Adaptive Wireless Wearable Neuro-Stimulator

DESIGN DOCUMENT

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1 Introduction

1.1 ACKNOWLEDGEMENT

We would like to acknowledge Adan Cervantes, the client who brought this project to us, provided assistance in the form of recorded data, as well as significant advice in moving the project forward.

1.2 PROBLEM AND PROJECT STATEMENT

In 2015, there were 1,600 deaths due to SIDS (Sudden Infant Death Syndrome) alone, according to the Center of Disease Control. This accounted for almost half (43%) of infant deaths, many parents were left with the cause of their child's death unknown. The search for the cause and correlations to prevent SIDS is ongoing.

Through data analysis and development of a device to be worn on the ankle, our aim is to combat SIDS. Our goal is to find if there exists data correlation backing the suspicion that SIDS is caused by energy (lighting resonance) using information provided by radio stations. Additionally, the wearable will track infant movement and other health metrics. The wearable will provide a pulse (vibration) to induce reflexive movement as stimulus to the infant.

The wearable will be developed first as a proof of concept. With the wearable, an Android application will be developed to connect to the wearable and show data received from the wearable. The wearable should be able to send the pulse based on information input through the application, as well as send back metrics for the application to send notifications if infant status may be at risk.

1.3 OPERATIONAL ENVIRONMENT

The environment in which the wearable is intended to be used is on an infant's ankle, indoors where the infant may sleep. Thus, the environment is not an extreme one, though the wearable should be comfortable to wear, as well as reliable in performance monitoring infant status.

1.4 INTENDED USERS AND USES

The intended user are parents concerned about monitoring and keeping track of their infant's health. The wearable will allow parents to be notified if the infant does not respond to the pulse from the wearable, as well as see other metrics in the application.

The other use is for researchers who may use data from the device in order to find correlations with SIDS rates.

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions:

- This device is intended to be used globally.
- Device will be used in research purposes. Data from device is to be sent to database which researchers may view in visualizations such as graphs. This also assumes enough parents would agree to have this (anonymous) data sent.

Limitations:

- Device must be small enough to fit on an infant's ankle. The device is designed to be a wearable on the ankle; the circuit design should lend itself to being able to made into a small enough board.
- Circuit needs to be done before the embedded code is developed. Embedded code relies on gathering data from sensors which depends on how sensors may be connected to the microprocessor.
- Due to schedule constraints and limited knowledge on PCB design, a custom PCB on a small scale was decided not feasible in the time frame. A prototype circuit is to be developed with an evaluation board as proof of concept.

1.6 EXPECTED END PRODUCT AND DELIVERABLES

End Product – Prototype of wearable: A prototype of the wearable able to connect to Android Application. Wearable should be configurable by application and send data back. Application should be able to visualize the data. Wearable needs to be able send pulse (vibrations) based on readings from sensors and the pulse periods based configuration (input from setup in application). Expected delivery is March-April 2018.

Graphs of data: Client gave us data to create graphs and see if the electrical energy in the atmosphere has any correlation the number of cases of SID. December 2017.

Software source code: The source code for the application, as well as the embedded code for the wearable. Expected delivery for all complete code: March-April 2018

Flow chart: An overall design of the software. Showing both software and hardware interactions. December 2017.

System diagram: diagram of the wearable connection, circuit diagram, etc. December 2017.

2 Specifications and Analysis

As seen in figure 1, there are three distinct parts for this project. We need some way to record data from an infant during sleep, this data would include movement and heart rate. This data then needs to be available to alert parents in real time, in case they need to take action, as well as uploading the data to a secure server for review later by medical professionals.

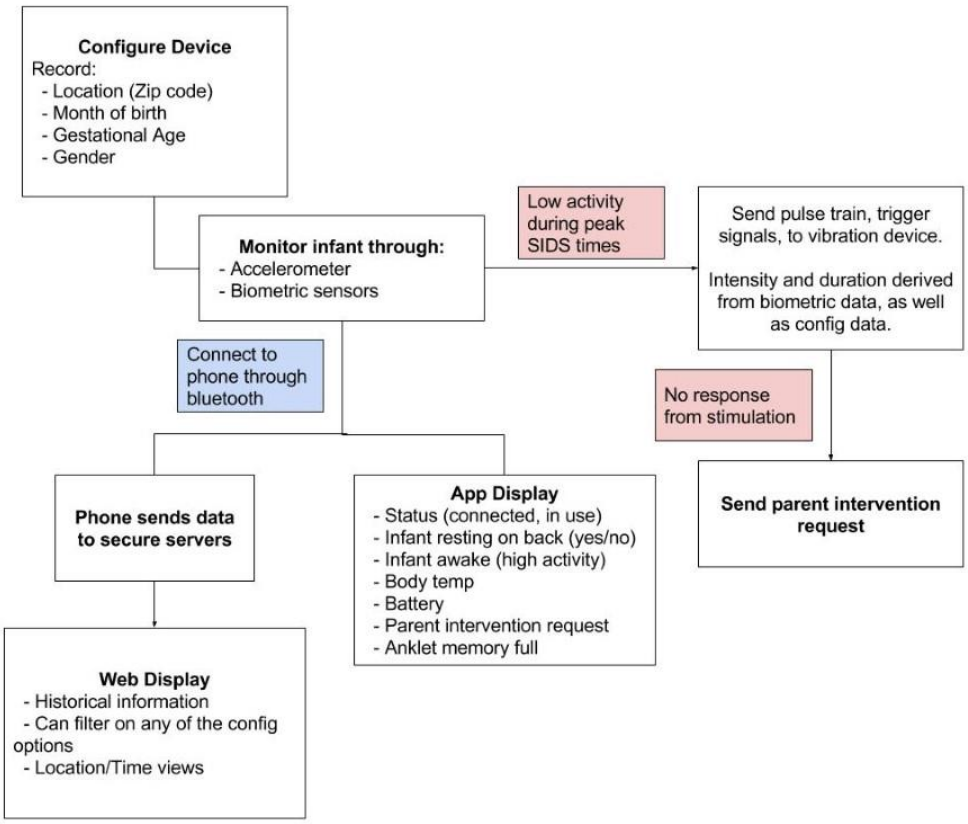


Figure 1.

2.1 PROPOSED DESIGN

Our design is to have a wearable, that has some customization setup steps, that will record data as the infant sleeps and upload this data to a phone in batches. This will allow the phone to see real-time data, and then we can upload the data from the phone to the secure server, which will save us having to make the wearable WIFI-enabled.

The wearable has a method to turn data recording on and off automatically. This was a requirement as we don't want to have to put more responsibility and another thing to remember onto the already busy parents. The way this will work is a temperature sensor and heart rate sensor will be running continuously, and when they detect a rise in temperature and a heart rate, then the whole data recording, including the acceleration, and uploading data will turn on.

The data recorded is heart rate, and acceleration, with temperature being used as an on/off detection system, this is all fed into our embedded code that monitors these readings and based on those readings, plus the data set in the config step, will send stimulating vibrations to the ankle. If no response is recorded for that or subsequent pulse trains, then the parents will be alerted.

The phone app is meant for parents to monitor their child as they sleep, as such, it contains mostly real-time data, with an easily consumable dashboard for main data notices. These notices include battery low, data full, child on back, and wearable connected. The app is easy to use and is mostly for answering the question "Is my child OK?".

The web app on the other hand is meant mainly for medical professionals looking into the causes of SIDS. It is able to correlate data from all devices around the world and see graphs of the data for that specific device. Because this information could be considered medical information, the user's information is hidden and just an ID is shown.

2.2 DESIGN ANALYSIS

So far, we have created a block diagram to visualize how the system will work. Put research into components that we will need for the wearable. This is a particularly challenging part as we have to make sure the wearable can run on battery power for extended periods of time, and have enough storage to handle becoming disconnected from the phone. We need parts that are extremely low power and produce accurate readings.

We have identified some parts that we believe will meet our requirements and discussed with our faculty advisor about the validity of them. We are in the process of placing an order for the parts. In the mean time we have started the design of our circuit. We will be using an evaluation board and a bread board to wire up the parts to produce our proof of concept. This design will be used once we receive the parts to assemble the circuit and get to testing faster.

For the visualizing side of things, we have created screen sketches for the app, as well as designed the server's database, and produced proof of concept graphs that had upwards of 480,000 data points. While the graph was created and you could view it, the large amount of data did make it hard to work with. Once we have real readings we will work on a way to produce more responsive graphs, possibly by using average data, or less data points, with the option to see more if you zoom in.

3 Testing and Implementation

3.1 INTERFACE SPECIFICATIONS

Wearable Device

As our device is going to be a proof of concept, the whole thing is essentially a test bench that we are creating. The hardware pieces will be placed into a solderless breadboard in the orientation dictated by our circuit design, and connected to an evaluation board. This will allow us to test the circuit as though it is a final product, without having to create a printed circuit board to test off of.

Android Application

To test the Android application before the circuit is done, we will need to spoof the Bluetooth input from the device. To do this, we will need to write code that enables us to use a different device to connect to the application and test the data transmission.

Web Application

Part of the testing for the web application is using the application itself to make sure that it works as intended. So, we will be developing the web application with the intention of building in the

functionality to test it and see the information that we need to from it in the process of doing functionality testing.

3.2 HARDWARE AND SOFTWARE

Testing Hardware

To test the physical circuit, we will be using the various tools available to us in the Iowa State labs. We will be using a multimeter to test the various voltages and currents running through each portion of the circuit to ensure they have the proper current and voltage running through them to power the components without damaging them. We will also be using a variable power source to test the potential variations in voltage that could potentially run through the circuit. We would test the variation in voltage to make sure that our circuit will not malfunction or fail due to a slight variation in the power to the device.

Testing Software

We have multiple software based parts of our project that will need to be tested. For the Android app, we will be doing the development in the Android Studio IDE. The software has its own built in error detection that we will use to avoid having any poorly written lines of code get into the final product. To ensure that all of the code that we write, regardless of its final destination (Web Application, Android application, and embedded code), we will be using the Git application to check each other's work. Before anything is merged into the master branch, or any other time a merge is requested, we require that at least two other group members go through their code to make sure that everything works as it should.

3.3 FUNCTIONAL TESTING

For the device itself, which is a combination of hardware and software, we will have multiple different types of tests to verify that our parts function as expected and can correctly identify dangerous situations, respond accordingly, and report to the Android application. These would be classified as performance and compatibility tests, as they involve testing that our biometric sensors can record accurately enough and fast enough for our needs, as well as being able to sense connection based on the temperature sensor. Also, we will be testing that the device can store at least one day of data, and can send vibration using the motor that we hook up. We will still have more tests that verify the rest of the hardware requirements, but they will be very similar types to these. Moving to the embedded code, we will have more system tests for things such as verifying the device can communicate over Bluetooth to the Android application, and that after a period of time, and based on the initial set up config, a vibration pulse of varying length is sent to the motor. These tests will have their acceptance values based on the research our client has provided us, so we know that a certain gender, in a certain location, that is a certain age, should receive one length pulse, while another user will receive a different length. We can also write some lower level integration or unit tests to verify things such as the config data can be entered and it is stored correctly and can be accessed. There should be a large amount of these tests, and should cover all of the associated requirements we have for the device itself.

The two applications we create, Android and web, which are the software only parts of the project, will have unit and integration tests to assert that the applications are accessible and work correctly, such as going through the login page in a test so we know the information is secure. These types of tests will depend on the actual implementation of the applications, but in general will be asserting things such as data received on a Bluetooth connection is stored and then sent wirelessly to a database, or when a user has defined bounds on their web interface, the correct query is executed to give them the graph that they want. The goal of these tests is to cover as much of the code base as possible to ensure that any updates we make do not break existing workflows. The Android application also has UI tests associated with it, so we can verify that a user can hit the overview button and be shown the overview page, for all of the pages of the app. These tests will then be run on every software update, and will cover all of the requirements in the requirements section.

3.4 NON-FUNCTIONAL TESTING

3.5 PROCESS

The non-functional tests will consist of both one-off tests, that we only have to really try once, and tests that we can run on each software update to ensure the non-functional requirements are still working. These tests are more about ensuring what the user sees is helpful and complete, like graphs having the correct axes labels, and downloadable data is in the correct format.

For the two software applications of the project, we test incrementally as we build. Therefore, every time there is a new feature developed, we test it before it reaches the production level.

For the hardware, we will pick parts, design on paper, simulate and test, build and test. This process will be iterative, so if we find a part that does not meet our specifications, we can go back to the design stage and try a different setup.

3.6 RESULTS

As of October 12, 2017, we have drawn screen sketches, started the design of a circuit, and worked on analyzing a set of data. Our first run through on analyzing the data was on the incorrect set of data. Our test of this analysis was to present the data analysis to our client, but once he realized the miscommunication, he notified us that we had analyzed the incorrect portion of the data. The result of this test and test analysis was that we now know what specific data we need to analyze and how to read the data in a format that allows us to automate the analysis of it.

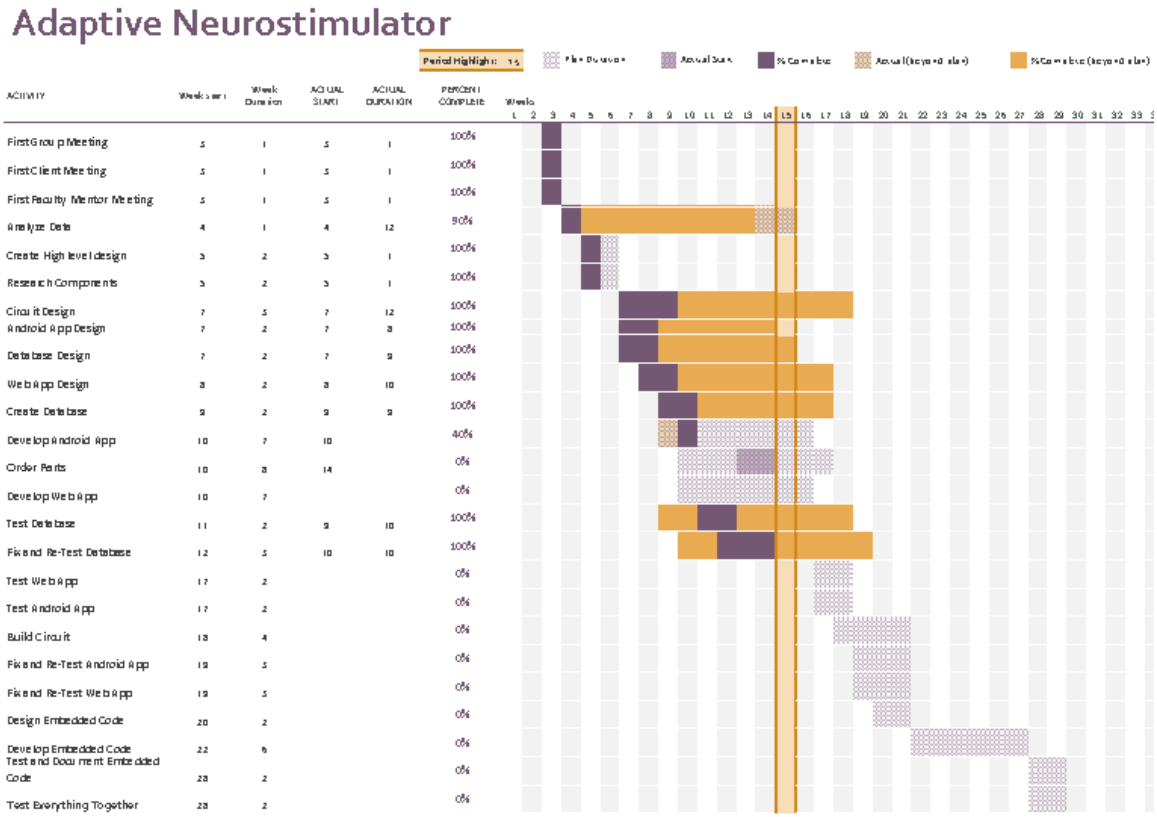


Figure 2.

3.7 MODELING AND SIMULATION

Android Application

Android studio allows us to model the layouts of the application in real time. We will be using this feature to ensure that the layouts follow our screen sketches. There is also a feature in android studio that allows us to run an emulator to test the various possible inputs from a user. Simulation of a user using the application will help us find various bugs and improper behavior that it may have.

Web Application

For testing of the web app, we will spoof input that the database should be giving it so that way we may fully test the web app on its own. Once all data has been fully added into the database, we can then simulate actual data flow between database and web application.

3.8 IMPLEMENTATION ISSUES AND CHALLENGES

We have run into some issues with the Android application which we have been resolving with our faculty advisor. Discussions on the application side included plans on Bluetooth implementation for the application and layout issues, such as fragments.

Regarding the wearable, we had found that with our limited experience of circuits, designing a custom PCB would not be feasible in the given timeframe. After discussion with our faculty advisor

and client, we decided to move forward a proof of concept design using an Arduino device with sensors attached.

4 Closing Material

4.1 CONCLUSION

The goal of this project is to provide a way for SIDS researchers a way to study the effect of low energy radiation generated by lightning and its possible correlation to the rate of SIDS. The device and application suite we will be creating are all aimed at the accurate collection and display of biometric data gathered from the infant wearing our device. The end goal in the creation of the device is to have something that allows the parent to take active action towards increasing the survival of their infant in the years that SIDS has an effect.

The current progress of the team is focused on ensuring that each part of the project will be created to the specifications of the client. We have met with our advisor to discuss the feasibility of creating a complete packaged device with a custom printed circuit board that allows us to achieve our desired functionality in the time that we have, and with the skill set of the group. After our discussions with our advisor, we needed to reevaluate and change the full device creation to the creation of a proof of concept that does not involve the creation of a printed circuit board and packaging. After our decision that the creation of a complete, production ready device was not feasible, we met with our client to notify him of the infeasibility of creating such a device along with all other parts asked for. Once the device structure change was approved, we moved on to gathering a firm list of requirements for each individual piece of the project so that we could produce products that the client will be satisfied with and to help him get a better idea of what he wants the final products to look like.

Our plan to complete this project is best done by following the timeline we have set for ourselves. We believe this will best allow us to achieve our goals because it gives us a chance to manage our schedules so that we have enough time to work on each piece that we are assigned to do. This is the best solution for us because it gives us a structure to follow instead of randomly assigning tasks without a set timeline of what comes next. Our schedule gives an exact timeline of what needs to happen and when it needs to be done by. The schedule also has what follows the previous task, and this allows the individual units in our team to progress after they finish with their current task without any delay because they know what comes next. Time will not be wasted trying to figure out what needs to happen next. Barring any significant delay or issue, following our timeline will allow us to finish all necessary tasks on time.

4.2 REFERENCES

SIDS Information and Statistics:

"Sudden Unexpected Infant Death and Sudden Infant Death Syndrome." Centers for Disease Control and Prevention, Centers for Disease Control and

Prevention, 17 Apr. 2017, www.cdc.gov/sids/data.htm.

4.3 APPENDICES

Figure 1.

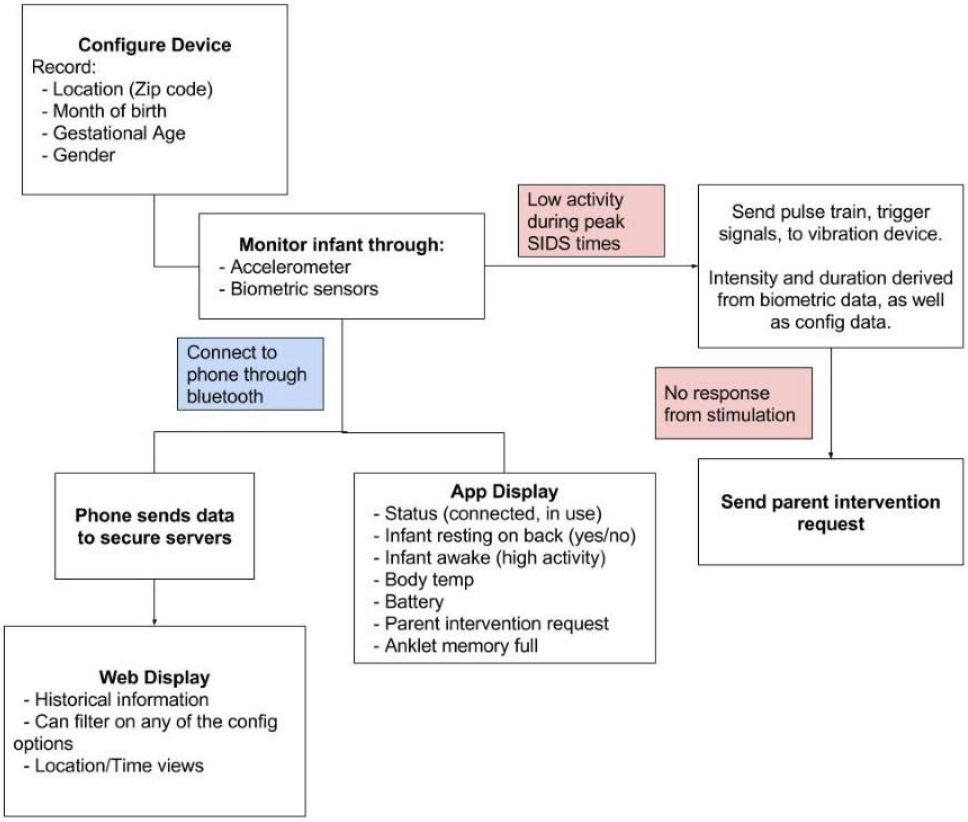
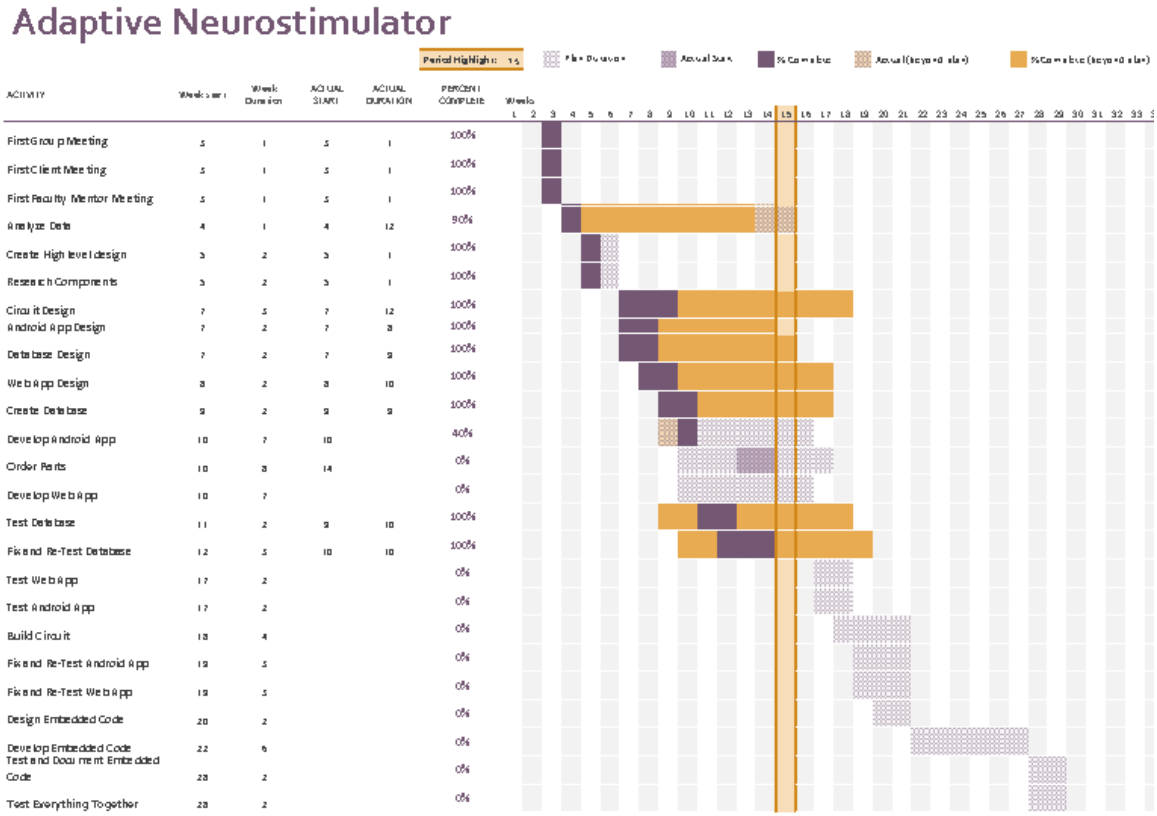


Figure 2.


Adaptive Neurostimulator
Period Highlight: 15
Plan Duration
Actual Start
% Complete
Actual (beyond plan)
% Complete (beyond plan)
ACTIVITY
Week start
Week Duration
ACTUAL START
ACTUAL DURATION
PERCENT COMPLETE
Weeks
First Group Meeting 5 1 5 1 100%
First Client Meeting 5 1 5 1 100%
First Faculty Mentor Meeting 5 1 5 1 100%
Analyze Data 4 1 4 12 90%
Create High level design 5 2 5 1 100%
Research Components 5 2 5 1 100%
Circuit Design 7 5 7 12 100%
Android App Design 7 2 7 8 100%
Database Design 7 2 7 9 100%
Web App Design 8 2 8 10 100%
Create Database 9 2 9 9 100%
Develop Android App 10 7 10 40%
Order Parts 10 8 14 0%
Develop Web App 10 7 0%
Test Database 11 2 9 10 100%
Fix and Re-Test Database 12 5 10 10 100%
Test Web App 17 2 0%
Test Android App 17 2 0%
Build Circuit 18 4 0%
Fix and Re-Test Android App 19 5 0%
Fix and Re-Test Web App 19 5 0%
Design Embedded Code 20 2 0%
Develop Embedded Code 22 6 0%
Test and Document Embedded Code 28 2 0%
Test Everything Together 28 2 0%