ATHLETIC
INNOVATIONS

Sam Hafezi, CEO

March 19th 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: RunWare by Athletic Innovations Design Specifications

Dear Dr.Rawicz,

The attached document, *RunWare by Athletic Innovations Design Specifications*, outlines the technical guidelines for our product, *RunWare.* Our team aims to tap into the growing market for wearable technology, by creating a product that combines the benefits of indoor ergometers with the freedoms of outdoor activity.

The design specifications in this document are strictly for the proof-of-concept for *RunWare.* We aim to achieve much more than what is currently in progress for this project, but it as they will not be implemented at this stage, they are outside the scope of this document.

Athletic Innovations is composed of a highly talented team of individuals. Our organization alongside myself includes senior engineering students Ricky Tran, Chelsea Huang, Michael Ng, and Neha Chhatre. With our diverse background and expertise, I am certain we can achieve everything we set out to with *RunWare* and more. If you have any questions or concerns about our proposal, please do not hesitate to contact me by phone at *(778) 885-0499* or by e-mail at *shafezi@sfu.ca*.

Sincerely,

Sam Hafezi
Chief Executive Officer

Enclosure: RunWare by Athletic Innovations Design Specifications

Athletic Innovations
159-8333 Jones Rd.
Richmond, B.C., V6Y-3W9
Phone: (778)885-0499
E-Mail:shafezi@sfu.ca

ATHLETIC**INNOVATIONS**
159-8333 Jones Rd.
Richmond, B.C.,V6Y-3W9
Phone: (778)885-0499
Email: shafezi@sfu.ca

RunWare

Sam**Hafezi**
Chelsea**Huang**
Neha**Chhatre**
Michael**Ng**
Ricky**Tran**

Prepared For
Dr. Andrew Rawicz (ENSC440w)
Professor Steve Whitmore (ENSC305w)
Simon Fraser University
School of Engineering Science

March 19th, 2015

DESIGN SPECIFICATIONS

Abstract

Athletic Innovation's *RunWare* product design specifications are discussed in detail in this document. The five cornerstones of our design are Communication, Health Monitoring, Entertainment, Navigation, and Safety. We have detailed the specific methods, parts and considerations taken in the design process. For Communications and Entertainment, *RunWare* will have built-in speakers and a microphone in the jacket to control the *RunWare* application. Also the application will provide phone functionalities like music and phone calls. Health monitoring will be done by an optical pulse sensor located in the wrist, and controlled with a microcontroller. The *RunWare* application will use Google Maps to provide navigation for the runner through the built-in speakers. Also an accelerometer controlled by the microcontroller will be added to count the users steps. Finally the jacket will have strips of electroluminescent wires, connected to a phototransistor to keep the user safe. Test plans for the individual subsystems and the completed product are also included. This document will be used by the Athletic Innovations team to design and test our product along with the Functional Specifications of *RunWare*. Two prototypes, a male and female version, of *RunWare* will be completed by April 2015.

The freedom to Run Anywhere, with RunWare

ATHLETIC**INNOVATIONS**

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Glossary

API – Application program interface
App – Software, commonly used in reference to smart phone applications
AUX – Auxiliary communication port for audio inputs
BPM – Beats per minute
EL Wire – Electroluminescent Wire
IBI – Inter-beat interval
IDE – Integrated development environment
IEC – International Electrotechnical Commission
IP – Ingress Protection
LED – Light emitting diode
Opamp – Operational Amplifier
PPG – Photoplethysmogram; Optical technique to detect changes in blood volume
VO2max – Maximum rate of oxygen consumption

1. Introduction

Athletic Innovation`s *RunWare* will provide runners with an elevated running experience that promotes a healthy, active lifestyle. *RunWare* will improve five areas of the running experiences; Communication, Health Monitoring, Entertainment, Navigation, and Safety. *RunWare* has incorporated the latest wearable technology to create a jacket and complimentary Android Application. The following document will outline the design specifications for *RunWare*.

1.1 Scope

This document specifies the design of *RunWare* and describes how the design meets the functional requirements as described in Functional Specifications for *RunWare* [Functions Specs]. The design specification includes all requirements for a proof-of-concept and prototype models of *RunWare*. This refers to all functional requirements marked I and II in the Functional Specifications for *RunWare* [Functions Specs].

1.2 Intended Audience

This document is intended to be used by the Athletic Innovation team to serve as a guide for designing and testing the *RunWare* jacket and application.

2.Overall System Design

RunWare consists of 5 subsystems; heart rate sensor, variable lighting, audio system, and an Android application, all of which communicate with an Arduino microcontroller. A high-level system block diagram is shown in **Figure 1.**

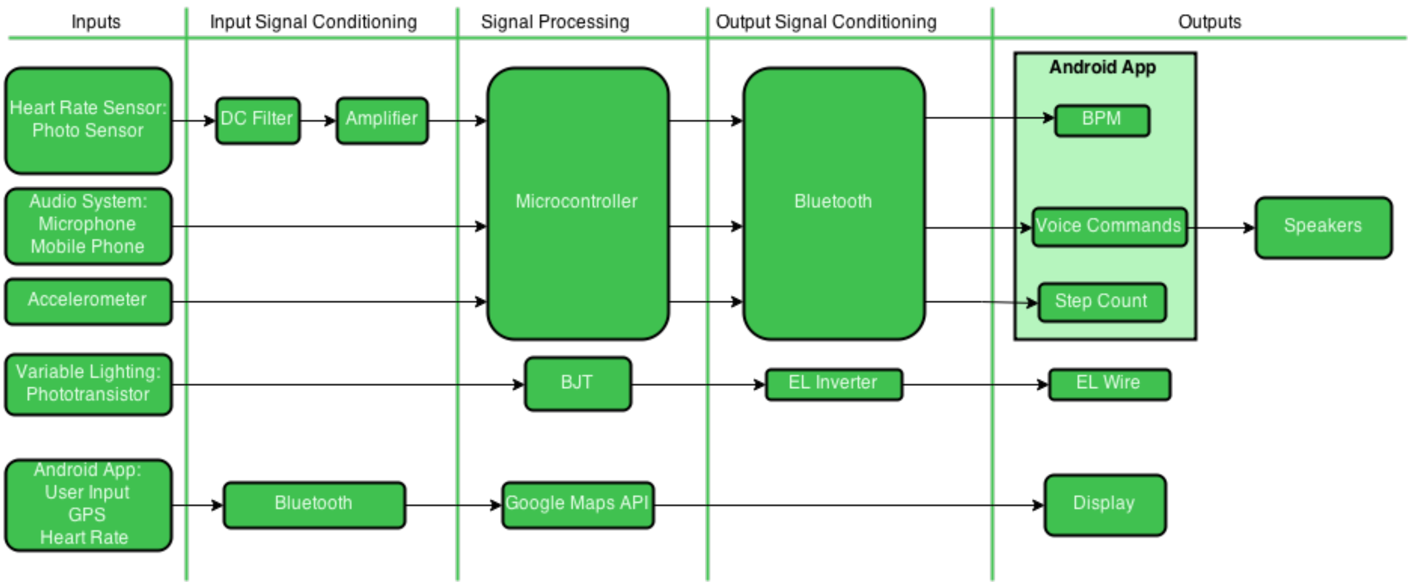


Figure 1 High-Level System Diagram of *RunWare*

2.1 Heart Rate System

2.1.1 How to measure Heart Rate: Biology and Physics perspective

The heart rate will be measured with a process called photoplethysmogram (PPG), in which the change in blood volume is detected using a light source and a sensor. There are two types of PPG: transmittance and reflectance [1]. For our design, we will be using reflectance PPG to detect the changes in volume. With incident light entering the tissue, the light will be absorbed, transmitted or reflected. In our case we will be detecting the change in the reflected light due to change in blood volume.

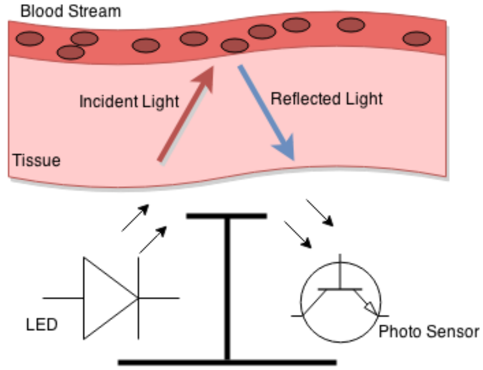


Figure 2 Diagram of Reflective PPG Method

In **Figure 2** the setup for reflective PPG is shown with the incident light from the LED being reflected by the blood stream and detected by the photosensor. The change in blood volume occurs when the heart beats and therefore will allow us to calculate the heart rate.

2.1.3 Circuit Design

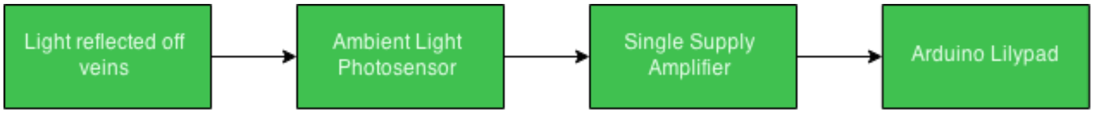


Figure 3 Process Flow of Heart Rate Detection

The process begins with the LED (MLEGRN-A1) projecting green light (528 nm) over the veins in the wrist. This light is then reflected from the veins and the reflectance is measured by the photosensor. The output signal is passed through a DC filter consisting of two capacitors before reaching the amplifier stage of the circuit.
The amplifier stage is in a single supply amplifier configuration and consists of an operational amplifier (opamp) and four resistors. The single supply configuration is required instead of other configurations because the circuit is powered by a unipolar voltage supply instead of a bipolar +/- supply [2]. With a dual-supply opamp, the output will fluctuate above and below the ground (0 volts). But for this configuration, a voltage divider provides V_{in+} for which the output will fluctuate over.

$$V_{in+} = \frac{R_2}{R_2 + R_1} V_+ \qquad (1)$$

In this configuration we have 100kΩ resistors as the R_1 and R_2 and 3.3V for V_+, which gives us 1.65 V as V_{in+}. Therefore the amplified AC signal from the photosensor will fluctuate over 1.65V when measured at the output of the opamp. Aside from the DC offset, the configuration still functions as an inverting amplifier with a gain of -330 V/V(See **Equation 2**)

$$Gain = -\frac{R_4}{R_3} = -\frac{3.3M\Omega}{10k\Omega} = -330 \quad (2)$$

After the amplifier stage, the circuit has completed its purpose and the output signal is sent to the Arduino Lilypad, via pin A0, to process the data. The circuit was based on an open-source design called Pulsesensor [3]. The changes we made to the circuit involved switching to a different LED and using a through-hole opamp instead of a surface mounted opamp.

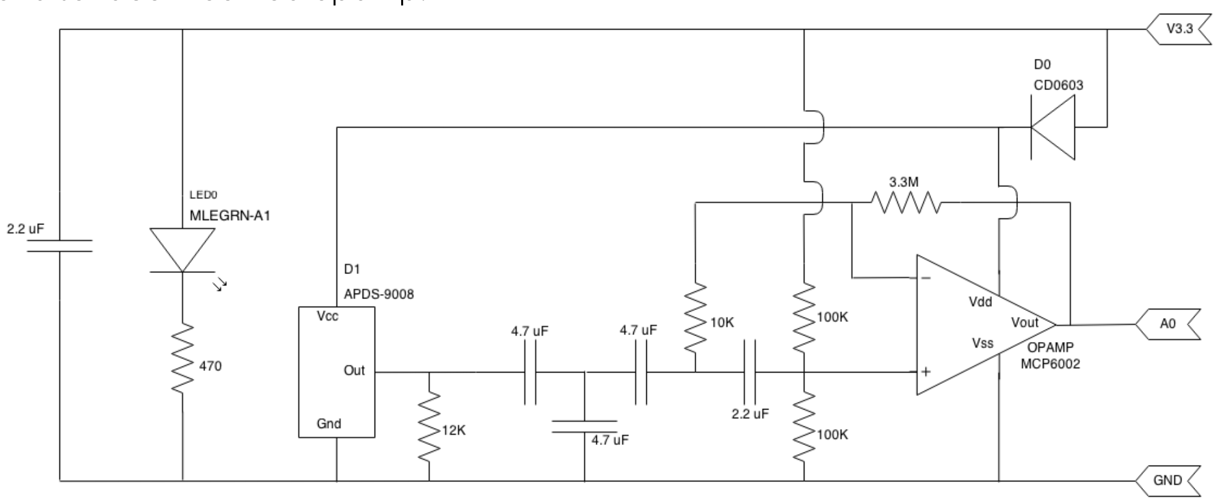


Figure 4 Schematic of Heart Rate Circuit

2.1.4 Power Requirements

The heart rate detection circuit has a supply voltage of 3.3V and after initial testing it has a current of 1.5 mA. Therefore the power required for this circuit is 4.95 mW.

2.1.5 Design Considerations

In order to maintain the ease of use for the user, the heart rate sensor will be implemented as compact and lightweight as possible. The important LED and photo sensor will be embedded into the wrist area of the jacket. This will allow heart rate detection without requiring the user to wear a strap. The rest of the circuit will be located in the lower back of the jacket. Wires will connect from the circuit to the LED and photo-sensor at the wrist.

2.2 Variable Lighting

The entire variable lighting subsystem will allow the wearer of the *RunWare* jacket to be seen more easily at night, as well as making the jacket more pleasing to the eye. The system will be able to detect incoming light so it will not turn on during the day. Likewise, if the system detects no light, the system will be activated.

2.2.1 Mechanical Design of EL Wire

The variable lighting system will be designed using Electroluminescent Wire (EL Wire), a plastic wire that contains a thin strip of copper in its core. This core is coated by phosphor that lights up when a current runs through it. The variety of wire we have purchased will glow a bright white color when turned on, so it will be very visible at night. A diagram of the EL Wire can be seen below in **Figure 5** [4].

The EL Wire also requires an inverter, which outputs 110 V_{AC} to drive the wire. The inverter accepts an average of 3V to drive the wire. The true range of the inverter is between 2.7V and 4.2V inputs. Alternatively, an inverter that accepted 12V, but to minimize the power consumption the 3V inverter was chosen.

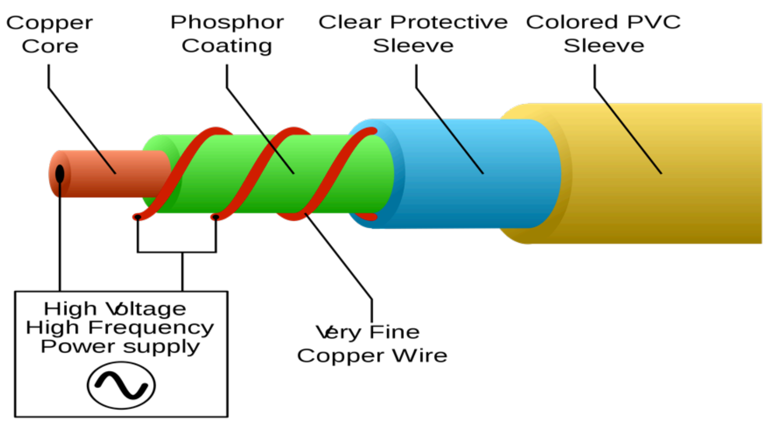


Figure 5 Diagram of EL Wire

2.2.1.1 Wire Placement

The *RunWare* jacket will be wrapped in 3 meters of the EL Wire, which will shine from 2-5 Lux when uncoiled @ 4.5V, and 30-32 Lux when coiled EL Wire @ 4.5V.

This area was chosen because it is the most visible to oncoming to traffic. Another reason behind this placement was to minimize strain to the wire, as the regions of the body that move the most are the shoulders and elbows. This way the longevity of the wire will be increased.

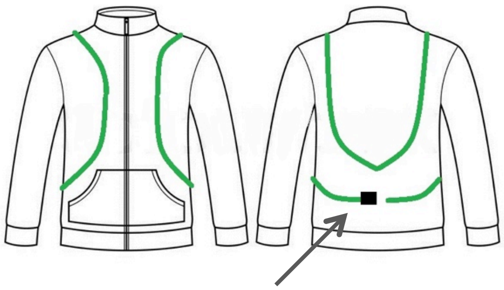


Figure 6 Wire Placement

2.2.1.2 Wire Integration

To attach the wire to the jacket, the wire will be sewn by hand, following the wire placement design. There will be a clear thread used between the EL wire and the jacket to add durability. A small waterproof pocket will contain the inverter in the lower back of the jacket.

2.2.2 Electric Circuit

The circuit design of the variable lighting subsystem can be seen below in **Figure 7.** The primary figure of interest in the circuit is the phototransistor (2N3904). The phototransistor is the component that allows the subsystem to be sensitive to incoming visible light.

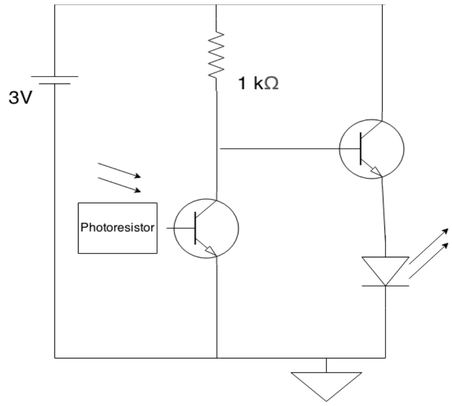


Figure 7 Schematic of the Light Subsystem

Should a bright light be detected, the phototransistor allows current to pass through it. This allows the voltage to go straight to ground. Similarly, if the phototransistor detects no light, then the phototransistor will decrease current flow through it to negligible amounts. This reroutes the current to pass through the BJT, which passes the current through the EL Inverter and EL Wire. In **Figure 7** the EL wire and EL inverter are represented together as the LED circuit symbol.

2.2.2.1 Power Requirements

The light subsystem will be powered by a 4.2V lithium ion polymer battery that will draw at most 100 mA. The system will then only require 420 mW of power.

2.2.2.2 Design Considerations

The EL wire was chosen due to its low voltage requirements and ease of use. The LED's that were previously considered required 12V to be sufficiently bright. The 3V requirement of the EL Wire allows for a smaller battery, reducing the circuit's footprint.

2.3 Accelerometer

Since publishing the Functional Specifications document, a three-axis accelerometer has been added to the design. For the proof-of-concept model, the accelerometer will function as a step counter. The application will display the steps when prompted by the user. Although the accelerometers are calibrated at the factory, to have a better level of precision in more critical applications it is important to calibrate the sensor [5]. Hence the accelerometer will be calibrated every time the microcontroller is turned on. In future developments the accelerometer will be used as a fall detection sensor. This is very important when *RunWare* is added to ski and snowboard jackets.

2.3.1 Mechanical Design

For the accelerometer to give the best results it will be placed away from the center of the body, in line with the user`s knee [6]. **Figure 8** shows the location of the accelerometer on the *RunWare* jacket. The accelerometer is designed to be used as part of a wearable circuit and it has a flat design so it will not obstruct the user when they are running. Before attaching the accelerometer to the jacket, it will be placed inside a waterproof nylon pocket, and then sewed on to the jacket. In the future, it will be placed inside a durable plastic enclosure to add durability. Conductive thread will be used to connect the accelerometer to the microcontroller. The thread will also strengthen the bond between the accelerometer and the jacket.

Figure 8 Accelerometer Placement Within Jacket

2.3.2 Electric Circuit

The accelerometer will be powered by the microcontroller and will be connected as shown in **Figure 9.**

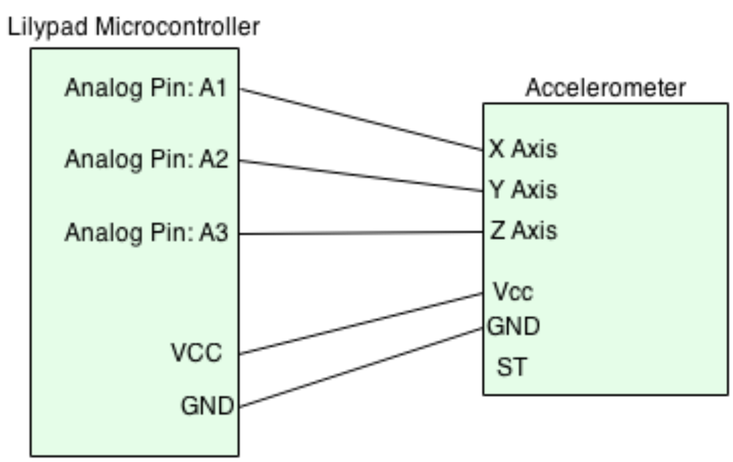


Figure 9 Schematic of Accelerometer Connections to Microcontroller

2.3.2.1 Power Requirements

The accelerometer connected to the microcontroller will be powered by a 4.2V lithium ion polymer battery that will draw at most 6.7 mA. The system will then only require 28 mW of power.

2.4 Microcontroller

Since the microcontroller would be attached to the jacket, it needed to be light and compact. The Lilypad by Arduino is designed for wearable projects, and can be sewn into fabrics. If the microcontroller is detached from the power source it can even be washed [7]. The Board is based on the ATmega328V microcontroller.

The microcontroller will be attached to the lower back of the jacket. After observing runner's movements the lower back is fairly steady and placing the microcontroller there will not obstruct the runner in any way [8]. Since the microcontroller is flat, when the runner is sitting in a chair it will not be obstructive or uncomfortable. **Figure 10** shows the placement of the microcontroller in the jacket. The microcontroller will be placed inside a waterproof plastic enclosure and sealed inside a nylon pocket.

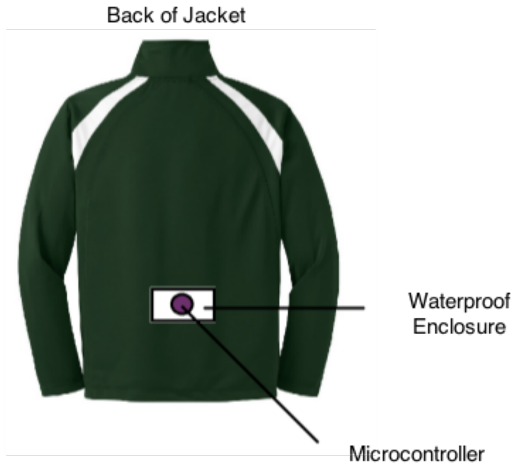


Figure 10 Microcontroller Enclosure Placement Within Jacket

2.4.1 Bluetooth

A Bluetooth connection will be used to communicate between the microcontroller and the Android Application on the user's smartphone. A Bluetooth module was chosen based on the following criteria:

- It should be able to pair quickly with majority of cellular phones available on the market
- It should require less than 5V to operate
- It should be reasonably priced

The chosen HC - 06 Bluetooth module will be connected to the microcontroller as shown in **Figure 11.**

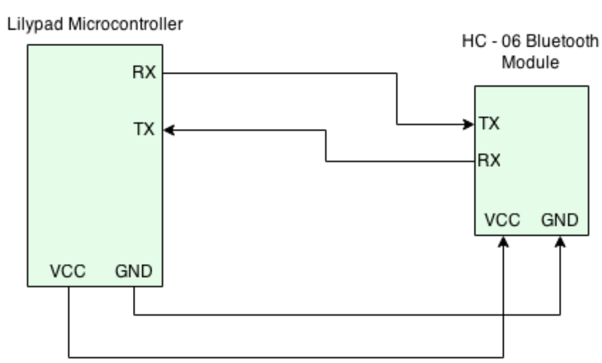


Figure 11 Microcontroller to Bluetooth connection schematic

2.4.2 Heart Rate Sensor

The Arduino code for the heart rate sensor will be based off of the open source code from Pulse Sensor Amped [9]. It will read the change in voltage produced by the change in light intensity, and calculate the beats per minute (BPM). The microcontroller will measure the inter beat interval (IBI) by timing between moments when the signal crosses 50% of the wave amplitude during the upward rise. The flowchart shown in **Appendix A-1** summarizes the Arduino code required for calculating the heart rate.

2.4.3 Accelerometer

The steps are measured by the microcontroller by comparing the acceleration with respect to the starting point [6] . The flowchart in **Appendix A-2** summarizes the accelerometer Arduino code.

$$Acceleration = \sqrt{(x^2 - \bar{x}) + (y^2 - \bar{y}) + (z^2 - \bar{z})} \quad (3)$$

Where

$\bar{x}, \bar{y}, \bar{z}$ are the starting points.

2.5. Audio System

Embedded in the collar and hood of the two prototypes will be the audio subsystem. The audio subsystem will consist of a pair of speakers and a microphone that will receive and send signals to and from the microcontroller. This system will provide added entertainment and safety to *RunWare* users through easy access to music streaming and calling functions from a mobile phone. The open ear speaker structure also adds to the safety of *RunWare* by not obstructing hearing.

2.5.1 Materials Used

In order to increase the sustainability of the prototypes, the speakers will be reused from old over-ear dynamic headphones. The two headphone models that speaker parts were retrieved from are Audio-Technica ATH-M50 and Shure SRH550DJ; their specifications can be seen in **Table 1**.

	ATH-M50	SRH550DJ
Sensitivity	99 dB/mW	109 dB/mW
Impedance	38 Ω	32 Ω
Frequency Range	15 – 28,000 Hz	5 – 22,000 Hz
Maximum Input Power	1,600 mW	3,000 mW
Weight	284 g	235 g
Cable Style	Copper-clad Aluminum Wire	Oxygen-Free Copper
Plug	Gold-plated 3.5 mm	Gold-plated 3.5 mm

Table 1 Specifications of Audio-Technica and Shure Headphones

Each speaker will be enclosed in a plastic cabinet and sealed using marine epoxy to maintain International Electrotechnical Commission (IEC) waterproofing standards. The use of these materials should allow a minimum rating of Ingress Protection 54 (IP54), as the back side of the speakers will not be contactable due to the plastic enclosure and the epoxy seal will protect the speakers from splashing water from all directions as well as prevent dust from entering. For fabrication the enclosure can be further tested to see if it meets IP67, where it will be completely dust-tight and can be submerged in up to 1m of water [10]. To test that the enclosure can meet IP67, a dust chamber with talcum powder blowing around for 2 to 8 hours will need to be used, and the enclosure will need to be submerged in a meter of water for 30 minutes [11]. The microphone (POW-1644L-B-R) chosen for this subsystem has an IP57 rating [12]. Both the microphone and the speakers will be connected through the jacket to the Lilypad Arduino to transmit and receive signals to and from the user's Android smartphone via Bluetooth.

2.5.1.1 Jacket Design

There are two designs for the audio subsystem to fit with the two different jackets used for our prototypes. As the female prototype jacket has a hood, the speakers will be sewn in the upper half of the hood such that they sit comfortably when the hood is down and they can help keep the hood weighted on top of the user's head when the hood is up, without being uncomfortable. A mockup of this design can be seen in **Figure 12.** The female prototype will contain the Audio-Technica speakers because they are heavier, and the extra fabric in the hood will provide more structure for holding the speakers. For the male prototype, as there is a collar instead of a hood, the speakers will be sewn into the collar as can be seen in **Figure 13**. There will be one speaker on each side of the head. For both jackets, the microphone will be located near the top of the zipper on the right side.

Figure 12 Speaker and Microphone Placement in Female Prototype Jacket [13]

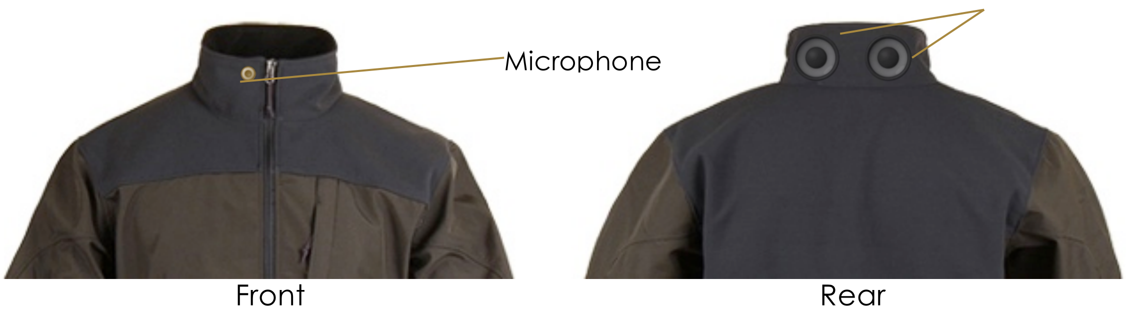


Figure 13 Speaker and Microphone Placement in Male Prototype Jacket

2.5.2 Electronic Components

Due to the sensitivity of the speakers, careful consideration must be put into the amount of power supplied. The audio subsystem will receive signal from the microcontroller and output to the speakers. From the specifications of the speakers as seen earlier, the estimated volume level out can be calculated in decibels based on the power supplied to the speakers. For the safety of the users' hearing, following **Figure 14,** the speakers will have a maximum output volume of 99dB.

dB	DIRECT SOUNDS	EXPOSURE TIME
140	Jet take-off, Gun shot	DANGER ZONE
130	Jack hammer	
120	**Threshold of pain**	Less than 7 minutes
115	Rock concert	15 Minutes
110	Dance club	30 Minutes
105	Voice shouting	1 Hour
100	Factory	2 Hours
95	Subway	4 Hours
90	Heavy traffic	8 Hours
80	Busy street	
70	Restaurant	
60	Average conversation	
50	Average suburban home	
40	Quiet auditorium	
30	Quiet whisper	
20	Extremely quiet recording studio	
10	Anechoic chamber	
0	**Threshold of hearing**	

Figure 14 Sound Levels and Maximum Exposure Time [14]

Therefore, a maximum of 1mW will be supplied to the Audio-Technica speakers and a maximum of 0.9mW to the Shure speakers. The battery will supply a voltage of 4.2V to the circuit. Therefore, a resistance of 781Ω will be needed for the Audio-Technica circuit and a resistance of 760Ω to the Shure circuit. Each audio subsystem will have 2 speakers, but since each speaker has the same impedance and receive their own channel source, the circuits will be identical and simply consist of a power source, resistor, and speaker. The calculations are shown using **Equations 4 to 6.**

Calculations for Audio-Technica with Lilypad source

$$\boldsymbol{Max\ Power} = \frac{\boldsymbol{Max\ dB}}{\boldsymbol{Sensitivity}} \quad (4)$$

$$Max\ Power = \frac{99dB}{\frac{99dB}{mW}}$$

$$Max\ Power = 1mW$$

$$\boldsymbol{P = I^2 R} \quad (5)$$

$$1mW = I^2(38)$$

$$I = 0.0051299$$

$$\boldsymbol{V = IR_{Total}} \tag{6}$$

$$4.2V = 0.00512989(R_1 + 38)$$

$$R_1 = \frac{4.2 - 0.00512989(38)}{0.00512989}$$
$$R_1 = 780.7\Omega$$

Calculations for Shure with Lilypad Source:

$$Max\ Power = \frac{109dB}{\frac{99dB}{mW}}$$
$$Max\ Power = 0.9mW$$

$$0.9mW = I^2(32)$$
$$I = 0.0053033009A$$

$$4.2V = 0.0053033009\ (R_1 + 32)$$
$$R_1 = \frac{4.2 - 0.0053033009(32)}{0.0053033009}$$
$$R_1 = 760\Omega$$

Alternatively, with the use of an auxiliary (AUX) port, the speakers can also use a mobile phone as the power and signal source. It is assumed that the phone is a Samsung Galaxy S4 with an input voltage of 2.3V. An additional 410Ω resistance will be necessary for the Audio-Technica speakers and an additional 402Ω resistance will be necessary for each speaker in the Shure circuit. The calculations can be seen using **Equations 4 to 6** once more. Both methods are feasible as long as the source current to the speakers is the same.

Calculations for Audio-Technica with Samsung Power Source:

$$Max\ Power = \frac{99dB}{\frac{99dB}{mW}}$$
$$Max\ Power = 1mW$$

$$1mW = I^2(38)$$
$$I = 0.0051299\ A$$

$$2.3V = 0.0051299(R_1 + 38)$$

$$R_1 = \frac{2.3 - (0.0051299)(38)}{0.0051299}$$
$$R_1 = 410.4\Omega$$

Calculations for Shure with Samsung Power Source:

$$Max\ Power = \frac{\frac{109dB}{99dB}}{mW}$$
$$Max\ Power = 0.9mW$$

$$0.9mW = I^2(32)$$
$$I = 0.0053033009A$$

$$2.3V = 0.0053033009(R_1 + 32)$$
$$R_1 = \frac{2.3 - (0.0053033009)(32)}{0.0053033009}$$
$$R_1 = 401.7\Omega$$

The microphone will be attached to either the microcontroller or mobile phone in a similar manner. If the microphone was connected to a mobile phone, a 3.5mm jack with 3 channels will need to be used to account for the extra channel, as pictured in **Figure 15.** The resistance of the microphone is 2.2kΩ and the maximum current is 0.5mA [12]. Using this information and the same methods as with the speakers, the microphone circuit would need an additional resistance of 7.8kΩ with the Lilypad as the source and 6.8kΩ with the Samsung source.

Figure 15 3-channeled AUX Cable (left) Stereo AUX Cable (right) [15]

2.5.3 Power Consumption

The power consumed by each speaker with the Lilypad source is 21.6mW for Audio-Technica and 22.3mW for Shure. The power consumed by each speaker with the Samsung source is 11.8mW for Audio-Technica and 12.2mW for Shure. The power consumption of the speaker circuits can be reduced up to 1mW depending on user's volume preference; power is reduced in a parabolic relation to volume increment. For the microphone, the power consumed with the Lilypad source is 2.5mW and the power consumed with the Samsung source is 1.2mW. Therefore the maximum total power consumed in the Lilypad case is 45.7mW for the Audio-Technica circuit and 47.0mW for the Shure circuit. The total power consumed in the Samsung case is 24.7mW for the Audio-Technica circuit and 25.5mW for the Shure circuit. Assuming the Lilypad will be used as the voltage source, the average power consumption for each prototype's audio system is 46.4mW.

2.6 RunWare Application

The main interface between *RunWare* and our user is the proprietary Android application that we have developed. By utilizing the GPS system built into nearly all Android phones, as well as the heart rate detection features of our jacket, we can provide the user with accurate up-to-date information regarding their exercise. A high-level design of how the application communicates with the jacket is shown in **Figure 16.**

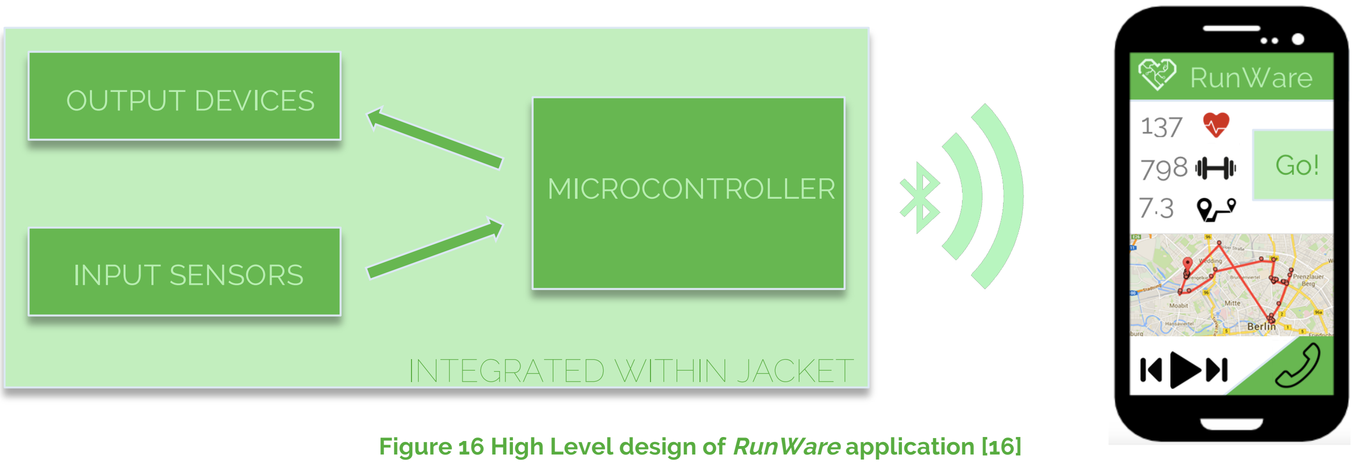


Figure 16 High Level design of *RunWare* application [16]

2.6.1 Details of Features

2.6.1.1 Application Platform

Our application is coded natively in Java for Android, using Android Studio integrated development environment (IDE) . The *RunWare* application is targeted for application program interface (API) 17 – 21, supporting Androids with versions 4.2.x – 5.0 [17]. This allows us to reach about 70% of all Android phones with version 2.2 and up [17].

2.6.1.2 Flow of Application

The *RunWare* application is reliant on Bluetooth and GPS connectivity. As a result, they are the most important checks that must occur. Once an activity has started, the application will then begin receiving location data from the phone, and the users' heart rate from the jacket. The total distance covered is calculated from the GPS coordinates, and displayed both in kilometers and overlaid on a map of the user's trail. **Appendix A-3** shows the flowchart for the application.

2.6.1.3 Distance Calculation

The GPS within the user's phone returns their current coordinates in degrees longitude and latitude. To be able to calculate the distance covered from these given values, we made use of the *Haversine* formula for calculating great-circle distances on two points of a sphere [18]. It is important to note that this calculation does not take into account distances covered due to elevation. This is acceptable because for our proof-of-concept application we will not be calculating elevation for use in calculating distance or calories burned.

The distance is calculated using **Equation 7.**

$$d = 2R \times arcsin\left(\sqrt{\sin^2(\frac{\varphi_2 - \varphi_1}{2}) + \cos(\varphi_1)\cos(\varphi_2)\sin^2(\frac{\lambda_2 - \lambda_1}{2})}\right) \tag{7}$$

Where

d is the distance traveled in meters
R is radius of Earth, 6,371,000 meters [19]
φ_1, φ_2 are the latitude of point 1 and 2
λ_1, λ_2 are the longitude of point 1 and 2

Since the Earth is only roughly spherical, this can only be correct up to 0.5% due to the change in radius from the Earth's poles to its equator [19].

2.6.1.4 Calorie Calculation

For the proof-of-concept version of *RunWare* there will not be unique user profiles, so specific users' age, height, or weight will not be accounted for in our calorie calculation. This will be added in the prototype version of *RunWare*. Instead we will use a generic user profile for *RunWare*: a 25 year-old male, weighing 80kg, with a height of 5'10".

The calculations will make use of the distance calculated previously, and in the final version will use the resting heart rate of the user as well. It will again be assumed that the user will be running at a constant elevation, with minimal incline. Another assumption is that the user has an average VO2max for their age at 44.2 [20]. The formula being used is shown in **Equation 8.**

$$CB = \left((0.95)M + TF\right)\frac{d}{1000} * CFF \tag{8}$$

Where

CB = Calories Burned
M = Mass in kilograms
TF = Treadmill factor = ~0.84 when running outdoors with no wind at 2.5 m/s
CFF = Cardiorespiratory Fitness Factor = 1.06 for our user

CFF is used due to findings that showed athletes with greater personal fitness, as determined by VO2max, burn fewer calories performing the same exercise [21]. VO2max calculation is shown in **Equations 9 to 11.**

$$VO2_{max} = 15.3\left(\frac{RHR}{MHR}\right) \tag{9}$$

Where

$$MHR = 208 - (0.7 \times Age) \tag{10}$$

$$RHR = BPM\ while\ seated \tag{11}$$

The CFF is determined by checking the user's VO2max with **Table 2.**

VO2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	CFF
VO2max ≥ 56	1.00
56 > VO2max ≥ 54	1.01
54 > VO2max ≥ 52	1.02
52 > VO2max ≥ 50	1.03
50 > VO2max ≥ 48	1.04
48 > VO2max ≥ 46	1.05
46 > VO2max ≥ 44	1.06
VO2max < 44	1.07

Table 2 VO2max to CFF conversion

2.6.1.5 Battery Consumption

GPS is notorious for high battery consumption. A majority of battery consumption occurs during signal acquisition, as communicating with each satellite will take roughly 12-30 seconds, and during this time your phone cannot enter a 'sleep' state [22].The reason most phones are efficient with battery usage is the ability to enter sleep between running processes, but GPS negates this.

Android utilizes assisted GPS, or A-GPS, which uses the cellular network and known Wi-Fi locations to send navigational data to the user, reducing the time that is spent without the ability to enter the deep sleep state.

Another way battery consumption can be mitigated is by controlling the polling rate for the GPS. Since *RunWare* will be constantly in communication using Bluetooth to receive the user's heart rate, more consideration is necessary in determining how often we request the user's location. Using a rough average running speed of 2.5 meters per second (the same value used in calculating the Treadmill Factor due to air resistance in stagnant air conditions), we find that the user would cover 150 meters in one minute. The size of an average block in the city of Vancouver ranges from 100 to 230 meters [23].As a result, polling once every minute would accurately obtain the user's information for most city paths. However, doubling the sampling rate to every 30 seconds gives information accurate to every 75 meters the user runs.

In future iterations of *RunWare*, location (trails that require increased sampling, or city blocks that do not) and speed based sampling will be included, to further increase battery efficiency for the user.

3. Electric Circuit Summary

3.1 Total Current

System	Current Required (mA)
Heart Rate System	1.5
EL Wire Visibility System	100
Audio System	11
Arduino Lilypad	28
Total	140.5

Table 3 Total Current of Systems

In order to power the jacket, a voltage supply of at least 3.3V is required. It is expected that the prototype of *RunWare* can be utilized for a maximum of 2 hours on a single full charge. In future iterations, the battery life will be extended. The amperes required for our current design is 140.5 mA and therefore the power supply must be at least 281 mAh. A lithium ion polymer battery, with output range from 4.2V charged to 3.7V was chosen to power the jacket. The battery has a rating of 850 mAh and will be able to power *RunWare* for 6 hours.

4. The Jacket

For the creation of the two prototypes, one jacket was sponsored from LOTUSACTIVA and the other is an old Ecko jacket that will be repurposed. The use of two designs was chosen to showcase *RunWare*'s versatility with different materials and shapes.

4.1 Textile Materials

The LOTUSACTIVA jacket is made out of bamboo, cotton, and spandex. Although this mixed material is thin and not waterproof, it is a good example of the material most running jackets are made of. For *RunWare*, it is vital to have a waterproof compartment to contain the microcontroller and the user's mobile phone. Therefore additional pockets will be created using a thin-coated waterproof nylon ripstop fabric. These pockets will be either completely sealed or sealed with a zipper and the seams will be lined with marine epoxy. The Ecko jacket has an inner layer and outer layer made out of a waterproof polyester. The jacket also has 5 pockets on the front, which are secured with zippers and buttons. This jacket is a much better fit with *RunWare* and not as many modifications will be required.

4.2 Durability and Reliability

With wearable technology there is a lot more wear and tear, and as a result the reliability of *RunWare* takes a stronger forefront. The two areas of largest concern for *RunWare* are sweat and strain relief [A]. For all electronic and mechanical devices, strain relief is important for the reliability, performance, and endurance of any product because it diverts any mechanical forces applied onto a wire away from delicate electrical connections. In *RunWare*, all connections will be permanent within the jacket, so the most effective method for integrating strain relief will be to use custom rubber grommets that mold over each electrical connection, similar to **Figure 17.**

Figure 17 Various Rubber Grommets Used for Strain Relief [24]

In addition to having strain relief for each electrical port, it will also be important to use the jacket as leverage in the strain relief of the wiring. In just the arms alone, the movement of the wrists, elbows, and shoulders must be accounted for[C]. There will be sufficient wire such that it will not obstruct any movement. Additionally, we will attach the wire to the pliable fabric of the jacket, so that mechanical force will be applied to the jacket and not electronic components when the wire is tugged. The wire will also be coiled around the arm instead to reduce lateral strain.

To address sweat and other wet weather conditions, the microcontroller will be sealed within a plastic enclosure using marine epoxy and placed in a nylon pocket on the back of the jacket. Additionally, all connections will be placed within heatshrink and the rubber used in addressing strain relief will serve as added protection against water at each port.

5. System Test Plans

5.1 Heart Rate Sensor

The heart rate sensor will be tested for a stable output when placed close to the wrist. Before the output can be connected to the microcontroller, the output signal must be verified with the expected output waveforms from literature. Once testing of heart rate sensor is completed, it can be connected to the microcontroller and accuracy of heart rate measurement can be tested.

5.2 Variable Lighting

The variable lighting subsystem will be tested by ensuring that there is current passing through the circuit. This can be done by using a function generator or a lithium ion battery. The next step is to determine just how much light is being emitted from the EL wire based on how much light is being transmitted into the phototransistor. Based on our circuit configuration, the two factors are inversely proportional. We can determine that the subsystem is working as intended if the EL wire bet brighter when the phototransistor receives less light.

5.3 Microcontroller

It is important to test the wired and Bluetooth connections to the microcontroller separately before testing the functions of the microcontroller to make sure any discrepancies in outputs are due to errors in the microcontroller code. For the Heart Rate sensor functionality the outputs will be tested against a separate dedicated heart rate sensor. Similarly, the step counter results from the accelerometer will be compared to a pedometer. This will ensure the results are comparable or better than market products.

5.4 Audio System

After construction of the 3 circuits into the jacket prototype, initial testing can begin through sending audio signals from the microphone and ensuring the reception of the signal in the microcontroller. An audio signal must also be successfully sent from the microcontroller to the speakers. Varying the output voltage from the microcontroller and using a sound meter to measure the decibels output from the speakers can test the volume and power. By measuring the voltage before each speaker, the power to the speakers can also be calculated.

5.5 RunWare Application

The application testing will start with ensuring a Bluetooth connection is formed from the users smartphone to *RunWare*. We will ensure that audio playback can be controlled from the application. Next, we will confirm that the application can display the heart rate information sent from the microcontroller correctly, and be updated in a timely manner. We will then check that the users GPS coordinates are updated accurately and the users travel distance is displayed on the application. Depending on the progress made, voice control may also be tested.

6. Conclusion

This document has outlined the design specifications of *RunWare* and how Athletic Innovations will achieve providing communication, health monitoring, entertainment, navigation, and safety to users. Using the test plans and our specific design information the heart rate, variable lighting, accelerometer, microcontroller, audio, and mobile phone application functions of *RunWare* will be fulfilled in our two prototypes. Thus creating a groundbreaking running experience with wearable technology.

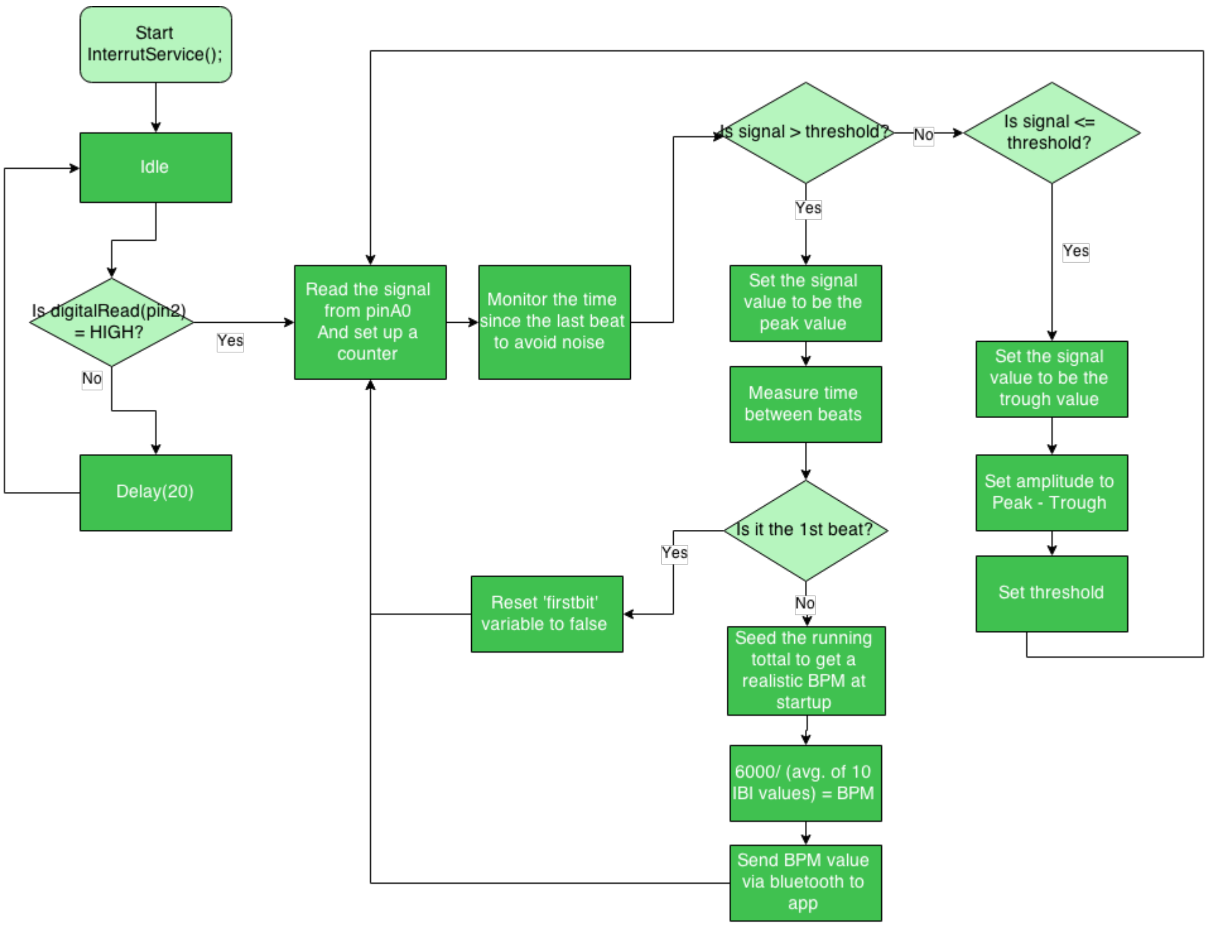
The freedom to Run Anywhere, with RunWare

ATHLETIC**INNOVATIONS**

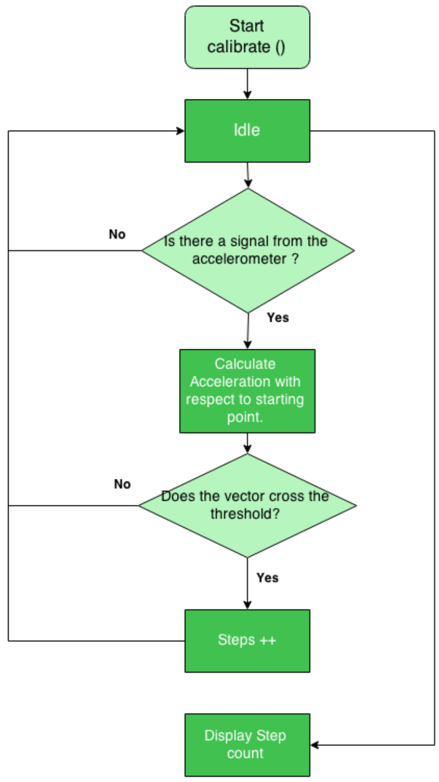
Appendix

Appendix A : Flowcharts

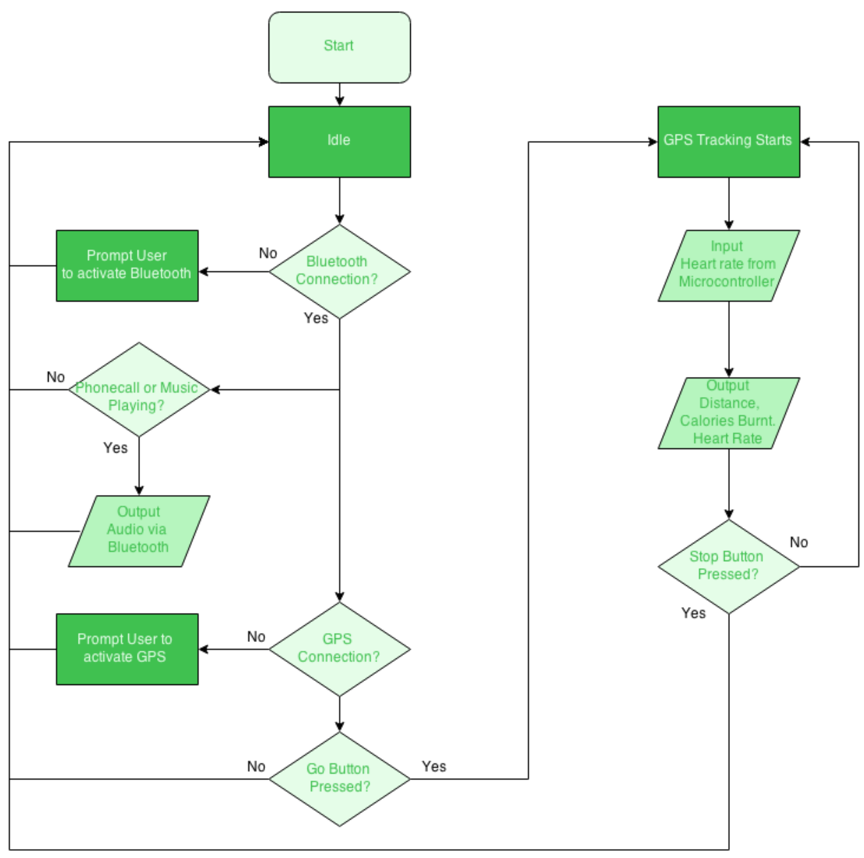
1. Pulse Sensor Arduino Code



2. Accelerometer Arduino Code



3. RunWare Android Application



Appendix C : Test Plans

Athletic Innovations

Test Sheet	
RunWare	Date:

Heart Rate Sensor	
Photo Sensor	Comments:
Detects reflectance changes: □Yes (pass) □No (fail) Can be placed against wrist: □Yes (pass) □No (fail)	
Single Supply Amplifier	Comments:
Amplify signal: □Yes (pass) □No (fail) Correct gain applied: □Yes (pass) □No (fail)	

Light System	
EL Wire	Comments:
Varies brightness with voltage: □Yes (pass) □No (fail) Is easily visible in the dark: □Yes (pass) □No (fail)	
Phototransistor	Comments:
Varies current with light: □Yes (pass) □No (fail)	

Microcontroller	
Bluetooth Module	Comments:
Pairs with Phone: □Yes (pass) □No (fail) Receives signal from App : □Yes (pass) □No (fail) Sends signal to App : □Yes (pass) □No (fail)	
Heart Rate Sensor	Comments:
Measure resting BPM: 60 – 100 □Yes (pass) □No(fail)	

Measured BPM is ± 2 BPM of Heart Rate found using a heart rate watch: □Yes (pass) □No (fail) Gives App correct BPM value when called: □Yes(pass) □No (fail)	
Accelerometer	Comments:
Measured step count for 500m is ± 5 of step count found using a pedometer: □Yes (pass) □No (fail) Gives App correct step count when called: □Yes(pass) □No (fail)	

Audio	
Audio-Technica Speaker Circuit	Comments:
Is able to play music from source: □Yes (pass) □No (fail) Power over speaker is less than 1mW: □Yes (pass) □No (fail) Measured maximum volume is 99± 5 dB-SPA: □Yes (pass) □No (fail)	
Shure Speaker Circuit	Comments:
Power over speaker is less than 0.9mW: □Yes (pass) □No (fail) Is able to play music from source: □Yes (pass) □No (fail)	
Microphone Circuit	Comments:
Is able to transmit signal: □Yes (pass) □No (fail)	

RunWare App	
GPS	Comments:
Show's user's location: □Yes (pass) □No (fail)	

<table>
<tr><td>Tracks user’s movement: ☐Yes (pass) ☐No (fail)
Calculates distance: ☐Yes (pass) ☐No (fail)
Calculates calories: ☐Yes (pass) ☐No (fail)</td><td></td></tr>
<tr><td>Audio</td><td rowspan="2">Comments:</td></tr>
<tr><td>Plays and controls music: ☐Yes (pass) ☐No (fail)
Handle’s phone calls: ☐Yes (pass) ☐No (fail)</td></tr>
</table>

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