is not properly connected
- If the device is to lose power, it will not lose all currently collected data
- The system operates at 3.3V

Limitations

- No larger than 5” x 5” x 3”
- Wires long enough to have the electrodes placed on the skin above the heart
- The electrodes that get attached to the body are limited where they can be placed so that they can pick up a reading
- The system must be safe to keep next to the body
- User must have a device to connect the heart monitor to via bluetooth

## 1.7 EXPECTED END PRODUCT AND DELIVERABLES

The client will be provided with a wearable heart rate monitor that will transmit the gathered data into an application on a smartphone. For this reason, the client will need to have a smartphone with access to the application.

The end product will be a device that is small enough to either be comfortable to wear on the client’s torso or fit into a pocket. The device will be able to monitor the heart and send the data to a smartphone which will need an app that has been developed, by our team, for the device to store and read the data. The user will need to have a smartphone with the application installed and the user may need to replace electrodes if they aren’t sticking to the client.

There will be a user manual on how to set up the device and a power cord to recharge the device. The delivery date of our final product to our client will be April 27th.

# 2. SPECIFICATIONS AND ANALYSIS

## 2.1 PROPOSED DESIGN

We will be using an AD8232 heart monitor, Arduino Mini, and a Bluetooth Mate 4.0 to obtain, process, and send the data to the smartphone. The smartphone will be graphing and storing the data sent out to be viewed by the client.

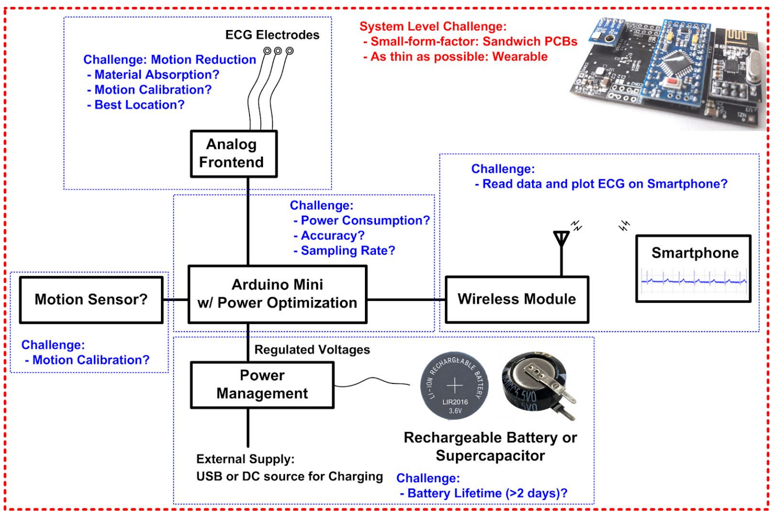



*Figure 1 - General Overview of the Project Design*

Figure 1 shows the general design of the project. It has been broken down into five specific areas which we will be working on to build an optimized product. Our initial focus was on establishing a reliable reading from the analog ECG electrodes and maintaining a bluetooth connection with the device. Upon successfully finishing these we moved into optimizing the power management of the device and work on potentially using motion sensors to eliminate any electrode noise if time permits.

## 2.2 DESIGN ANALYSIS

We initially had a general block diagram for our project provided to us by Dr. Cheng. We are to create a system that has a small form factor and is easy to use for people. This device will attach to the human torso with three electrode pads and will be worn for up to 48 hours.

We discovered that the original Arduino we were looking at is no longer made so we had to find another one; we ended up using the Arduino mini. However, the overall design of our device was sufficient and didn't require any changes.

As we continue to work with the parts and better understand the capabilities and actual way the parts interact with each other we will gain a better understanding of what additional parts we may need for the second semester. This method is fine for the first semester, but it could slow down the roll for the second semester if we need to keep reordering parts that work better after we test them.

## 2.3 DEVELOPMENT PROCESS

We followed the Agile method. This allowed us to set short term goals and have an idea of where we were as a group on the tasks we need to complete. This also allowed us to have a way to look back at our project timeline and see ways that we improved throughout our project.

## 2.4 DESIGN PLAN

The design plan for the initial prototype is going to go through a heart rate monitor, with a signal sent out to an Arduino. The Arduino will then process this data, and send the signal out to a bluetooth chip. Lastly, this will send the signal over bluetooth to a bluetooth connected smartphone which will record the data, as well as show a live heart rate and, ideally, alert the user if there is some sort of anomaly.

The parts we have chosen are very small to fill the size requirement. After we have a working prototype we plan to go back and limit power usage in all the places we can in order to meet the two day battery life requirement. After or during power management, we will attempt to design an algorithm to reduce false positives in the heart rate detector due to movement.

Lastly, we will perform final tests to make sure wearing the product over a long period of time remains consistent and that everything is up to the standards we have set. This will contain outside opinions of people who do not understand the technical aspect of the product, to get feedback on the user interface of the app and product itself. This will be key in figuring out if the product is user friendly and incentivising to use.

# 3. STATEMENT OF WORK

## 3.1 PREVIOUS WORK AND LITERATURE

We will be using many open sourced pieces for this project including Arduino libraries and the Android libraries. These libraries come with their own documentation and also have multiple examples available online to help us understand what we need to complete our final project. We have also looked at other existing versions of wearable cardiac monitors to find key similarities between them. We have specifically taken note of the layout, design, and features these other systems have implemented in their adjoining software to help make sure we can find ways to make our version equal to or better.

One product in particular, which is similar to what we will be doing, is the Qardio's Wearable ECG which can be seen in figure 2. This product has a nice application layout and is a sleek design which can be worn by the consumer during normal daily activities.

*Figure 2 - Qardio Wearable ECG*
*https://www.getqardio.com/*

## 3.2 TECHNOLOGY CONSIDERATIONS

Our biggest technology consideration for this project is our power consumption; we are wanting to keep it as low as we possibly can. Back when the technology was first starting to come out, everyone was just worried about getting products to work properly. Now since technology has grown, we are more focused on improving older products while still creating newer products that help make everyday tasks easier. Our group wants to make the typical heart rate monitor smaller and more user-friendly.

One of the biggest technological advances that we have today, which helps our project immensely, was the creation of Bluetooth. Our heart rate monitor will rely heavily on the Bluetooth module communicating between the physical monitor and the application. By getting the hardware to properly send the data over to the application, it will allow us to reduce the size of the typical heart rate monitor. Once we can get a smaller heart rate monitor, it will make it easier to use on a daily basis if needed.

The downfall to creating a smaller heart rate monitor is that it may not work the way we plan. Our group has never made a heart rate monitor before so this is something that is new to each one of us. Another thing that will impact our project is learning new skills as we do this project; it will benefit our knowledge but it could affect our project negatively. An example of this is with the communication aspect of the project, we have two people working on this section and both are electrical engineers. There are some programming courses within the curriculum but a computer or software engineer would know more about the programming side of things.

## 3.3 TASK DECOMPOSITION

In developing our project we have separated our group into three groups; Hardware, Software, and Communication. Hardware is developing the ECG to monitor the heart and have the data sent to the Arduino. Communications is taking that data then sending that data from the Arduino to a phone through bluetooth communications. Software is working on creating an application for the phone to collect the received data sent from the device's bluetooth and display a graphical representation of the heart beating.

| | |
|---|---|
| Hardware | Work with an ECG to monitor the heart and have the data sent to the Arduino. |
| Communication | Developing the code for our device to process the data and to send the data to a phone. |
| Software | Developing the app that will store the data from the device and do data processing to display the graph of the heartbeat. |

*Table 1 - Project Break down*

## 3.4 POSSIBLE RISKS AND RISK MANAGEMENT

As it stands, there is a pretty big issue with the ECG monitor we are using. It is very sensitive to movement which is the exact opposite of what we would like for our product. We have thought of a few solutions as of right now, but they may not work as anticipated. We also have some research to do on the software side involving the Bluetooth connectivity. None of us have much experience with this and we will be required to learn how it works before we can complete the project.

Another less pressing risk is in the user interface. We know from experience and research that if the UI is not user friendly enough or scuffed, the likelihood of the product being used decreases. To combat this we will be getting feedback, as mentioned in section 2.4, to provide the cleanest looking and most useful app possible.

## 3.5 PROJECT PROPOSED MILESTONES AND EVALUATION CRITERIA

There are three significant milestones currently with our project. The first is getting a working prototype that doesn't revolve on power and is somewhat accurate with minimum adjustment for noise. The second is getting the noise problem completely worked out without ruining the project. The third is getting our power consumption as low as possible as to not need to recharge the monitor every day. We have been not completely ignoring the third milestone throughout this project, so we have picked low energy parts and have built in some features to reduce power in communication. Low power consumption is our third milestone because it will be a process to get it as low as we need it to be and we want everything else to be in place beforehand.

Our initial plan for confirming it works was to test our device with another heart rate monitor we acquired through the ETG on campus called BioPac. This will be done on one person to ensure our data matches what the BioPac monitor is reading. After that, we will test it on all six of us with given requirements. For the first test, we will just sit relatively still and get a reading sent out to our app that will ideally display the same as an oscilloscope would. Our second test would be sitting down but include a greater range of motion. Lastly, we will have someone wear our device over the course of a couple of days to see how long we can get the battery to last and verify our functionality works. If it lasts longer than some set amount at the beginning, with regular checking of the app, that will be classified as a success.

After our initial tests were in place, we needed to change these up to accomodate for the closure of the campus due to Covid-19. We were unable to get our device off of the breadboard which led to us not completing our final product. Our changed testing plan consisted of still testing on just one single person but we were unable to test it on all six of us; we were also unable to wear it around for a couple of days. Luckily, before everything shut down, we were able to talk with Cosette Scallon, MD from the Student Health Center and acquired a reading of one of our teammates to compare our data to.

## 3.6 PROJECT TRACKING PROCEDURES

Project tracking has been done through weekly and bi-weekly reports which seem to be working most effectively. This can be continued into the upcoming semester, possibly with the addition of photos. As we complete certain aspects of the project we have been updating our client to ensure that they are pleased with the results and take any additional input they may have.

## 3.7 EXPECTED RESULTS AND VALIDATION

At the end of our project, we will have a working wearable heart rate monitor. This monitor will be able to send a heart rate to a bluetooth module which will then send that data to an Android application. This application will be able to provide the user with a graphical representation of their live heart rate and alert the user when an irregularity has occurred.

Our group was able to borrow a bigger and older heart rate monitor called BioPac from the ETG which we planned to be our verification that our monitor is working properly. We will compare the measured heart rate from our monitor to the one we borrowed. After trying to get BioPac to run our tests, we were unable to acquire the data we were needing. Since we couldn’t get the BioPac to work, we talked to the Student Health Center on camus. During our time at the Student Health Center, we were able to get a reading from one of our teammates to compare our data to. We were then using the data from the Student Health Center to verify our data was correct.

# 4. PROJECT TIMELINE, ESTIMATED RESOURCES, AND CHALLENGES

## 4.1 PROJECT TIMELINE

| | | | | |
|---|---|---|---|---|
| Research on Product | T | 09/15/2019 | 09/29/2019 | 10 days |
| Project Planning | T | 09/30/2019 | 10/07/2019 | 6 days |
| Resource Gathering | T | 10/08/2019 | 10/14/2019 | 5 days |
| Hardware, Communications, Software Definition/Work | T | 10/15/2019 | 10/28/2019 | 10 days |
| Group Work | T | 10/29/2019 | 11/08/2019 | 9 days |
| Arduino Sending/Receiving Data | M | 11/09/2019 | 11/09/2019 | - |
| Working to Connect Each Groups Work | T | 11/09/2019 | 11/16/2019 | 5 days |
| Reduced Noise in Heart Monitor | M | 11/17/2019 | 11/17/2019 | - |
| Connect Pieces | M | 11/18/2019 | 11/18/2019 | - |
| Fix Current Project Issues | T | 11/17/2019 | 11/24/2019 | 5 days |
| PowerPoint/Presentation Creation | T | 12/02/2019 | 12/06/2019 | 5 days |
| Design Doc Redesign | T | 11/25/2019 | 12/09/2019 | 11 days |
| Working Base App | M | 12/05/2019 | 12/05/2019 | - |
| Working Base Prototype | M | 12/16/2019 | 12/16/2019 | - |
| Break/Light Individual Work | T | 12/21/2019 | 01/12/2020 | 15 days |
| Reassess Issue and Create a Plan of Attack | T | 01/06/2020 | 01/13/2020 | 6 days |
| Fix App Latency/Laggy Issue | T | 01/14/2020 | 01/28/2020 | 11 days |
| Work to Fix Motion Issue | T | 01/14/2020 | 01/28/2020 | 11 days |
| Work on Packet Sending Problems | T | 01/14/2020 | 01/28/2020 | 11 days |
| Bring Together With Second Working Prototype | T | 01/30/2020 | 02/05/2020 | 5 days |
| Demonstrate New Better Working Prototype | M | 02/06/2020 | 02/06/2020 | - |
| Test Power Capabilities | T | 02/14/2020 | 02/18/2020 | 3 days |
| Devise Plan to Fix Power Issues | T | 02/19/2020 | 02/21/2020 | 3 days |
| Work As Group to Fix Power Consumption | T | 02/19/2020 | 03/13/2020 | 18 days |
| Have Power Consumption Down to Where We Want it | M | 03/13/2020 | 03/13/2020 | - |
| Meeting to Discuss Project | M | 03/13/2020 | 03/13/2020 | - |

| | | | | |
|---|---|---|---|---|
| Reassess Project on Feedback | T | 03/14/2020 | 03/27/2020 | 10 days |
| Fix Final Issues Based on Feedback | T | 03/28/2020 | 04/10/2020 | 10 days |
| Test Product/ Do Surveys | T | 04/11/2020 | 04/19/2020 | 5 days |
| Final Changes/Revisions Based on Test Feedback | T | 04/20/2020 | 04/29/2020 | 8 days |
| Finial Product Prototype | ▼ M | 04/30/2020 | 04/30/2020 | - |

*Table 2 - Project Timeline*

The biggest part of getting our project done in two semesters is making sure we get some working prototype by the end of the first semester. It will be much easier than attempting to start from the very beginning second semester. That is why we have set it as a milestone on our chart. Also seen above, are the 2 different branches of work happening, with a third group helping with both: the software side, and the hardware side. The communication group gets a taste of both, but focuses on getting the data from the hardware to the software. We then have a large section of time cut out for completing this document as well as preparing our presentation which will be on December 9th for the first semester. Lastly, for this semester, we will try and get the base prototype working.

Once this is complete, our second semester will be split in half, one side working towards getting the best data possible out of the heart rate monitor, and the other focused on getting our power consumption lower. These ended up going hand in hand as reducing the noise from the monitor ended up taking less power than we originally anticipated. To accommodate for them going hand in hand, we still had the two seperate teams but one side was working on getting the best possible data we could will the other was focused on the application.

## 4.2 FEASIBILITY ASSESSMENT

Base functionality of reading an ECG by a small package device and transmitting to Android. A two-day battery life will pose significant challenges, but should be manageable before the end of the project. The motion noise cancellation will be worked on, but may not be implemented sufficiently.

## 4.3 PERSONNEL EFFORT REQUIREMENTS

| Task | Hours | Explanation |
|---|---|---|
| Electrocardiogram hardware | 80 | Obtaining and maintaining a good reading |
| Arduino Communication | 80 | Connecting to the device with Bluetooth |
| Android Development | 80 | Creating an application for live readings and ECG data storage |
| Power Management | 40 | Finding ways to minimize power consumption |
| Noise Reduction | 40 | Using motion detection to eliminate ECG noise |

*Table 3 - Effort Requirements*

## 4.4 OTHER RESOURCE REQUIREMENTS

| Part | Ref./type of part | Cost | Quantity | Supplier | Supplier# / Part# |
|---|---|---|---|---|---|
| Single Lead Heart Rate Monitor | AD8232 PCB | $19.95 | 1 | SparkFun | SEN-12650 |
| Arduino Pro Mini 3.3 V 8 MHz | Microcontroller | $9.95 | 1 | SparkFun | DEV-11114 ROHS |
| Single Lead Heart Rate Monitor | Sensor Cable | $4.95 | 1 | SparkFun | CAB-12970 |
| Bluetooth Mate 4.0 - HM - 13 | Bluetooth Module | $19.95 | 1 | SparkFun | SPX-14839 |
| LP705176JS + PCM + WIRES 70MM | Lithium Ion Battery - 3Ah | $23.42 | 1 | Digikey | 1908-1375-ND |
| | Electrodes | $15.99 | 50 | 3M | |
| **Total Cost** | | $94.21 | | | |

*Table 4 - Components used in heart rate monitor*

## 4.5 FINANCIAL REQUIREMENTS

Our client is a professor at Iowa State University and the funding to complete this project is solely based on the cost of the materials to build our device. These funds will be provided by the ECPE department.

# 5. TESTING AND IMPLEMENTATION

## 5.1 INTERFACE SPECIFICATIONS

Our project will use the Arduino Micro to interface between our hardware and software aspects of the project for the most part. The Arduino allows us to process the data from the electrodes and package it into a signal we can send using bluetooth. Once the bluetooth signal is in the air, the Android device will be able to receive that signal and process it into a graphical user interface to allow the user to view and interact with the data collected.

## 5.2 HARDWARE AND SOFTWARE

For hardware, we will have three biomedical sensor pads placed on the user's chest based on Einthoven's triangle; you can learn more at the website listed under the 'References' section for the article titled "On the Einthoven Triangle: A Critical Analysis of the Single Rotating Dipole Hypothesis,". Einthoven's triangle is the placement of sensors for electrocardiography, to detect bioelectricity and send that data to the monitor. Our monitor will collect and process that electrical signal and convert the analog signal to a digital signal for the Arduino. We will design the monitor with AD8233 chip as the core to achieve this goal.

For the communication side, we initially started testing by setting up a voltage dividing circuit with a potentiometer and having the Arduino read the voltage followed by sending that data to a phone. Then we used an app on the phone called Arduino Bluetooth Controller to read the data that was being set from the device. This test allowed us to see how we needed to set up our code to send the data over to our app.

For the software side, we initially met up and tested our bluetooth connection with a simple LED circuit. The bluetooth device would broadcast a '1' when we wanted the Arduino to turn the light on otherwise it was off. Once we got that working it allowed us to see how to build off of that to get our signal transmitted instead. From there, we were sure our connection worked as expected so we started to work on the user interface in order to assure our application was easy to use for the clients.

## 5.3 FUNCTIONAL TESTING

| | |
|---|---|
| Unit Testing | Putting all components together, hardware and software, to make sure everything works together properly. |
| ECG Testing | Understand how the ECG is picking up the signal; get an understanding of how to read the signal and process the data that is collected from the signal. |
| Bluetooth Testing | Understand how to send and receive data to and from the Arduino using the Bluetooth Mate 4.0. |
| App Testing | Stress test app by graphing data for long periods of time and compare the results with a live EKG reading. Have nontechnical users try app and get feedback on UI design. |
| Integration Testing | Connecting the ECG with the Arduino and having the data sent to the app. Working on different ways to process the data that we are reading from the ECG to get out as much noise in our signal for when we try to plot our data points. |
| System Testing | Making sure that the bluetooth signal is being maintained through activities. Also making sure the user data is being saved under the proper account after the user logs into the application. |

*Table 5 - List of functional tests*

## 5.4 NON-FUNCTIONAL TESTING

We have been working on different application layouts and designs to make sure that the application isn't confusing for the users. During the second semester, we will start working on more of the physical non-functional requirements as we start to package our circuit up into its case.

## 5.5 PROCESS

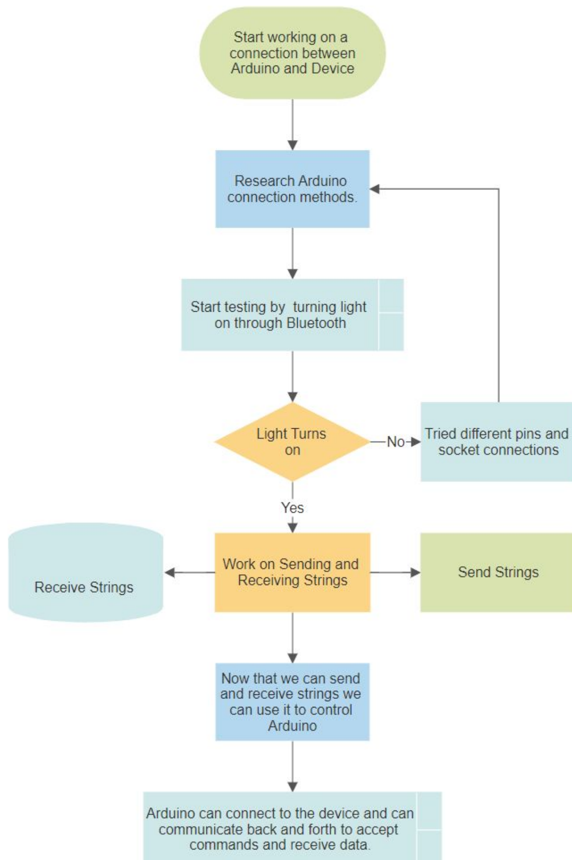



*Figure 3 - Bluetooth Communication Testing*

The testing we did during the first semester from the communication and software side revolved around the bluetooth connectivity. We started by establishing a connection and doing simple tasks to ensure it was working properly. The first test we did included using a potentiometer to send various voltage values over the bluetooth connection to ensure that the changes we were seeing had been caused by us. These various voltages were to simulate the effect we will receive from the heartbeat. After that, we used an LED light to ensure that we could send control signals between the device and the Arduino. Finally we hooked up the ECG and we were able to send commands to the Arduino from the device and the Arduino sent readings back to the device for it to graph.

## 5.6 RESULTS

From the software side, our biggest issue was maintaining the bluetooth signal through various activities. We initially tried creating an app wide resource and passing data through activities but that got messy. The next step was for us to take another look at using an app wide thread to handle the bluetooth connection. The local instance of the bluetooth activities had potential to work initially for us to get started but after doing research many sources say this may not be the best practice as the connection can be dropped if the device enters a low power mode. Throughout the second semester, we still had troubles with maintaining the bluetooth connectivity. The signal will stay connected for the most part but it does drop the connection on random occasions.

On the communication side, we were able to send the data over to the application where it was able to graph the results. One of our biggest challenges was getting the Bluetooth Mate 4.0 programmed to the extent we needed to get everything working properly with the application. Overall, our biggest challenge was the noise levels we were picking up through the wires from every small movement we made. We were able to reduce a lot of the noise while the client is sitting still, however, we were never able to get movements without any noise.

On the hardware side, our initial plan was to get our circuit onto a printed circuit board (PCB) and package our device into a case that would either fit into a pocket or be held up somehow. Due to Covid-19, we were unable to complete this section as businesses were shut down and we were unable to test the PCB through the labs on campus to ensure proper functionality. Since we were unable to get our circuit onto a PCB and packaged up, our device is still on the breadboard which was approved through our client and advisor given the circumstances.

# 6. CLOSING MATERIAL

## 6.1 CONCLUSION

Throughout this project, we worked on determining the type of signal we received and how to best turn that signal into usable data. There were some noise issues while collecting a heart beat and we needed to make sure we could eliminate that noise in our final data sample so that the user will have accurate values. Unfortunately, we were unable to reduce our noise in our final product.

For the first semester on the communication side, we had to work with the hardware and software sides. We needed to ensure that we were properly getting the data from the physical hardware to the software without losing any data and ensuring it is not getting distorted in any way. Once that was accomplished, we started working on recognizing a heart beat through our received data as well as trying to reduce noise where possible. Recognizing a heart beat and reducing the noise proved to be more of a challenge than we initially thought as we spent a majority of the second semester working on that. We were able to reduce the noise while the client is sitting in place but any movements skew the data and make it almost unrecognizable as a heart beat.

For the first semester on the software side, we developed an application which is able to store the heart beat data at all times and also allowed the user to view that data on their device for real time feedback. Since all of the data needed to be stored on the device, even while it is not being operated by the user, we needed to work with the communication team to make sure we were sending data as efficiently as possible. We also are wanting to add an option to upload the data to Google Firebase, a database which would allow the data to be more accessible to the user. Firebase also allows for us to implement a more secure authenticated login by allowing users to use Google accounts, or other popular social media platforms to log into our app and verify it is truly them. Throughout the second semester, we were able to complete our application to work as we originally hoped so we spent time working on the user interface. We wanted to make sure the app was as user friendly as possible to make sure it was easy and appealing for the client to use.

## 6.2 REFERENCES

"Documentation : Android Developers," *Android Developers*. [Online]. Available: https://developer.android.com/docs/. [Accessed: 08-Dec-2019].

G. D. Gargiulo, P. Bifulco, M. Cesarelli, A. L. McEwan, H. Moeinzadeh, A. O'Loughlin, I. M. Shugman, J. C. Tapson, and A. Thiagalingam, "On the Einthoven Triangle: A Critical Analysis of the Single Rotating Dipole Hypothesis," *Sensors (Basel, Switzerland)*, 20-Jul-2018. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6068749/. [Accessed: 26-Aug-2019].

## 6.3 APPENDICES I

Bluetooth Mate 4.0 links:
Datasheet:
https://cdn.sparkfun.com/assets/c/5/2/7/8/bluetoothdual_en.pdf

Schematic:
https://cdn.sparkfun.com/assets/5/3/a/f/a/Bluetooth_Mate_4.0-x01-schematic.pdf

## 6.4 APPENDICES II - Operation Manual

**Required parts:**

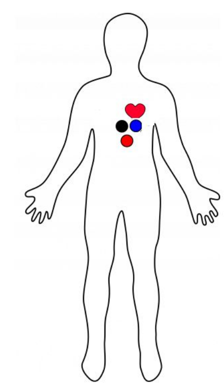
- Team 24 Wearable Heart Monitor
- Micro USB cord with USB connector
- Smartphone
- Team 24 app

**Additional parts required for debugging:**

- Computer with USB adaptor
- Arduino IDE installed on your computer
- Team 24 official code

**Setup:**

1. Make sure that the team 24 app is installed onto the smartphone.
2. Open up the app and sign in or create an account.
3. Take Team 24 Wearable Heart Monitor and hook it up to body.
    a. Hooking up Team 24 Wearable Heart Monitor by first finding the point where your ribs separate.
    b. Place the center black electrode approximately 1 inch to the left of this point where your ribs separate.
    c. Place the center of the blue electrode approximately 2 inches to the left of the center of black electrode.
    d. Place the center of the red electrode approximately 1 inch below the middle between the center of the black and blue electrode.



4. Turn on Team 24 Wearable Heart Monitor.
5. Pair Team 24 Wearable Heart Monitor with smartphone.
6. Once pair the device is all connected and will start collecting data.

**Additional setup for debugging:**

1. Take the case off of Team 24 Wearable Heart Monitor.
2. Follow steps 1-3 in Setup.
3. Connected Team 24 Wearable Heart Monitor to the micro usb cable through the arduino micro usb adaptor.
4. Then connect the usb side of the cable to the usb adaptor on your computer.

5. Open up Arduino IDE on your computer and open up Team 24 official code in the program.
6. Select **Tools** in the toolbar.
7. Inside of the **Tools**, select **board**,  select Arduino Pro or Pro mini.
8. Then inside of the **Tools** again, select processor, select ATmeg328 (3.3V 8Mhz)