Executive Summary

Wearable Cardiac Monitor

Design Document

Team 24

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Development Standards & Practices Used

List all standard circuits, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

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

Summary of Requirements

List all requirements as bullet points in brief.

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

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

1. CprE 185
2. CprE 288
3. CprE 388
4. E E 224
5. E E 230
6. E E 303
7. E E 324
8. E E 330
9. E E 475
10. ComS 227
11. ComS 228
12. ComS 309

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired which was not part of your Iowa State curriculum in order to complete this project.

- 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.

Table of Contents

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

1 Introduction

1.1 ACKNOWLEDGEMENT

(If a client, an organization, or an individual has contributed or will contribute significant assistance in the form of technical advice, equipment, financial aid, etc, an acknowledgement of this contribution shall be included in a separate section of the project plan.)

Thank you to Cheng Huang for providing guidance throughout the project.

1.2 PROBLEM AND PROJECT STATEMENT

– This is included so that the reader will have the correct conception of the problem and the solution approach upfront. Each shall be written in a non-technical manner that a lay person would understand.
– Consists of two components, each separated and clearly identified:
-General problem statement – defines the general problem area
-General solution approach – defines the proposed solution approach
-This section should also highlight the purpose of the project, what you are trying to do.
Explain what is driving this project. Why is it important?
Explain what the project is.
Explain what you hope to accomplish. What are the outputs of the project?

We are making a heart monitor that will be cheap and easy to use for our client that may be used for future clients. 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 day.

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 help point out any irregularities that might occur in someone's heart such as a heart murmur.

1.3 OPERATIONAL ENVIRONMENT

– For any end product other than simply a calculation or simulation, it is essential to know the environment in which the end product will be used or to which it is expected to be exposed or experience. For example, will the end product be exposed to dusty conditions, extreme temperatures, or rain or other weather elements?
– This information is necessary in order to design an end product that can withstand the hazards that it is expected to encounter.

Our product is a wearable device and attaching to the human body, ideally, this should be worn all day long. Therefore, it will follow people's daily actions such as walking, running and showering. Shaking and hitting against body could potentially happen. It may be exposed to water during showering and raining.

1.4 REQUIREMENTS

List all requirements for your project – functional requirements within your project context, economic/market requirements, environmental requirements, UI requirements, and any others relevant to your project.

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

1.5 INTENDED USERS AND USES

– To properly design an end product that will provide the maximum satisfaction and perform in the most efficient manner, it is essential to understand the end user and the associated end 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 be coming from a doctor's office or a pharmacy. The client will wear this heart rate monitor for 48 hours with the gathered data storing to a smartphone application via bluetooth connection.

1.6 ASSUMPTIONS AND LIMITATIONS

– Two separate lists, with a short justification as needed.
– Extremely important, as it can be one of the primary places where the client can go to determine if the end product will meet their needs.
– Examples of assumptions: The maximum number of simultaneous users/customers will be ten; Blue is the best background color and will be used; The end product will not be used outside the United States.
– Example of limitations: The end product shall be no larger than 5"x8"x3" (client requirement); The cost to produce the end product shall not exceed one hundred dollars (a market survey result); The system must operate at 120 or 220 volts and 50 or 60 Hertz (the most common household voltages worldwide).
– For limitations, include tests not performed, classes of users not included, budget/schedule limitations, geographical constraints, etc.

For our product we will make the following assumptions: Users will need to wear the device for 12 to 24 hours a day. The device will only need to store irregular heart beats. The device will only need to send data through bluetooth. Wearable means pocket size or smaller. The device will only be used by one user at a time.

Limitations for our products are as follows: Our end product will no larger than 5"x5"x3" with wires long enough to have the electrodes placed in the right area on the body. The electrodes that get attached to the body are limited where they can be placed so that they can pick up a reading. The device will need to be able to last at least 48 hours on battery life span. The system must be safe to keep next to the body. If the device is to lose power it will not lose all currently collected data. The device will need to detect when it is not properly connected.

1.7 EXPECTED END PRODUCT AND DELIVERABLES

These tie in with the goals. What deliverables are necessary to meet the goals outlined in the introduction?

List the end product and any other items, along with a brief description, that will be delivered to the client prior to the end of the project.
– If the end product is to be commercialized, the description shall be of the commercialized end product.
– It shall be in the form of a technical product announcement, as opposed to a product advertisement, and shall not include a list of technical specifications.
– Any other items that will be delivered to the client shall also be included and described unless their definition and description are obvious.
– Examples might include a household power supply to eliminate the need for batteries, a user's manual, or other project reports.
– There shall be at least a one-paragraph description for each item to be delivered.
– Delivery dates shall also be specified.

The client will be provided with a 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.

2. Specifications and Analysis

2.1 PROPOSED DESIGN

Include any/all possible methods of approach to solving the problem:
– Discuss what you have done so far – what have you tried/implemented/tested, etc?
– We want to know what you have done
• Approach methods should be inclusive of functional and non-functional requirements of the project, which can be repeated or just referred to in this section
If your project is relevant to any standards (e.g. IEEE standards, NIST standards) discuss the applicability of those standards here

Our proposed design is to develop a wearable device that can monitor the heart and send the data to a smartphone and use the smartphone as an electrocardiogram. We have currently ordered parts to start building a prototype for our project. We have done research into how heart monitors work and what premade modules are out there for arduinos that we can use. Our approach in developing the device is to create, our first prototype from these premade modules parts to get us something to start off with and for us to get a better understanding of what we are trying to develop. As we are able to work with this first prototype we will be able to discover new ideas on how we might be able to implement our device and come up with a solution to make the device as comfortable as possible.

2.2 DESIGN ANALYSIS

So far we have a general block diagram for our project. We are trying to create a system that has a small form factor and is easy to use for people. We are still deciding how we want our clients to wear the control box for the monitor. This will likely depend on how our testing of the bluetooth ecg pads work with our system.

We discovered that the original Arduino we were looking at is no longer made so we had to find another one. For the most part the design seems to be sufficient and shouldn't require many 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 addition parts we may need. This method is fine for the time being, but it could slow down the roll out of this if we need to keep reordering parts that work better after we test them.

2.3 DEVELOPMENT PROCESS

We plan on following the Agile method. We think this will allow us to set short term goals and have an idea of where we are as a group on the tasks we need to complete. This will also allow us to

2.4 DESIGN PLAN

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.

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 sends the signal out to a bluetooth chip. Lastly, this will send the signal over bluetooth to a hooked up 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 as 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 one to 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.

3. Statement of Work

3.1 PREVIOUS WORK AND LITERATURE

Include relevant background/literature review for the project
– If similar products exist in the market, describe what has already been done
– If you are following previous work, cite that and discuss the advantages/shortcomings
– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available
Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

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.

3.2 TECHNOLOGY CONSIDERATIONS - Sam

Highlight the strengths, weakness, and trade-offs made in technology available. Discuss possible solutions and design alternatives

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 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. If we can get 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 is 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 order to solve the problem at hand, it helps to decompose it into multiple tasks and to understand interdependence among tasks.

In developing our project we have separated our group into three groups; Hardware, Software, and Communications. Hardware is developing the ECG to monitor the hard and have the data sent to the arduino. Communications is taking that data sending it from the arduino to a phone through bluetooth. Software is working on creating an app for the phone to collect the data sent from the device's bluetooth and display a graph of the heart beating.

3.4 POSSIBLE RISKS AND RISK MANAGEMENT - Peyton

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

As it stands, there is a pretty big issue with the ecg monitor we are using itself. It is very sensitive to movement which is the exact opposite of what we would like for this product. We have thought of a few solutions as of right now, but they may not work as anticipated. This is the biggest issue we are having currently that will likely take a large amount of time to get completely sorted out.

3.5 PROJECT PROPOSED MILESTONES AND EVALUATION CRITERIA -Peyton

What are some key milestones in your proposed project? Consider developing task-wise milestones. What tests will your group perform to confirm it works?

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, so we have picked low energy parts and have

been thinking efficiently. We are just are putting that last 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 before hand.

Confirming it works will be testing it on all six of us with 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. Second would be the same, but with a much greater range of motion. Lastly, we will have someone wear over the course of a couple of days and see how long we can get the battery to last. If it lasts longer than some set amount at the beginning, with regular checking of the app, that will be classified as a success.

3.6 PROJECT TRACKING PROCEDURES

Project tracking has been done through weekly reports, which seems 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

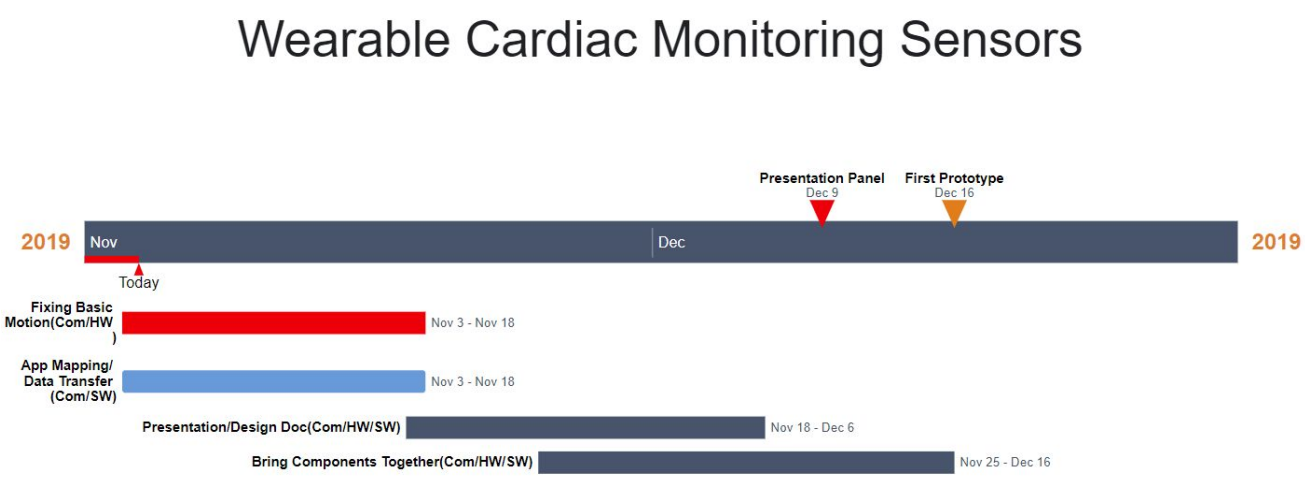
At the end of our project, we are wanting to have a working heart rate monitor. This heart rate monitor will be able to send a heart rate to a bluetooth module which will then send that data to an Android application. This application will be able to provide the user with their live heart rate and alert the user when something is irregular with their heart. Our group was able to borrow a bigger and older heart rate monitor which will be our verification that our monitor is working properly. We will compare the measured heart rate from our monitor to the one we borrowed.

4. Project Timeline, Estimated Resources, and Challenges

4.1 PROJECT TIMELINE -Peyton

• A realistic, well-planned schedule is an essential component of every well-planned project
• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity
• A detailed schedule is needed as a part of the plan:
– Start with a Gantt chart showing the tasks (that you developed in 3.3) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered
• Completely compatible with an Agile development cycle if that's your thing
How would you plan for the project to be completed in two semesters? Represent with appropriate charts and tables or other means.
Make sure to include at least a couple paragraphs discussing the timeline and why it is being proposed. Include details that distinguish between design details for present project version and later stages of project.



The biggest part to 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 app side, and the hardware side. The Communications group gets a taste of both, but focuses on getting the data from one to the other. 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. Lastly, for this semester, we will try and get the base prototype working.

Once this is complete, our second semester will likely be split in half, one side working on getting the best data possible out of the heart rate monitor, and the other focussed on getting our power consumption lower. These may end up going hand in hand as reducing the noise from the monitor may take more power, but they are divisible in nature.

4.2 FEASIBILITY ASSESSMENT

Base functionality of reading an ECG by a small package device and transmitting to Android. Two-day battery life will pose significant challenges, but should be manageable

before end of project. Motion noise cancellation will be worked on, but may not be implemented sufficiently.

4.3 PERSONNEL EFFORT REQUIREMENTS

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just “X” hours per week for the number of weeks that the task is active

4.4 OTHER RESOURCE REQUIREMENTS

Identify the other resources aside from financial, such as parts and materials that are required to conduct the project.

Part	Ref./type of part	Cost	Quantity	Supplier	Supplier# / Part#
Single Lead Heart Rate Monitor	AD8232 PCB	$19.95	1	SparkFun	SEN-12650
Arduino Micro	Microcontroller	$20.63	1	Digikey	1050-1066-ND/ A000053
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

4.5 FINANCIAL REQUIREMENTS

If relevant, include the total financial resources required to conduct the project.
Our client is a professor at Iowa State and the funding to complete this project is solely based on the cost of the materials to build. These funds will be provided by the ECPE department.

5. Testing and Implementation

Testing is an extremely important component of most projects, whether it involves a circuit, a process, or a software library
Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results
Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 INTERFACE SPECIFICATIONS

– Discuss any hardware/software interfacing that you are working on for testing your project

Our project will use the Arduino Mini to interface between our hardware and our software 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 take 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

– Indicate any hardware and/or software used in the testing phase
– Provide brief, simple introductions for each to explain the usefulness of each

5.3 FUNCTIONAL TESTING

Examples include unit, integration, system, acceptance testing

5.4 NON-FUNCTIONAL TESTING

Testing for performance, security, usability, compatibility

5.5 PROCESS

– Explain how each method indicated in Section 2 was tested
– Flow diagram of the process if applicable (should be for most projects)

5.6 RESULTS

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes

- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

• This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place
-Modeling and Simulation: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.
-List the implementation Issues and Challenges.

6. Closing Material

6.1 CONCLUSION

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 REFERENCES

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 APPENDICES

Any additional information that would be helpful to the evaluation of your design document.
If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.