Funky

An Unobtrusive Fingertip Health Tracker

ECE4011 Senior Design Project

Section A05, JH3

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Executive Summary

We are designing an ultra low powered device that monitors visceral signals from the body for the presence of certain symptoms relating to common illnesses experienced in America today. The form of this device is a non-obtrusive fingertip clamp that is wireless-enabled and synced to transmit data to the user's smart phone or tablet. Information from the user's smart phone sensors (accelerometer, gyroscope, compass, and barometer) will be monitored in addition to the user's physiology in order to see the larger picture. Finger pulse oximeters exist today, but do not provide statistics and data trends in a manner that is easily understood by the common population. The aim of our device is to bridge this gap and make professional medical advice easily accessible and understood. Our device will monitor the user's blood oxygen saturation and finger pulse in combination with their cell phone statistics in order to alert the user when there are any signs of health concern or with suggestions to improve health and wellness. The diagnostic that our device provides is similar to that which a doctor would prescribe, saving the user the hassle of scheduling an appointment and traveling to an office. This device is not recommended as a substitute to visiting a doctor, but a supplement to give the user insightful information regarding their bodily health during the times a doctor is not accessible. Essentially, our device is a doctor's check-up right at your fingertips! The production cost of such a device is $115 per unit. The device could be sold at $150.00 per unit for a profit rate of 20%.

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Funky: An Unobtrusive Fingertip Health Tracker

1. Introduction

The aim of our design is to create a health monitoring system that records a history of the user's physiology and returns useful feedback such as overall health status, suggestions for treatment, and even recommended local doctors to go visit depending on which symptoms are monitored. Our team, JH3, requests $500.00 in order to develop our product.

1.1 <u>Objective</u>

Our overall object is to monitor the heart rate and blood oxygen level and transmit the data for display in real time. Our project will be an accessory to a smartphone.

1.2 <u>Motivation</u>

Cardiovascular disease is the number one cause of death in America and most people that will become affected are simply unaware of their condition. Some of these people may die at home alone due to stroke and some of them just cannot prevent the emergency from happening. A mobile heart rate monitoring device could become widely available and interface directly with popular devices like smart phones. Our device is intended to monitor the heart rate and blood oxygen saturation of users throughout the day and send updates to their smart phone via low powered Bluetooth technology. The convenience that our device offers is great because the user simply has to check their phone in order to receive useful information about the state of their heart and physiology. In case of emergency, the smart phone will automatically send an alert to local paramedics indicating the user's location and health status.

1.3 Background

The pulse meter allows the non-invasive measurement of heart rate with sensors placed on or near the skin with arterial blood flow. Oxygenated blood has a high content of oxyhemoglobin compared with deoxygenated blood that contains a high concentration of deoxyhemoglobin. Oxygenated blood is pumped from the heart to the body tissue through the arterial system [1].

The pulse meter technology relies on two principles of human physiology. One, a specific property of oxyhemoglobin: it reflects red light at approximately 660 nm. Deoxyhemoglobin absorbs more red light and thus reflects less red light [2, 3]. Thus a pulse meter utilizing red light waves will reflect more light during systole, when the left ventricle contracts, and oxyhemoglobin is in high concentration. Conversely, less red light will be reflected during diastole and deoxyhemoglobin is in high concentration, absorbing more red light. Second, blood volume increases during systole and decreases during diastole. More blood volume allows more red lights to be reflected during the contraction phase. These two principles can be leveraged to measure a distinct biosignal from the skin surface at approximately 1 Hz [2, 4].

The key to sensing a change in red light reflectance is a device design that interfaces closely with the surface of the skin. The typical design utilizes the transmission of light through a body extremity like the tip of a finger. A light emitting diode can be positioned near the skin surface to project light toward the skin. A photodetector diode is placed on the opposite side of the skin surface. This design creates a pathway for the light to be transmitted through the skin and detected on the opposite side by the photodetector. The transmitted light is converted to a current by the photodetector. The current is converted to a voltage by a transimpedance amplifier acting as a current to voltage converter. The circuit design can then filter and amplify this voltage to create a voltage signal of the pulse [5].

2. Project Description and Goals

Project Goals

We defined several project goals for the device design:

- Embed a heart rate monitor into an ring
- Monitor heart signal at the skin surface and transmit the signal through Bluetooth in real time
- Send the data to smartphone periodically or alert a doctor when there is an emergency.

These project goals allowed us to identify available resources for designing, building, and testing the device.

Project Description

We designed a block diagram to outline the device component functionality to meet the project goals (Figure 1). The device will first measure the heartbeat signal from the surface of the skin on a user's finger. Then it will transmit the signal through a Bluetooth chip. After receiving the signal, smartphones will process and display it to the user. We can also collect the data from the user to create a baseline for different conditions such as exercising, sitting and sleeping. We will send alert to user when the value exceeds a certain range. In extreme conditions, we will send alerts to doctors through cellular network. The circuit design incorporated an analog band pass filter through a cascade of a low pass and high pass filter.

3. Technical Specifications

3.1 Quantitative Specification

Item	Specification
Lowest Working Temperature	-40 C
Highest Working Temperature	100 C
Supply Voltage	5 V DC
Working per charge	24 Hours
Weight	200 g
Charging Method	Wireless Charging
Apple HealthKit	Compatible

Table 1 Device Specification

3.2 Qualitative Specification

- Exceptional User Experience
- User Customizations
- Bluetooth Communication

4. Design Approach and Details

4.1 <u>Design Approach</u>

4.1.1 Hardware

The Hardware of this design will be a custom-built IC. It includes two LED diodes, a SFH 203 P Photo detector diode, three UA741CP amplifiers, a microprocessor and communication parts. This integrated circuit will be constructed and put into a ring printed by a 3-D printer in the Biomedical Engineering Department of Georgia Tech. The Hardware Assembly can be seen in the Figure 1.

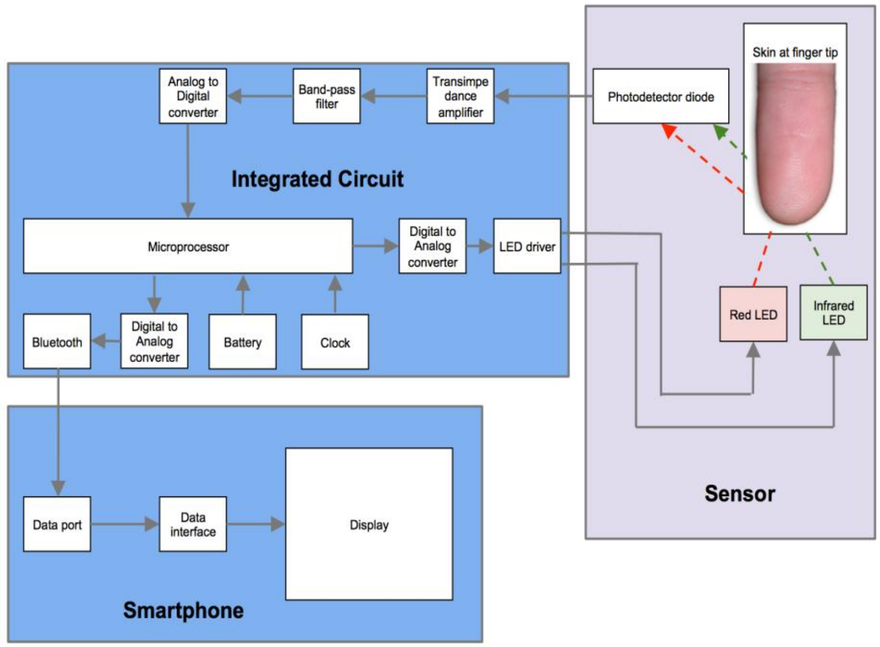

Figure 1 Hardware Diagram

The preliminary Circuit design can be seen in the Figure 2.

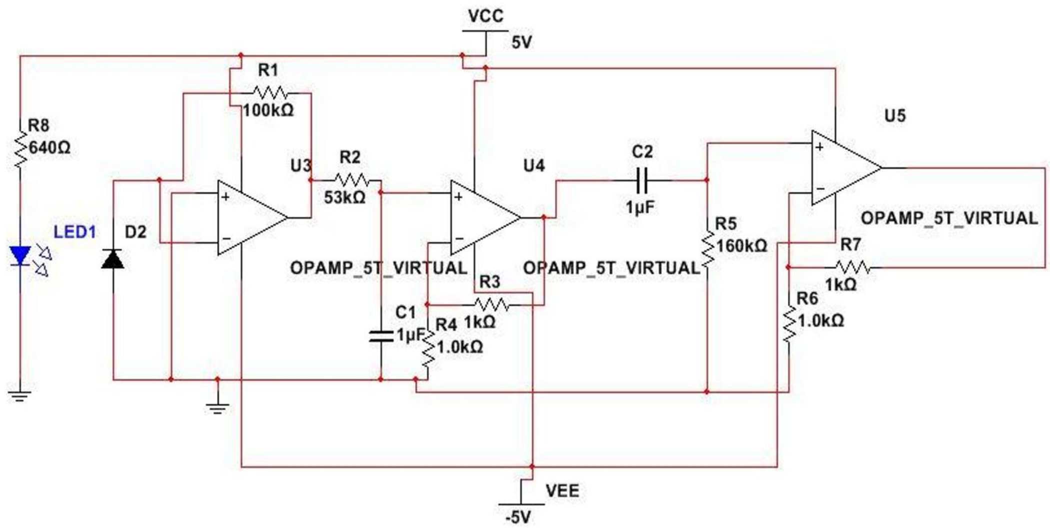

Figure 2 Preliminary Circuit Design

4.1.2 Software

In our software design, we separate the software into the device end code and smartphone end code and they are connected by Bluetooth low power communication mechanism.

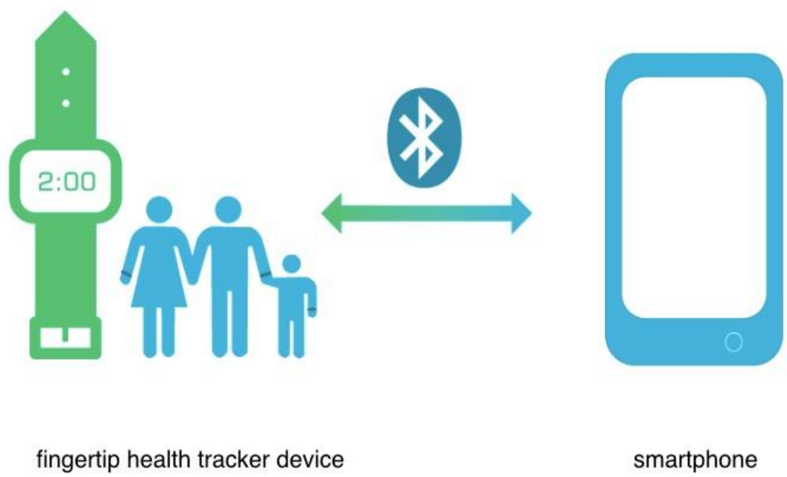

Figure 3 Software Communication Diagram

On our wireless-enabled passive fingertip health tracker device, it will run mbed OS, an operating system for IoT devices developed by ARM. [5] Real time collected data will run through an on-the-fly data serializer to make the data very compact and then the data will be stored locally on the chip memory. With a combination of scheduling mechanism such as by proximity and timer, the device will sync its data to any BluetoothSmart compatible device such as an iPhone.

The next part of the software design will be focusing on a smartphone application. This application will be implemented in the iOS platform because of its ease to develop, huge installed base and availability of various activity fitness sensors. [6] We will design our app following Model View Controller paradigm. In our Model, we will implement the functionality to establish the Bluetooth connection with fingertip health tracker device, exchange data with the tracker device only when the application is active in the phone foreground or the device initiate a emergent *wakeup call to the phone. The data will be stored into Apple's HealthKit store, which will be encrypted if the phone is locked by user's passcode or TouchID [7]. We will also implement communication to a remote server. When the data is in transit, it should all be encrypted and only the user and doctor can decrypt the data. The server acts only as a temp storage and relay the information to the doctor. We will also implement the functionality to do data analysis on the collected heart and oxygen data saturation in order to predict heart disease. In addition to that, we will also experiment analysis the relationship between the heart sensor data with activity fitness sensor data to see if we can improve users' workout efficiency. In our View, we will display the statistics and trends of collected data. We will warn user if an abnormal data pattern appears. We will provide suggestions on heart health condition and tips on improving workout habits. In our Controller, we will query the data from the device database and present the data in the View.

4.2 Codes and Standards

Bluetooth 4.0 will be used as the main data transmission mechanism between sensor and data processing unit (Phone) in an ultra-low power consumption situation.

FCC mark is a certification mark employed on electronic products manufactured or sold in The United States which certified that the electromagnetic interference from the device is under limits approved by the federal communications commission.

4.3 Constraints, Alternatives, and Tradeoffs

Constrains.

Limited space with a ring size.

Low capacity battery

Alternatives

Apple watch (coming in February new year) can be considered as alternative products as it also provide heart rate information to users' cell phones. However, our design could provide the oxidation information for users, which makes our design competitive. Fitbit and Jawbone has similar product with heart rate monitor, but both of them design are focused on activity tracking, and display result for user is raw data of heart rate, which is not understandable for normal user.

Tradeoffs

Power consumption vs. capable performance

Better Accuracy vs. limited space

5. Schedule, Tasks, and Milestones

The Gantt chart in Appendix A shows a task breakdown that must be completed.

6. Project Demonstration

The capabilities of the Funky tracker will be shown through the following demonstration:

- User wears our fingertip for a brief moment. When he/she launches the companion iOS app on the paired smartphone, the recorded health data will be presented in the app.

- User authorizes sharing of his/her data to another person (doctor) from the iOS app. The other person will then launch an iOS app to view the data.

- User jumps up and down and deliberately to let Funky detect abnormal behaviors, the iOS app then should present an alert.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

There is a lot of wearable activity tracking device in the market. Two of them use iOS and Android app to display user personal data. The cost of buying each of them is shown in Table 2.

	Fitbit Charge HR	Jawbone UP3
Feature	Tracks continuous heart rate Activity tracking	Heart rate monitor Activity tracking
Price	$ 149.95	$179.99

Table 2 Similar Products comparison

Both the Fitbit and Jawbone allow for heart beat monitor, but both of them only display the raw data, which is user current heart beat on the smartphone. A major selling point for Funky will be the more accurate heart beat detection and analyzed data. The product show result to user in the experience they can understand.

7.2 Cost Analysis

Funky consists of an iOS app and a specially designed heart beat monitor. The cost of developing iOS app will be about 30 hours . The parts that are needed to implement heart beat rate monitor device are listed with prices in Table 3. In the design, Microcontroller needs to capable with Bluetooth 4.0 standards. The cost of battery, print circuit board and packaging are estimated based on digitkey's current catalog.

Item	Price
Capacitor EEA-GA1H1R0H [9]	0.35
MTE6800N2-UR Visible Emitters [10]	3.15
UA741CP Amplifiers [11]	1.68
SFH 203 P Photodiodes [12]	0.74
BLE Nano Kit [13]	37.91
UNO R3 Rev3 EVM Board	12.95
PBC and Packaging	30.00
Total	86.78

Table 3 Development Phase Parts Cost

Task	Hours
Research & Meeting	30
Lecture	20
Hardware Design & Assembly	10
Software Development	10
Integration	3
Testing	5
Demonstration	1
Total	79

Table 4 Development Phase Labor Breakdown per Engineer

Five Engineers contribute to design and development of Device. It is assumed that a qualified engineer is paid $30 per hour in the team. The individual labor breakdown for this project is shown in Table 4, and the total labor cost for five engineers is $11850.00. Assuming 30% fringe benefits of labor and 120% overhead on materials, labor, and fringe benefits, Table 5 summarized the cost of development for the Device.

Item	Cost
Parts	86.78
Labor	11850
Fringe Benefits	3555
Subtotal	15491.78
Overhead	18590.20
Total	34081.98

Table 5 Development Cost Estimation

The Profit over one year of production of Device is given with assumptions. Based on Fitbit and Jawbone sales volume estimated, 2500 units are sold per year.[14] In the production period, the parts cost will reduce to $70.00 for buying in bulk. Additionally, there is a 10% sales expense and fringe benefits. Device is sold for $150.00 per unit. There is a $437500.00 profit over five years production and consider the development cost with $403419.00 net profit, which is about 20%. The selling price with $150.00 is higher than Fitbit activity tracker, but the more accurate and ease-to-use heart monitor is a major feature which other competitor's products is not focused.

Production Cost Item	Cost
Parts	70
Labor	10
Fringe Benefits	3
Subtotal	83
Overhead	100
Sales Expense	15
Total	115

Table 6 Product Cost in Production Phase

8. Current Status

The JH3 team currently is researching the relationship among blood oxygen saturation , finger pulse and heart health. The team is separated into hardware and software sub-teams. Hardware team will be working on the initial circuit and overall design. Software team will be working on the communication protocol and researching Apple's HealthKit framework. The team has decided the list of hardware components that are required to be purchased.

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Appendix A

Table A1. Complete Task List with Duration, Dates, and Assignments

	Task Name	Start Date	End Date	Duration	Assigned To
1	**Proposal**	**11/19/14**	**12/03/14**	**11**	**Group**
2	Proposal Due	11/19/14	12/03/14	11	**Milestone**
3	**Hardware**	**12/03/14**	**01/01/15**	**22**	
4	Choose and Configure Sensor	12/03/14	12/05/14	3	Chu & Yang
5	Circuit Design	12/06/14	12/11/14	5	Chu & Yang
6	Microcontroller Integration	12/12/14	12/16/14	3	Ze & Avery
7	Bluetooth Integration	12/12/14	12/16/14	3	Ze
8	PBC design	12/17/14	12/31/14	11	Ze & Avery
9	Hardware Assembly	01/01/15	01/01/15	1	**Milestone**
10	**Data Analysis**	**01/05/15**	**01/28/15**	**18**	
11	Signal Process	01/05/15	01/28/15	18	Chu & Yang
12	Analyze Data for Heart Disease	01/18/15	01/28/15	9	Chu & Yang
13	**Software**	01/18/15	02/24/15	28	
14	Data Interpreting	01/18/15	01/28/15	9	Ze
15	GUI Design	02/10/15	02/16/15	5	Zeheng
16	Software Implementation	01/18/15	02/16/15	22	Ze & Zeheng
17	Software Testing	02/17/15	02/24/15	6	**Milestone**
18	**Testing**	02/24/15	03/02/15	5	
19	Integrate Software & Hardware	02/24/15	02/26/15	3	Ze & Zeheng
20	Black Box test & bug fixing	02/26/15	03/02/15	3	Ze & Zeheng
21	Implementation Success	03/02/15	03/02/15	1	**Milestone**
22	**Demonstration**	03/02/15	03/12/15	9	
23	preparation	03/02/15	03/12/15	9	**Group**
24	Final Demo	03/12/15	03/12/15	1	**Milestone**
25	Final Presentation	03/12/15	03/12/15	1	**Milestone**
26					

Figure A2. Project Gantt Chart