The Bioelectric Smartwatch

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***Abstract* — The Bioelectric Smartwatch is a small electrical device that has the capabilities to measure a person's vitals as well as send notifications or alerts to specified personnel in the event of a medical emergency. The smartwatch will also allow users to collect and send data wirelessly to a safe and secure mobile web application. The Bioelectric Smartwatch will provide aid with new age medical technologies as well was help users maintain a healthier lifestyle.**

***Index Terms* — health, emergency system, smartwatch, wireless communication.**

I. Introduction

Health has always been an important topic in our society. Thus, people are constantly monitoring their health, whether it is in the form of doctor check-ups, paying attention to nutrition, or going to the gym. With innovations in technology, tracking health progress has become easier as gadgets can provide statistics and tips based on real-time trends and scientific studies.

The bioelectric smartwatch is a device that not only contains many health features to track health progress but also serves as an alert system in times of distress. With many fitness trackers in the marker and distress beacons already in the market, the idea behind the bioelectric smartwatch is to integrate both the lifestyle improving characteristics of a smartwatch and an emergency beacon into one easy to use device.

This device is tailored towards elderly people, or people with an illness that needs to be tracked. The watch will can send a signal in the event of an emergency that will notify local authorities of the user's location. Being that older people and people with certain medical conditions are more at risk for accidents, having the ability to track vitals and send out an emergency GPS signal will help save lives. To help improve the life of the user, the pulse sensor and step count will help track their exercise.

Data from tracking the pulse and steps taken will be sent wirelessly using Bluetooth to a monitoring device web platform to help with tracking progress. A GPS system is integrated within the smartwatch to track the user's location so that in the event of an emergency, the user will be able to send a distress signal that will help authorities pinpoint their location.

II. Project Specifications

Some of the specifications that were listed in the beginning were to make sure that the Bioelectric smartwatch was at most 10cm by 7cm in size. This specification is important to make it a comfortable and practical device for users.

Other specifications are designed for the peripherals that are included in the smartwatch and are listed below:

- The accuracy for the GPS receiver will be within 3 meters
- The Bluetooth system will be able to work within a range of 5 meters
- The pulse sensor will be within the range of +/- 3 beats per minute
- The battery will have a charge time of 2 hours and a discharge time of 12 hours
- The accelerometer will be within the range of +/- 0.1 g

III. Hardware System

The Bioelectric Smartwatch is comprised of the following systems:

- Power System
- Emergency System
- Display and Notification system
- Microcontroller
- Monitoring Peripherals (Pulse and Accelerometer)

An overall block diagram of the Bioelectric Smartwatch can be seen in Fig. 1. Each block is color and assigned to a group member. The legend of each role can be seen in the legend on the left.

A. The Power System

This system is comprised of the battery charger, battery, two voltage regulators, and one button switch. Each component was reviewed and carefully considered before it was chosen and integrated into the design. The details for each component can be found below.

A lithium-ion battery was chosen to power the smartwatch. It has an output of 3.2 -4.2 Volts and a capacity of 500mAh. This battery was picked over similar batteries due to its size, weight, and cost. In addition to this battery, a compatible battery charger was selected that

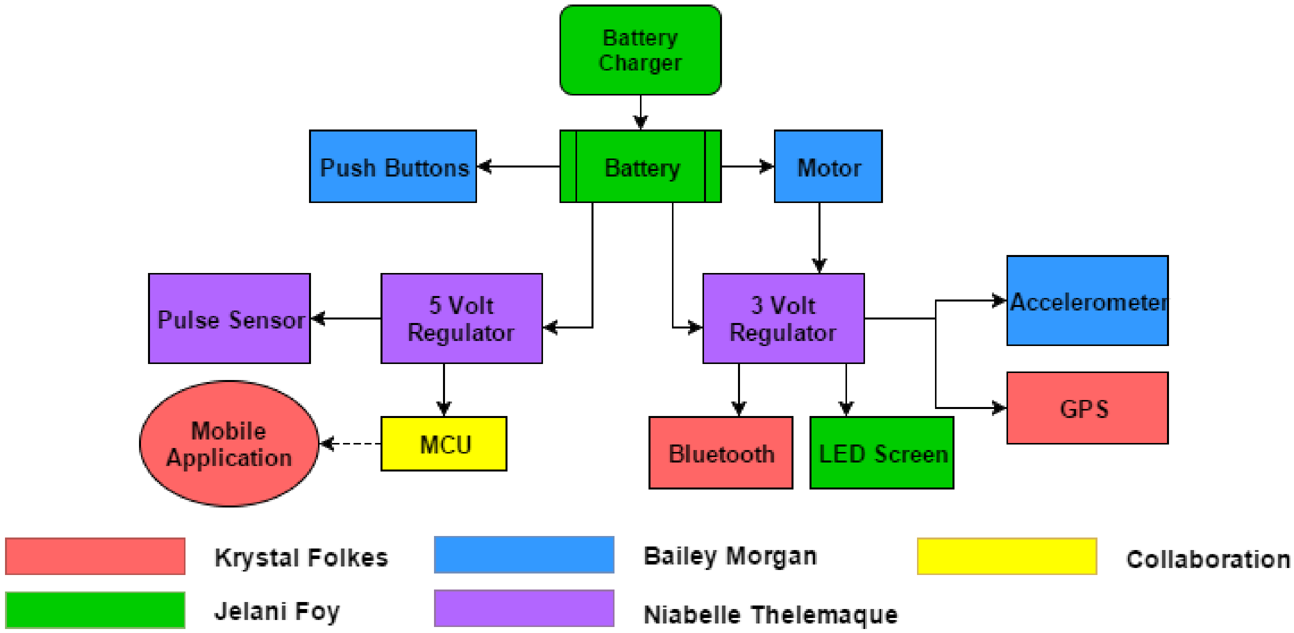

Fig. 1. Overall Block Diagram and assigned roles

had a micro-USB port to allow the user to recharge the battery.

During preliminary testing, a 3.3 voltage regulator was used to provide a constant input voltage to all the smartwatch's peripherals. This voltage regulator was chosen because its operating range is 0.5-5.5Volts. This allows the Bioelectric smartwatch to continue operating even as the battery levels decrease. The table below shows a test of the voltage regulator providing a constant voltage output.

TABLE I
VOLTAGE REGULATOR CHECK

Test Case	Voltage Supply	Input Voltage	Output Voltage
1	1.02	1.02	3.32781
2	2	2.04	3.32832
3	3	2.96	3.32714
4	4	4.01	3.33810

As tests progressed, it was discovered that an additional voltage regulator would be needed to get the pulse sensor and microcontroller working properly. A 5 Volt regulator was acquired to provide sufficient voltage to these two components. As a result, the battery splits off into the 3.3 Volt regulator which provides power to the GPS system, Bluetooth module, accelerometer, and two button switches, while the 5 Volt regulator supplies power to the pulse sensor and microcontroller. The circuit for the 3.3 Volt regulator can be seen in Fig. 2 while the circuit for the 5 Volt regulator can be seen in Fig. 3.

The last item is the button switch. Three button switches are necessary for the Bioelectric smartwatch; however, one button is included in this section because it is responsible for turning the device on and off. In order to prevent the user from accidentally pressing this power button and turning the device off, this button has been programmed to turn off after holding down the button for three seconds.

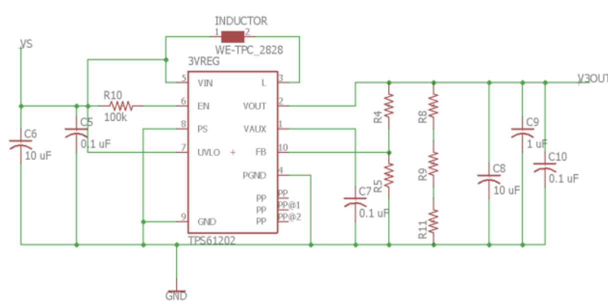

Fig. 2. 3.3 Volt Regulator Circuit

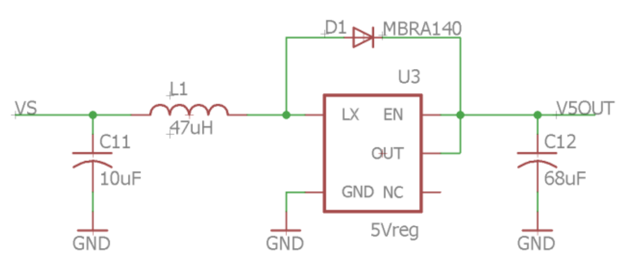

Fig. 3. 5 Volt Regulator Circuit

B. Emergency System

This system is comprised of the GPS system, Bluetooth module, and one button switch. The details for each component can be found below.

The main purpose of the GPS system for the smartwatch is to help authorities and authorized personnel pinpoint the exact location of a user who is in distress. Two GPS systems were reviewed; however, the GP-20U7 was ultimately chosen over the FPGMMOPAH system due to cost and performance. The GP-20U7 also has a low power consumption, making it ideal for portable applications like the Bioelectric smartwatch.

The Bluetooth module allows data to be sent from the smartwatch to the user's smartphone. This minimizes the amount of memory that is stored in the smartwatch because the storage will take place in the smartphone application.

The button switch is used to activate the emergency system. Once pressed, the smartwatch will communicate with the user's smartphone via Bluetooth and send a message to the user's specified personnel including their coordinate location. Similar to the power button, this button will need to be pressed three times to prevent any accidental button press.

In the Bioelectric smartwatch, the GPS is used to get the time and date to display on the home screen. Also, when the emergency system is activated, GPS sends the date, time, latitude, and longitude through Bluetooth.

C. Display and Notification System

This system is comprised of the motor, display, and one button switch. The details for each component can be found below.

The screen shows the results from the monitoring peripherals and display information for the user to easily view. The OLED monochrome screen was chosen over similar screens because a backlight is not required and it uses less power.

The purpose of the motor is to send vibrations that will alert the user. The configuration of the motor can be seen in Fig. 4. This motor is directly connected to the battery because its operation voltage range is from 2-5 Volts. To reduce current draw, a transistor, resistor, and diode are placed in the motor schematic. The transistor acts as a switch that uses a little current from the ATMega2560 digital output to help control the current of the motor. A resistor is placed on the base of the transistor to control the current coming into the transistor. The diode is connected across the motor to prevent from an inductive current spike caused by the motor [1].

The button switch is used to toggle between the home screen and the monitoring peripheral screen. This button only needs to be pressed once to change the screen.

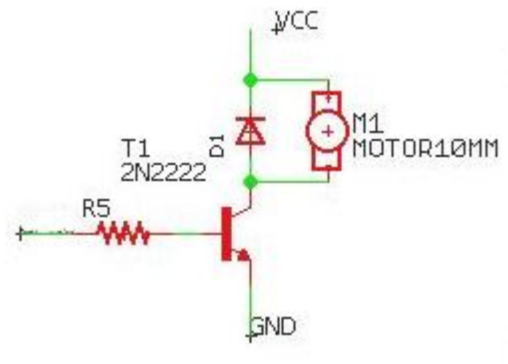

Fig. 4. Motor Circuit configuration

D. Microcontroller

The Bioelectric smartwatch is controlled using an ATMega2560. In the beginning of testing, a Raspberry Pi 3 board was used to control the peripherals included in the smartwatch. When it was discovered that the microchip on the Raspberry Pi was not easily accessible, the ATMega328 was chosen and then lastly changed to the ATMega2560. This microchip has 256 KB of program memory which is eight times as much memory than the ATMega328. This microchip also has 100 pins, with 86 of those pins serving as general purpose input/output pins. Another significant feature of the ATMega2560 microchip is that it supports digital communication peripherals that are necessary for some of the monitoring peripherals to measure and read in values. These include UART, SPI, and I2C which will be discussed later in the paper.

E. Monitoring Peripherals

The monitoring peripherals are the devices that will monitor and track the user's health. These peripherals are the heart rate sensor and the accelerometer. The details for each component can be found below.

The heart rate sensor measures the user's pulse periodically. The SEN0203 heart rate sensor was chosen for its small size and light weight. It is positioned underneath the face of the smartwatch so that it come into direct contact with the user's wrist. This sensor uses a technique called photoplethysmorgraphy (PPG), which is a volumetric measurement of an organ. To obtain a person's pulse, the sensor detects the blood volume changing in the microvascular bed of tissues by illuminating the skin. The sensor measures changes in light absorption are then translated into beats per minute [2].

The accelerometer counts the user's steps. The ADXL345 was chosen because of its chip size and an easily programmable measurement range. This accelerometer has three axes of measurements and supports Inter-Integrated Circuit Protocol (I2C), or Serial Peripheral Interface (SPI) configuration. For the smartwatch, the accelerometer is configured to I2C interfacing with the ATMega2560. I2C is a protocol that requires two signal lines to establish communication between chips on the PCB. I2C was chosen over SPI because I2C supports a multi-master system which allows more than one master to communicate with devices on the bus. It also allows for flexibility in connecting devices with different input and output voltages. Finally, I2C ensures that data that is sent is received by the slave device. Meanwhile, SPI does not verify that data has been received correctly [3]. The image of the accelerometer circuit can be seen in Fig. 5.

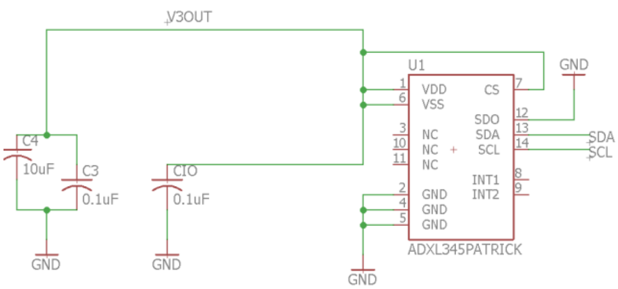

Fig. 5. Accelerometer Circuit

For these monitoring peripherals, the Bioelectric smartwatch has been programmed to update the heart rate and steps every two seconds. When the emergency system is activated, the heart rate monitor and the accelerometer are suspended until the emergency system is turned off.

IV. Software

The selection of the ATMega2560 was necessary to not only to cover the functionality of the peripherals but because of its RAM memory size. The ATMEga2560 has 8KB of RAM. The OLED screen, the Bluetooth packages, and other libraries essential to the functionality of the smartwatch use a third of the RAM on the microchip. For the Bioelectric smartwatch, the microcontroller software covers five major libraries. Each library is configured to the pins for the peripherals on the ATMega2560. Primary functions are reserved for each major component. This includes Bluetooth, GPS, the accelerometer, OLED Screen, and heart rate sensor. Secondary functions include coding for the three buttons. The functionality includes sleep mode, screen switching between the home screen and health monitoring screen, and emergency mode.

A. Mobile Application

After researching different options, it was decided that Ionic, a native cross platform for Android and IOS, would be utilized for the mobile application. Ionic relies on Node.js. Since the Ionic framework is built with web technologies, developing, building, and testing through the browsers is simple. The backbone of the application requires Apache Cordova to make this happen. This makes the mobile application accessible to the JavaScript libraries. The user interface is made to be simple for the target audience and takes less than 5 minutes to set up and run. The mobile application will make sure that a user's information is stored as needed. Also, the mobile application will only store recent data so that if the application were to be hacked, there will be minimal invasion of privacy to the health information that the smartwatch gathers. Table II gives a brief overview of the functionality of the mobile application. An image of the

TABLE II
SOFTWARE MOBILE DESIGN FUNCTIONALITY

Event Name	External Stimuli	External Responses	Internal Data and State
Activate	User Initiated	Activates the Smart watch and user's location is tagged on map	Sends signal to mobile application once they have logged in the phone
Send push notification	Watch Initiated	Sends message to the user that connection is paired and ready	Logged successful Bluetooth connection
Health monitor	User Initiated	Bluetooth to the mobile app which will collect data every 1-2 minutes	Resends if failed
Emergency service alert	User Initiated	Alert is sent out to emergency personnel	Alert is logged and GPS and information is sent, while health monitor and stats are disabled while in state.

phone interface is shown in Fig. 6.

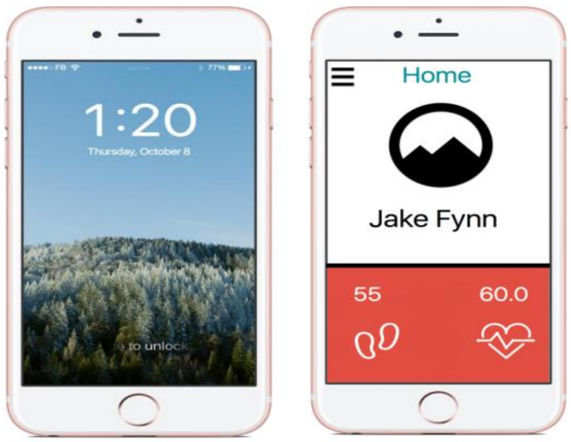

Fig. 6. Mobile Application Interface

V. Watch Casing

The casing for the Bioelectric smartwatch is a 3D printed case. When researching for different materials that the smartwatch should be encased in, 3D printing was the most cost-effective option. This allowed for customization of the watch. This proved to be an important factor due to the placement of the smartwatch's buttons, charger, and heart rate sensor.

A sketch of the 3D printed case can be seen in Fig. 7.

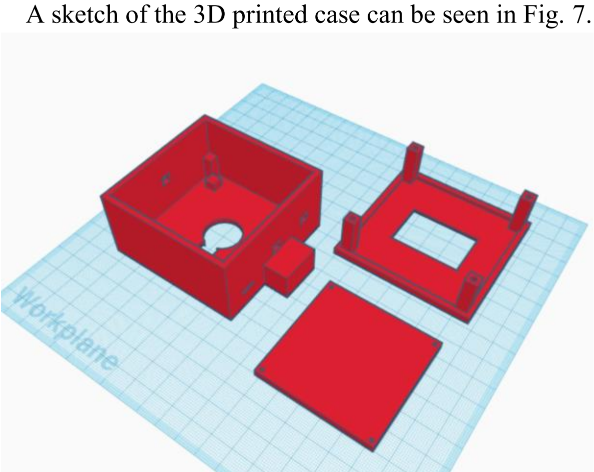

Fig. 7. 3D Sketch of Watch Casing

The watch case was made to be slightly larger than the PCB to allow for secure fitting. The top left box shows the main housing of the smartwatch. The hole on the bottom face of the watch is for the placement of the heart rate sensor while the holes on the side of the case are for the placement of the buttons and charger outlet. The outer square that is attached to the main housing has an identical square on the opposite side. They are placed here to hold the strap of the smartwatch.

The square at the bottom left of the image goes directly inside the main housing of the watch and rests on columns that are held together by screws. The PCB will sit directly on of this square for additional security.

The square on the top left of the image is the top part of the watch case The columns are placed on the edges to fit securely with the columns of the main housing with a screw. The hole in the center is for the placement of the OLED screen.

VI. System Testing

Testing has occurred throughout the course of Senior Design 1 and 2. Preliminary tests were done in Senior Design to verify that the researched components could be implemented. Some components were also integrated to determine their compatibility. The bulk of testing was done in Senior Design 2 where integration was necessary to perform the functionality of the Bioelectric smartwatch.

One of the earliest tests done during Senior 1 was ensuring that the OLED Screen would be able to display text and other information. This test was done using a Raspberry Pi 3 and the OLED Screen. Once the related libraries were installed, an image of Knightro was uploaded to check the resolution. From this test, it was discovered needed to be set to I2C instead of SPI. Due to this change, the image was able to be displayed on the screen as seen in Fig. 8.

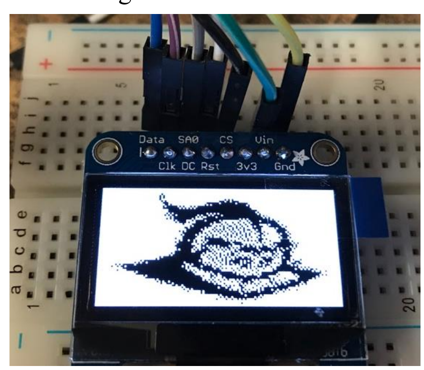

Fig. 8. OLED Preliminary Test

An important integration test that occurred in Senior Design 1 was the power system. This testing process was simple to implement because for the battery and battery charger, the voltage of battery was verified using a multimeter. The multimeter was able to show that the maximum charging voltage from the charger was 4.2 Volts. After this verification, the voltage regulator was wired to the battery and the multimeter was able to readout a voltage of 3.3 Volts.

The last major tests occurring in Senior Design 1 was on the emergency system components. A test was done to see if the battery and voltage regulator would be able to power the Bluetooth module. This test was successful and the next test was wiring the Bluetooth to a microcontroller to determine if a smartphone would be able to pick up the signal and connect. After many attempts, the Bluetooth was able to connect with a smartphone when it was wired in SPI configuration. A screenshot of the Bluetooth being visible to a smartphone can be seen in Figure 9. For this test, the name of the Bluetooth module is Adafruit Bluefruit LE 611F.

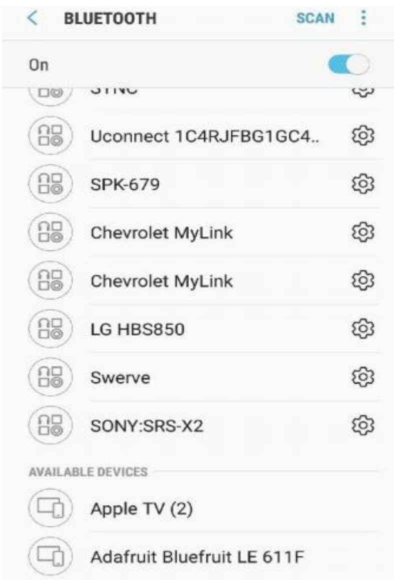

Fig. 9. Bluetooth Connectivity

In Senior Design 2, prototyping was finalized. The entire Bioelectric smartwatch was configured and working on a breadboard. The circuit was spaced out to ensure correct wiring. To determine which pins to use, an Arduino ATMega2560 R3 was used. From the connections of the Arduino, a pinout conversion table online was able to translate these connections to just implementing the microchip by itself. The breadboard setup can be seen in Fig. 10.

Through careful checks, a schematic was drawn up with the connections of all the components on the smartwatch. With this schematic, a PCB was designed to meet the smartwatch's size requirements. The first PCB design was tested and was redesigned due to connection errors and changes in components used. The final PCB design was altered to accommodate the changes and decreased in size for a square appearance. The image of the PCB can be seen in Fig. 11. The big square in the middle of the PCB near the bottom is the ATMega2560. The final PCB has dimensions of 54.61 by 54.61mm, which falls within the specification requirements that were defined in Senior Design 1.

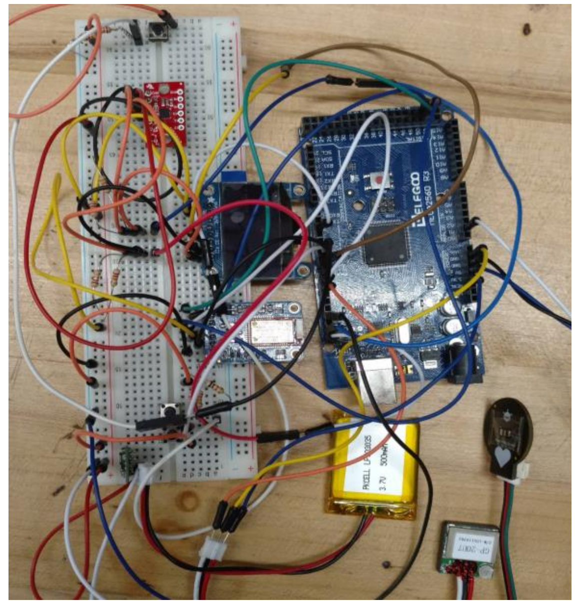

Fig. 10. Breadboard Setup

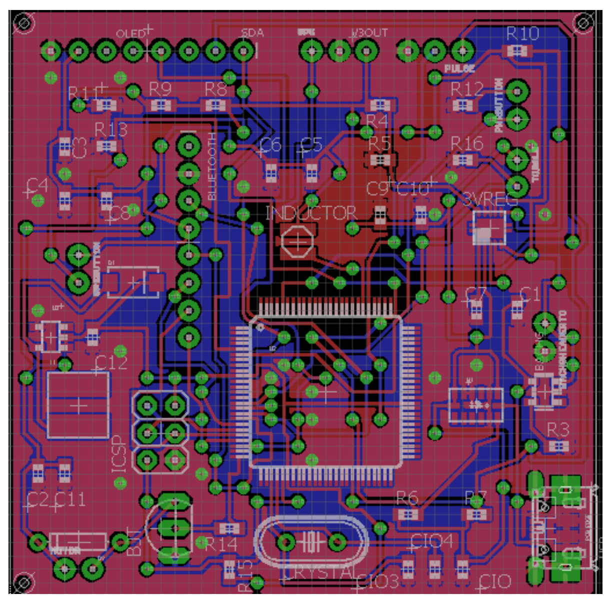

Fig. 11. PCB Design

VII. Possible Future Considerations

An alternative idea to this project is to include accessories, increasing the number of features to the bioelectric smartwatch. One additional feature would be to measure a user's blood pressure. However, instead of incorporating this health monitoring device within the bioelectric smartwatch, an accessory can be used instead. This accessory would be a blood pressure cuff, gauge, and bulb that can be attached to the smartwatch so that the smartwatch would serve as the digital monitor. The cuff would be inflated by squeezing the bulb until the gauge reaches a specified value. Then the user will read the systolic pressure calculated by the watch.

Another accessory would be to measure body fat percentage through bioelectrical impedance analysis. This analysis measures the body's electrical resistance. Body fat will be measured with the use of two electrodes that are safely attached to the body. One electrode would be placed underneath the face of the smartwatch, contacting the skin of the user. The other electrode would be created in the form of an attachable band that can be placed on a user's ankle.

VIII. Conclusion

Designing the Bioelectric Smartwatch has been an overall challenging and rewarding experience. Designing and testing the Bioelectric Smartwatch incorporated all the skills that were learned while studying the electrical and computer engineering disciplines. Many obstacles were encountered while designing the project. Some of these obstacles and problems were encountered in the testing phase.

The cutting-edge technologies that have been implemented in the design of this project are pulse oximetry, accelerometer measurements, and GPS tracking. Pulse oximetry is the newest technology out of every type of technology being implemented, and thus is the most difficult to implement. The method of getting heart rate from pulse oximetry will make for a successful fitness tracking watch because it is the forefront technology of heart rate monitors. Integrating the pulse oximetry will be the biggest accomplishment of the smartwatch design.

One of the major takeaways from this project has been working together as a team, to take what was just an idea to becoming a tangible product of our creation. Due to the nature of our product, we will be creating something that will help the well-being of people, which was the motivating factor of this project.

The main idea behind this project is to bring a product to the market that helps the elderly and sick live a safer and healthier lifestyle. This product will be able to satisfy the need of this market by using cutting edge technology. The Bioelectric Smartwatch will be the first of its kind to mesh fitness tracking abilities with the added of safety of an emergency GPS beacon.

Acknowledgement

The Bioelectric Smartwatch team wish to acknowledge the assistance and support from everyone who made this project a reality. A special thanks goes to Dr. Lei Wei for his advice and counsel through the course of Senior Design 1 and 2.

We would also like to thank Dr. Ricardo Zaurin for suggesting the original senior design idea of a watch/bracelet with accelerometers and a system that recognizes the vibration patterns for people like his mother, suffering from Parkinson's disease.

Our senior design process requires each person to contribute 30 independent ideas. Then each group of four students had to evaluate around 100 ideas and select one or two. After that, the teams needed to write 10 pages for 1 or 2 ideas. A watch for people with Parkinson's disease was one of the ideas we submitted. During our half-hour meeting, Dr. Wei pointed out the difficulty to differentiate Parkinson's-related vibrating movements from vibrating movements while walking. Dr. Wei pointed out certain difficulties in determining if someone fell on the ground or just dropped the watch on the ground. As a result, we added two sensors: one to measure pulse and one to measure body temperature. This is how this project idea developed.

Ms. Krystal Folkes also would like to express her appreciation to Dr. Wisniewski for two independent studies and one summer REU opportunity. Our team was made aware of Dr. Wisniewski and her team's NSF funded project for Carebit, a health monitoring app, similar to our project. Her project is to do a feasibility study.

Biography

Krystal Folkes is currently a senior at the University of Central Florida. She plans to receive her Bachelor's in Computer Engineering and minor in Information Technology in August 2017. Following graduation, Krystal is planning to attain a Masters in Computer Science and will Work for Microsoft Corporation.

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Bailey Morgan is currently a senior at the University of Central Florida. He plans to receive his Bachelor's in Science in Electrical Engineering in August 2017. Following graduation, Bailey will work for Duke Energy in the Protection and Control Department.

Niabelle Thelemaque is currently a senior at the University of Central Florida. She plans to receive her Bachelor's in Science in Electrical Engineering and minor in Mathematics in August 2017. Following graduation, Niabelle will work for United Technologies Corporation in the Engine & Control Systems Department.

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