Advanced Sports Timer

ECE 445 Design Document

Patrick Tchassem Noukimi

Cristian Velazquez

Santiago Gutierrez

Group 63

TA: Yuchen He

February 27, 2017

Contents

1 Introduction **3**

1.1 Objectives . . . 3

1.2 Background . . . 3

1.3 High-Level Requirements . . . 4

2 Design **4**

2.1 Power Module . . . 5

2.1.1 Charger . . . 6

2.1.2 Battery . . . 7

2.1.3 Voltage Regulator . . . 7

2.2 Control Module . . . 8

2.3 Interface Module . . . 10

2.3.1 Display . . . 10

2.3.2 Heartbeat Sensor . . . 11

2.3.3 Buttons . . . 11

2.4 Wireless Module . . . 12

2.4.1 RFID Transponder . . . 12

2.5 Total Power Consumption . . . 14

2.6 Software . . . 14

2.6.1 Timing . . . 15

2.6.2 Heartbeat Sensing . . . 16

2.6.3 Transmission . . . 17

2.7 Tolerance Analysis . . . 18

3 Cost and Parts List **19**

4 Schedule **20**

5 Ethics and Safety **20**

1 Introduction

1.1 Objectives

The objective of this project is to allow a track coach to monitor the performances of different athletes in a team at the same time. The problem came from the current process of monitoring athletes' performances, which requires sprinters and runners break form to pause and look at their times, and have to orally or manually write down their times for the coach to evaluate and consider.

We proposed a solution that could annihilate the different problems encountered in the current process by using a design similar to a stopwatch that can be easily and discreetly worn on the multiple fingers, without impeding their form when running. The device will be able to accurately record athletes' time and heartbeat as they run around a track, logging and saving their data on the device's memory each time the lap button is pressed. The device will be able to, wirelessly, transmit the results to a phone, using near-field communication (NFC), and be viewable in graphical form.

1.2 Background

The idea for the project came from a track coach from Rhode Island who was not satisfied with the current stopwatch timers on the market. The coach proposed the idea of being able to view multiple athletes' times as they run around the track. He thought about a device that will be comfortable in the athlete's hand, as well as allowing them to conveniently track their times without a change in gait, and more importantly, to be able to record data without interrupting practice. Those data will be saved onto the device's memory and then sent through Near-Field Communication to the coach's phone.

There are many stopwatches currently on the market, most of them do not have the number of modes that we are looking to implement (such as lap interval timer, countdown timer, interval exercise timer, etc.), and none of them allow the transmission of the data wirelessly to a phone where the data are viewed neatly in graphical form or table form which simplifies the training analysis.

1.3 High-Level Requirements

- Have a compact size housing size that fits around a hand, roughly 3 inches along palm and 2 inches wide across fingers.
- Being comfortable to wear without affecting the athlete's performance.
- Battery must be able operate for 2 hours long without charge.
- Have a transmitter with bandwidth of at least 2kB/sec for fast wireless transmission
- Preserve at least 2kB of time data logged in memory for transmission to phone.

2 Design

Our design is constituted of five modules that are interconnected with power flow and data flow. We have the power module, which is the block that processes power accordingly to every other module in the circuit. The power module is also equipped with a charging circuit for charging the lithium-ion battery. The wireless module is responsible for transmitting the data coming from the microprocessor to the phone via NFC. The control module is made up of just the microprocessor (STM32F030K6T6), which is responsible for running the different types of modes, keeping track of the measurement of time using the internal real time clock (RTC), communicating with the interface and wireless module, and for storing the data in its internal flash memory. The interface module is made up of five buttons and a LCD screen. The buttons will be used for start/stop (default: may have other functions depending on mode), reset (default: may have other functions depending on mode), mode, lap, and power on/off. The design block diagram is represented in Figure 1.

The device physical design is represented by the a raw sketch in Figures 2a, and 2b. which respectively show how we are intending to design the waterproof casing to be worn and the actual front and back side of the design. As we can see from Figure 2b, we will place the battery on the back of the device near the PCB,while the screen will be placed in the palm of the athlete, allowing him to easily read the screen.

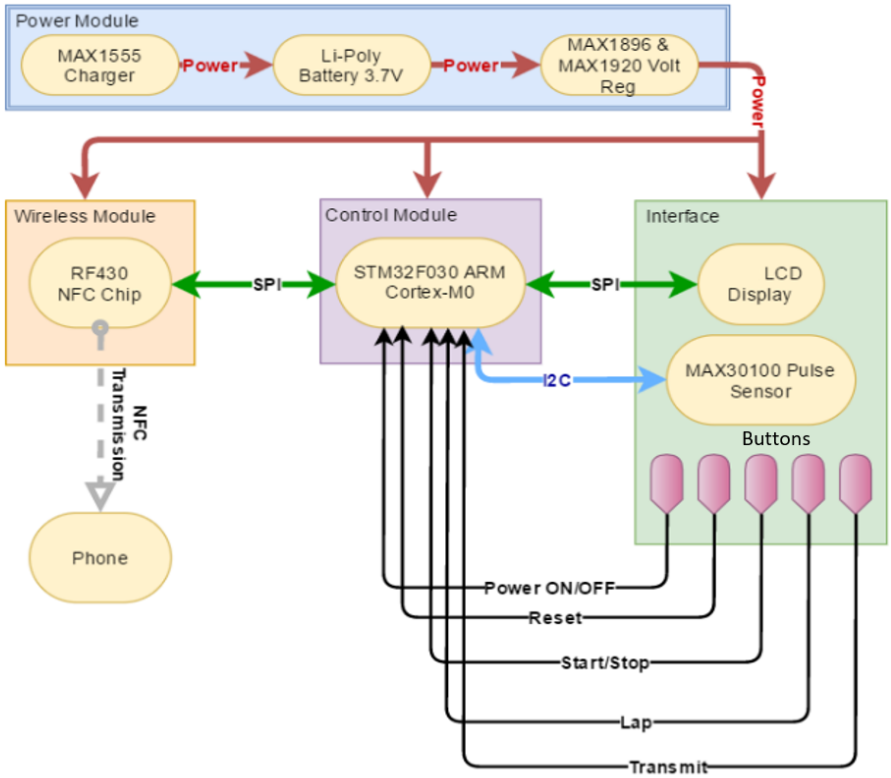
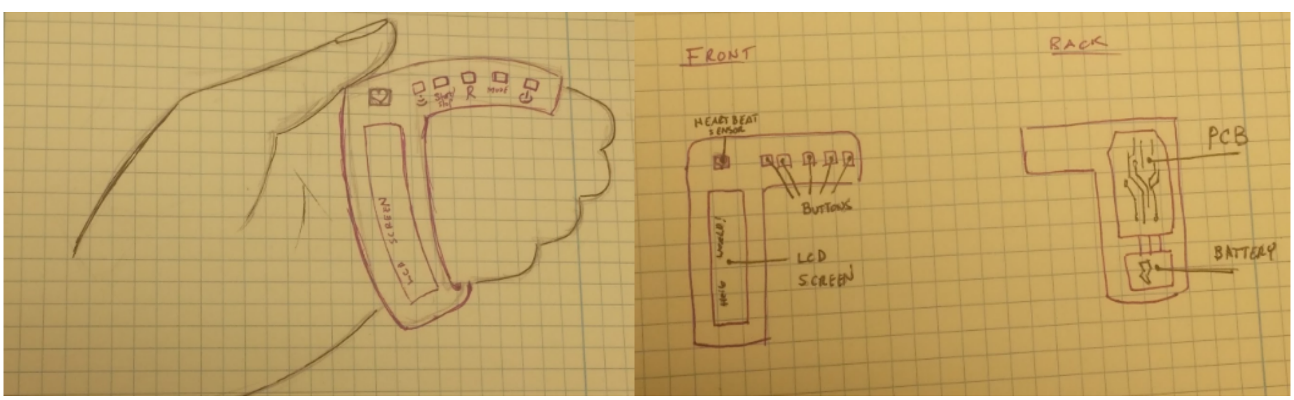


Figure 1: Design Block Diagram



(a) (b)

Figure 2: Physical Design Sketch

2.1 Power Module

The power module is made up of three components, the charging circuit, li-ion battery, and the voltage regulator. The charger circuit is used to charge the li-ion battery. It also contains voltage regulators, with help of Buck and Boost DC-DC converters, responsible for stepping up or down voltages for specific parts of the circuit that need required voltages or current inputs. It will provide different voltages: $5\pm0.5V$, with a maximum current of $300mA$, $3.3\pm5\%V$, with a maximum current of $200mA$, and $1.8\pm5\%V$, with a maximum current of $200mA$. The main power supply comes from the lithium-ion polymer battery. Figure 3 shows the schematic of the power module with its different sub-modules.

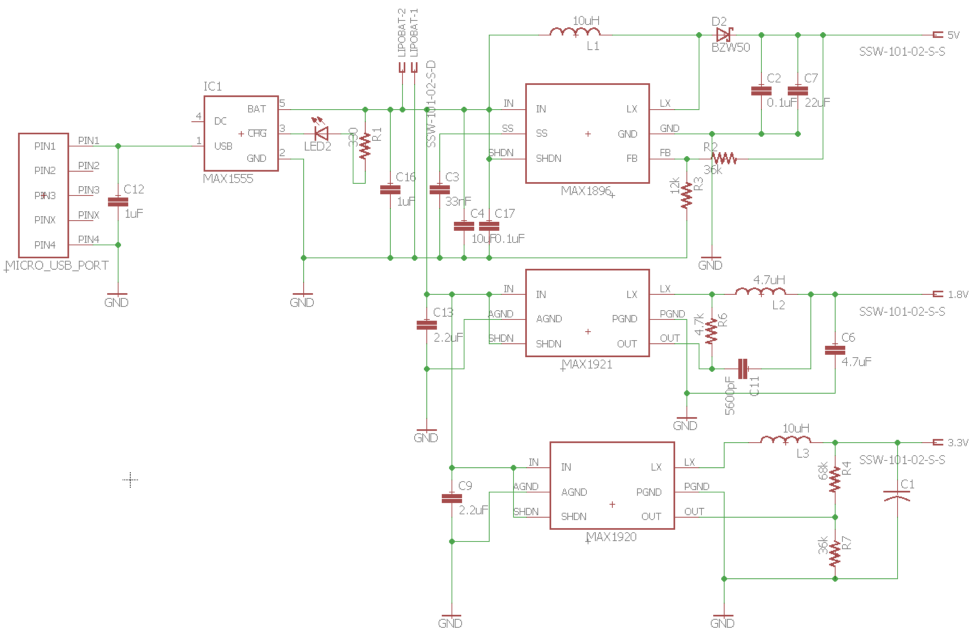


Figure 3: Power Module Schematic

2.1.1 Charger

The li-ion charger circuit will utilize the microusb port in order to charge the li-ion battery when it no longer contains charge. The charging circuit utilizes the integrated circuit MAX1555EZK-T from Maxim Integrated [5].

Table 1: RV for Charger

Requirements	Verification
The charging unit needs to continuously provide [80, 100]mA of current to the battery in order to avoid any damage [5].	• Use a multimeter with the prongs in series. • Verify the current is within range specified.

2.1.2 Battery

We will use a 3.7V, 2000mAh li-ion battery. The battery is will only dissipate power when the device is being used. Once discharged, the battery can be charged using a microusb for another cycle of usage. The battery used in our device is rated to last more than 400 cycles of charge [4].

Table 2: RV for the Battery

Requirements	**Verification**
Battery will have safe discharge rating of 400mA (0.2C) [5].	• Measure the current flowing out from the battery to the voltage regulator circuit using a multi-meter with prongs in series. • Ensuring the reading value is below the discharge rating.

2.1.3 Voltage Regulator

As mentioned earlier the voltage regulator module is made of one Boost converter MAX1896, from Maxim Integrated, that steps up the nominal 3.7V from the battery to 5V, which is the voltage required by the LCD screen. It is also constituted of two Buck converters MAX1920/MAX1921, also from Maxim integrated, that respectively regulate the input voltage to 3.3V, needed by the microcontroller, and the wiereless module, and step-down the input voltage to 1.8V needed by the heartbeat sensor.

The data sheet for the MAX1920/1921 [1], helped us to determinate the different values of components needed to respectively have 1.8V for MAX1921 and 3.3V for MAX1920, by providing us with several formulas. The following equations helped us find the minimum inductance, output capacitance and resistance for both the MAX1921 and MAX1920 . However, we are only displaying calculations of inductance and output capacitance for MAX1921, and resistances for MAX1920, since it will illustrate more hour we got our numbers from [1].

$$DutyCycle(MAX) = \frac{V_{\text{out}}}{V_{\text{in}}(MIN)} * 100\% = \frac{1.8}{3} * 100 = 60 \tag{1}$$

Since $DutyCycle(MAX)$ greater than 50, then $V_{\text{CRIT}} = V_{\text{out}}$. Thus L_{MIN} is

$$L_{\text{MIN}} = 2.5 * 10^{-6} * V_{\text{CRIT}} = 2.5 * 10^{-6} * 1.8 = 4.5\mu H \tag{2}$$

we chose the next standard inductor value, which is $4.5\mu H$.

We calculated the the value of the output ceramic capacitor with the help of the equation (3) provided.

$$C_{\text{out}}(MIN) = 2.5 * 10^{-6} * V_{\text{CRIT}} = 2.5 * 10^{-6} * 1.8 = 4.5\mu H \tag{3}$$

Here again, we chose the next standard value larger than $C_{\text{out}}(MIN)$ which is $4.5\mu H$. For finding resistances values, we first started by setting the value of resistance R_7 from Figure 3, then we used the following equation from the the datasheet, with R_7 chosen to be less than $50k\Omega$ and V_{ref} to be equal to 1.25V [1]. We chose R_7 to be $36k\Omega$.

$$R_4 = R_7 * (\frac{V_{\text{out}}}{V_{\text{ref}}} - 1) = 36 * 10^3(\frac{3.3}{1.25} - 1) = 67.68k\Omega \tag{4}$$

Table 3: RV for Voltage Regulator

Requirements	**Verification**
Able to provide voltage and current $5 \pm 0.5V$, with a maximum current of $300mA$.	• Measure the output voltage using an oscilloscope. • Ensure the output voltage stays within 5% of the expected output.
Able to provide voltage and current of $3.3 \pm 5\%V$, with a maximum current of $200mA$.	• Measure the output voltage using an oscilloscope. • Ensure the output voltage stays within 5% of the expected output.
Able to provide voltage and current of $1.8 \pm 5\%V$, with a maximum current of $200mA$.	• Measure the output voltage using an oscilloscope. • Ensure the output voltage stays within 5% of the expected output.

2.2 Control Module

The control module takes care of all the communication going on between the interface module and the wireless module, and includes only the microprocessor. It is also the module responsible for all the calculations and data storage in our design. The controlled module is governed by the microcrotroller STM32F030K6T6, from ST Electronics, which is incorporated with 4kB of Random Access Memory (RAM), and 32kB of flash memory that will be used to store the data that will later be transmitted. Figure 4 below shows the schematic connection between the remaining modules of our design. The microcontroller used in the control module runs at 48MHz [6]. It sends the logged

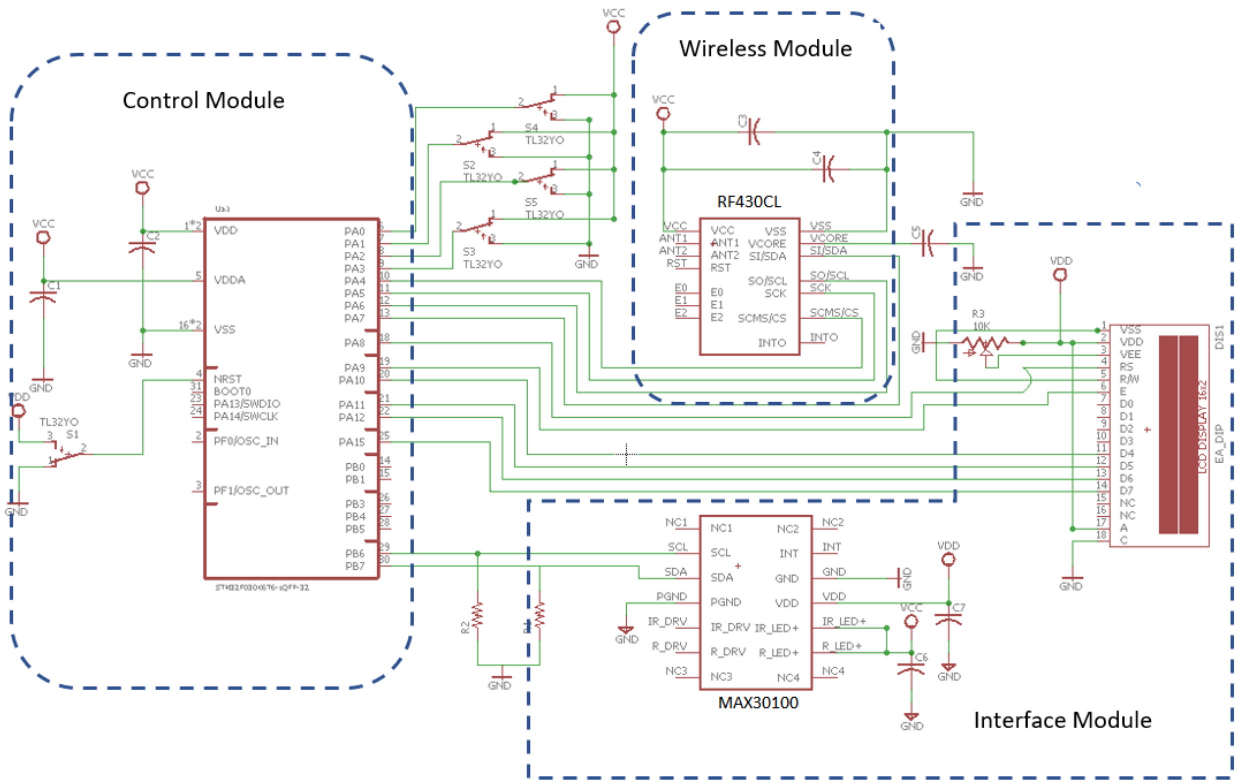


Figure 4: Control Module, Wireless Module and Interface Module Schematic

data to the RF430CL330HCPWR from Texas Instruments, for wireless transmission using NFC to a phone. The protocol used to talk to RF430CL330HCPWR is serial peripheral interface bus (SPI) [7]. The microcontroller also takes inputs from the buttons and performs the appropriate operations, such as stopping the timer when the stop button is pressed, or power the unit off when the power button is is pressed, just to name the few. The LCD screen communicates with the microprocessor in order to display the time, heartbeat, and the mode of the device. The LCD screen uses the SPI protocol to communicate back and forth with the microcontroller [8]. The later also communicates with the heartbeat sensor in the interface module using I^2C protocol. The heartbeat sensor is convenient in offering feedback to the athlete. Lastly, the microcontroller is used to run code for the different modes and stores the data temporarily in its internal flash memory for later wireless transmission.

Table 4: RV for Control Module (Microcontroller)

Requirements	**Verification**
The microprocessor must be able to communicate data to the display	• Run the device and a separate stopwatch simultaneous for ten seconds and stop the device. • See if the display shows the same time as stopwatch
Ensure a maximum power consumption of 400mW	• Use oscillator to get input voltage and current. • Multiply the two DC values to get the dissipated power

2.3 Interface Module

The interface module is how the user can communicate with the device. It contains the buttons, LCD display, and the heartbeat sensor as seen in Figure 4.

2.3.1 Display

The LCD display, (1.1"x2.8") is simple 16x2 character display with SPI communication protocol. The display is responsible for exhibiting the time, mode, and the heartbeat of the user wearing the device. Since the display is quite small and simple it will only require a 2.7V to 5V input and 4 bits of data in order to control it [8].

Table 5: RV for Display

Requirements	**Verification**
Must be able to successfully display time in a readable format	• Randomly write a sample of 16 characters. • Verify that LCD displays characters.
Ensure a maximum power consumption of 220mW	• Use oscillator to get input voltage and current. • Multiply the two DC values to get the dissipated power

2.3.2 Heartbeat Sensor

The heartbeat sensor we will be using is MAX30100EFD from Maxim Integrated. The sensor has a resolution between 50 sample per second and 1000 sample per second. This will be more than sufficient to measure our users heart rate in real time. It requires two voltages to operate. A voltage between 3.1V- 5V, for its infrared LED, and 1.7V-2.0V, for its logic. It draws at typical operation 20mA of current. Its total power dissipation is approximate to 44 mWh. The interfacing with the processor will involve reading and writing to a FIFO on the sensor [2].

Table 6: RV for Heartbeat Sensor

Requirements	**Verification**
Heartbeat sensor recorded data must be accurate within $\pm$ 5bpm	• Test own heartbeat by using a phone heartbeat sensor. • Verify that the heartbeat sensor value is within 5bpm.
Ensure a maximum power consumption of 7mW	• Use oscillator to get input voltage and current. • Multiply the two DC values to get the dissipated power

2.3.3 Buttons

The buttons will be active low and debounced in order to avoid any glitches and weird fluctuations that may corrupt data. Use two 4.7kΩ resistor for the active low buttons and two NAND gates for the debouncer circuit as shown in Figure 5 below.

Table 7: RV for Buttons

Requirements	**Verification**
Buttons need to be active low and debounced to avoid any data corruption.	• Build a debouncer circuit using NAND gates and resistors. • Verify that there is no glitch when the button is pressed using an oscilloscope.

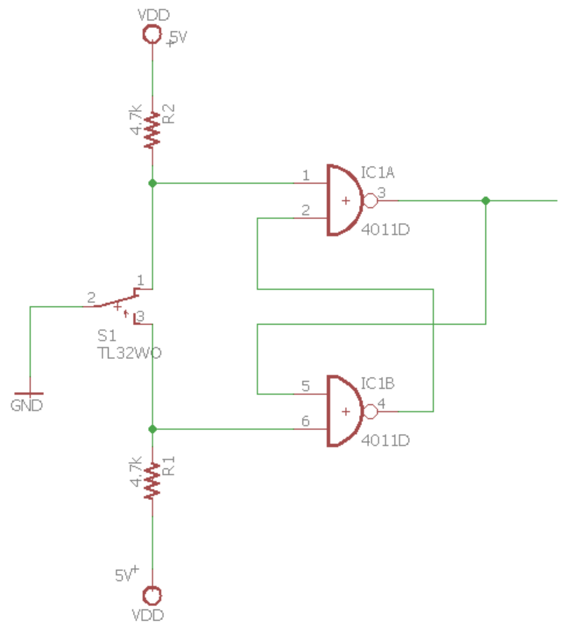


Figure 5: SR Debouncer Schematic

2.4 Wireless Module

The wireless module is responsible for receiving data from the microcontroller and transmitting them wirelessly to a phone, where they will be viewed graphically, or neatly in table.

2.4.1 RFID Transponder

The RF transponder is responsible for sending over the data wirelessly at a rate of 848 kbps using NFC. The range will be small, approximately 4 cm - 12 cm [7]. This will easily be within the range of most NFC/RFID chips. The frequency of the RFID chip will transmit at roughly 13.7MHz for optimum performance from the Texas Instruments RF430CL330H chip [7]. We will be using requires design of an antenna in order to create oscillation and electromagnetic waves that can be picked up by the phone. The process and calculations for the antenna design can be found below.

For the design of the antenna of the RF430CL330H chip we first have to measure the intrinsic capacitance of the chip's output. After verifying that the intrinsic capacitance falls between the stated value range below we can choose the appropriate inductance that will resonate at a frequency of 13.7MHz, given from the datasheet. From these two values we can calculate the resonant frequency from the values of the capacitor and inductor shown in equation (5). The chip operates most efficiently when operated close to 13.7MHz. Afterwards we measure the harmonic frequencies using a network analyzer and calculating the chip's bandwidth from equation (6), we can then calculate the the quality factor given from equation (7). Having a quality factor between 30 and 40 is essential for best performance.

Intrinsic Capacitance [31.5,38.5]pF

Inductance Needed [3.27, 4.28]μH

$$f_{\text{res}} = \frac{1}{(2\pi * \sqrt{LC})} = [12.399, 15.008]MHz \tag{5}$$

$$BandWidth = BW = f_2 - f_1 \tag{6}$$

$$QualityFactor = Q = \frac{f_{\text{res}}}{BW} = [30, 40] \tag{7}$$

Table 8: RV for RFID Transponder

Requirements	**Verification**
The RF430CL330H needs to transmit at a frequency of 13.7MHz	Use a network analyzer in order to capture the frequency of transmission from the RFID chip.
Internal capacitance of RF430CL330H needs to be between [31.5pF, 38.5pF].	Use a digital multimeter to measure intrinsic capacitance of the RFID chip.
Antenna has Q factor Between [30,40]	Measure bandwidth of frequency transmission with network analyzer and verify quality factor Q from equations (5) through (7)
Ensure a maximum power consumption of 7mW	• Use oscillator to get input voltage and current. • Multiply the two DC values to get the dissipated power

2.5 Total Power Consumption

Table 9: Total Power Consumed

Part	V_{in} (V)	I_{in} (μA)	P_{in} (mW)
Pulse Sensor	1.8 and 3.3	1200	6.12
Wireless (IC)	3.3	2000	6.6
Micro-controller	3.6	100000	375
Display	5	40000	200
Total Power	-	-	**570**

2.6 Software

The software handles the displaying of the current times, the polling of the pulse sensor, and finally the transmission of the cumulated information to a phone. The processor will poll its internal real-time clock (RTC) and keep track of the seconds that have passed, since start has been pushed. The pulse sensor will only be active when the user has a finger over it, the microprocessor will poll the heartbeat sensor at specified intervals. Finally the microprocessor will also handle the transfer of the data from temporary storage to the RF430's RAM for transmission.

Table 10: RV for Software

Requirements	**Verification**
Be able to correctly prioritize certain interrupts over others. For example when were servicing a pulse sample interrupt, and the Power Off button is pressed we handle the Power Off interrupt over finishing the Heartbeat interrupt.	• Run the software through various cases of overlapping interrupts, such as a pulse reading while transmitting, or Powering Off while transmitting. • Take note of what interrupt takes precedence and adjust code appropriately.
Prevent race conditions in the code that could freeze up the software.	• Go through functions of the device and see when it locks up. • Step through code to find race conditions. • Properly use locks and non blocking statements to ensure device functions properly.

2.6.1 Timing

The standard mode will have the same basic functionality as a stopwatch. When powered on the device will be in this standard timing mode to begin with. When in this mode the user can press the start button to begin timing. Once started the start button will be treated as the stop button, and the user can press the lap button to record the current time and save that lap. The processor will then move that lap time to temporary storage, and continue timing as normal.

Figure 6 demonstrates the logic associated with the regular timing mode.

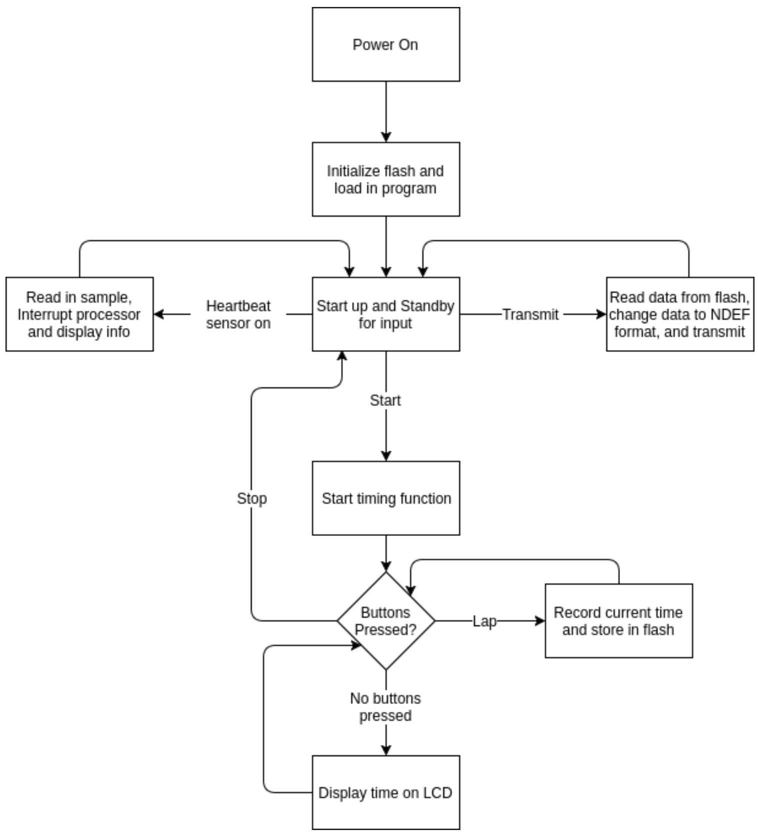


Figure 6: Timing Flow Chart

2.6.2 Heartbeat Sensing

The MAX30100 pulse sensor will allow us to display the pulse of the wearer as they are using it. In order to interface with the pulse sensor directly we will use the I2C protocol. We will have an internal software time interval set to 200-300 milliseconds. Each time an interval has passed the microprocessor will read from the pulse sensor and display the information. An alternative method that we can attempt to do is to receive an interrupt from the MAX30100 every time a sample has been acquired from the user and display it. An important thing to consider would be to make sure that the pulse sensor cannot interrupt the processor while it is doing a transmission to the phone. Figure 7 shows the steps taken by the microprocessor when the transmission button is pressed.

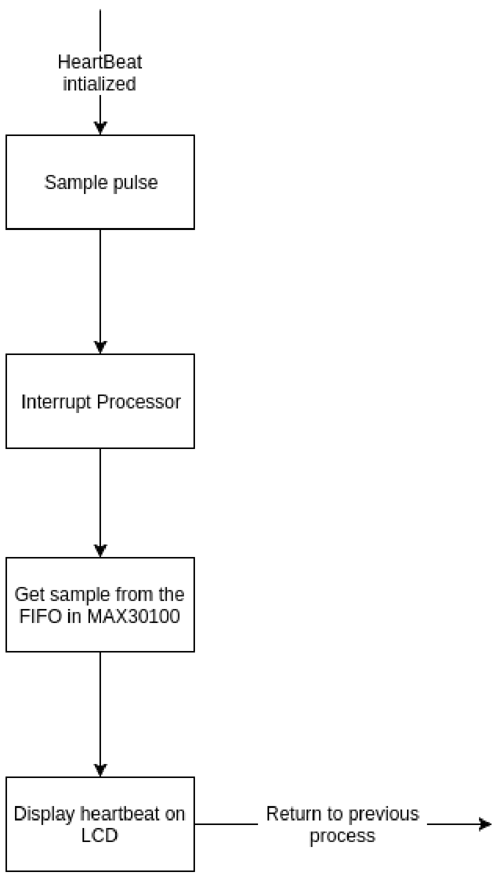


Figure 7: Heartbeat Flow Chart

2.6.3 Transmission

Wireless transmission will be handled by the RF430CL330H transponder. The way the software will work for transmissions, is by first fetching the data from flash storage and feeding it into the RF430's on-chip NDEF RAM. The Size of the NDEF RAM is 3kB so only 3kB can be sent at a time [7]. Once the processor writes data out to the chip, we wait for a phone to read the contents of the chip, then follow by sending the next 3kB. The way we can know if the phone has finished reading the data is by receiving an interrupt from the RF430 once the read has been finished, and continuing with the code.

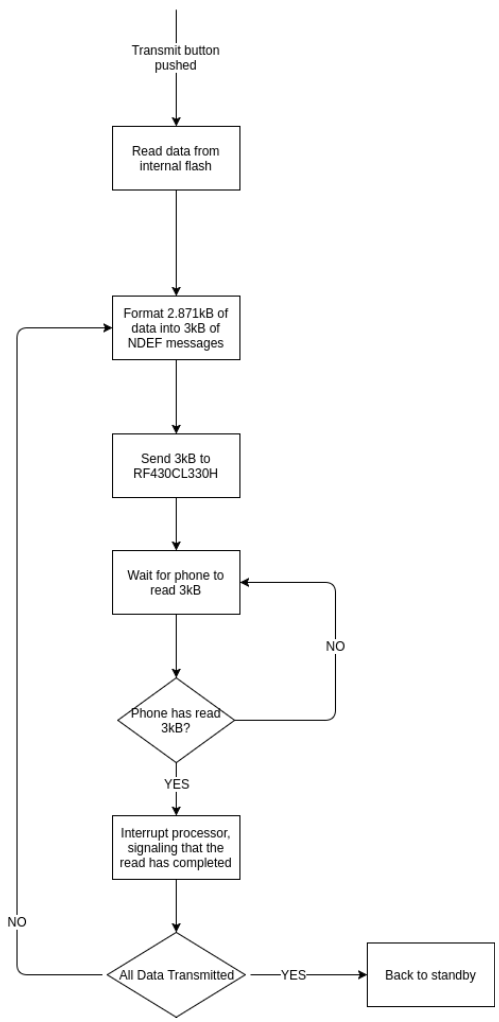


Figure 8: Transmission Sensor Flow Chart

2.7 Tolerance Analysis

Wireless transmission of the stored data must happen in 0.2 sec - 0.4 sec ideally. This time however, might not always happen. Since the RF430CL330H only has 3kB of RAM available for overwriting and the STM32F030K6T6 microprocessor has 32kB of flash storage, assuming that transmission rate is maxed at 424 kb/s, and every 255 Bytes of data in the flash must be converted to appropriate NDEF message formatting which turns the 255 Bytes of data into a 261 Byte message, then when the flash is close to full (>= 30kB of data) the total amount of bytes to transmit would be:

$$\frac{30kBytes}{255Bytes} * 261Bytes = 30.706kBytes \tag{8}$$

Since the transmission rate at max is 424kb/sec = 53kB/sec and since the NDEF RAM is only 3kB we can only send 11 entire messages at a time which would be 2871 bytes or 2.871 kB. That transmission would take approximately take 0.0542 sec. Now sending over the entire 30.706 kB of data would take approximately:

$$t_{\text{total}} = 0.0542 * 10.695 = 0.58s \tag{9}$$

This is not accounting for overhead such as converting each 255 byte chunk of the data to a correctly formatted 261 byte message, or the cpu waiting to write the new data to the RF430 each time a new 2.871 kB transmission needs to occur, as well as the reads from flash.

3 Cost and Parts List

Part Number	MFT	Description	Price	Qty	Total
max1896	Maxim Integrated	Boost Converter With Adjustable Volta	2.99	1	2.99
max1920	Maxim Integrated	Buck Converter With Adjustable Voltag	2.99	1	2.99
max1921	Maxim Integrated	Buck Converter With fixed Voltage	2.99	1	2.99
max1555	Maxim Integrated	USB Adapter 1-Cell Battery Charger	2.99	1	2.99
10118192-0001LF	Amphenol FCI	CONN USB MICRO B RECPT SMT R/A	0.46	1	0.46
2011	Adafruit	Lithium Ion Battery - 3.7V 2000mAh	12.5	1	12.5
587-1241-1-ND	Taiyo Yuden	1uF Ceramic Capacitor X7R	0.1	3	0.3
587-1227-1-ND	Taiyo Yuden	0.1uF Ceramic Capacitor X7R	0.1	3	0.3
587-1300-1-ND	Taiyo Yuden	10uF 10 V ceramic Capacitor X7R	0.1	2	0.2
587-1785-6-ND	Taiyo Yuden	4.7 uF Capacitor	0.13	2	0.26
587-1253-6-ND	Taiyo Yuden	2.2 uF Capacitor	0.13	2	0.26
587-1180-6-ND	Taiyo Yuden	10000pF 16 V Capacitor	0.1	2	0.2
587-1230-6-ND	Taiyo Yuden	0.47uF 6.3V Capacitor	0.1	1	0.1
399-3717-6-ND	KEMET	22uF 16V Tantalum Capacitor	0.63	1	0.63
399-11080-1-ND	KEMET	4.7uF 25V 530 mOhm ESR Tantalum	1.78	1	1.78
MBRX120LF-TPMS	Microcommercial Co	1A 20V rectifying Diode	0.45	1	0.45
MX3SWT-A1-0000-	Cree Inc	LED	1.45	1	1.45
311-330JRCT-ND	yageo	330 Ohm Resistor	0.1	2	0.2
311-12KJRCT-ND	yageo	12k Ohms Resistor	0.1	2	0.2
311-36.0KLRCT-ND	yageo	36K Ohm Resistor	0.1	2	0.2
311-100KGRCT-ND	yageo	100k Ohm Resistor	0.1	2	0.2
311-4.75KLDKR-ND	yageo	4.7k Ohm Resistor	0.1	3	0.3
311-68KJRCT-ND	yageo	68k Ohm Resistor	0.1	2	0.2
308-1483-1-ND	SUMIDA	10uH 1.1 A Inductor	0.76	1	0.76
308-2297-1-ND	SUMIDA	4.7uH 1.1 A Inductor	1.06	1	1.06
	SUMIDA	10uH 900mA A Inductor	1.06	1	1.06
STM32F030K6T6	STMicroelectronics	IC MCU 32BIT 32KB FLASH 32LQFP	1.48	1	1.48
HD44780U	Adafruit	Dot matrix liquid crystal display	13.95	1	13.95
MAX30100EFD	Maxim Integrated	IC SENSOR OXIMETER/HEARTRATE	7.03	1	7.03
buttons	ece shop	push buttons switch	0	4	0
SN74AS804BDW	Texas Instruments	Logic Gates Hex 2-Input NAND Driver	8.18	2	16.36
RF430CL330H	Texas Instruments	IC NFC DYNAMIC TAG TARG 14-TSSOP	1.62	1	1.62
LQW2UAS3R9J00L	Murata Electronics	FIXED IND 3.9UH 260MA 3.6 OHM	0.25	1	0.25
TOTAL					74.14

4 Schedule

Table 11: Schedule Table

Week	Patrick	Cristian	Santiago
2/20/17	Design Document	Antenna calculation, Design Document	Design Document
2/27/17	Start building power module circuit bench test	Design and bench test debouncer circuit	Start coding microprocessor
3/6/17	Finish power testing	Finish with the modes on microprocessor	Finish with the modes on microprocessor
3/13/17	Start layout of PCB	Communicate microprocessor with heartbeat sensor	Commnicate microprocessor to display
3/20/17	Finish communication with heartbeat sensor	Finish communication with heartbeat sensor	Finish communication with display
3/27/17	Communicate with RF430CL330H	Communicate with RF430CL330H	Communicate with RF430CL330H
4/03/17	Optimize PCB	Optimize PCB	Code simple app to view data graphically
4/10/17	Finish soldering PCB	Finish soldering PCB	Finish app and verify data transfer
4/17/17	Have a working prototype and prepare for presentation	Have a working prototype and prepare for presentation	Have a working prototype and prepare for presentation
4/24/17	Present project and work on final paper	Present project and work on final paper	Present project and work on final paper
5/01/17	Submit Final Paper and Turn in Notebook	Submit Final Paper and Turn in Notebook	Submit Final Paper and Turn in Notebook

5 Ethics and Safety

Since our project is a pitch project and not our original idea, we will discuss what we have built and what the mechanical engineering team will build. The entire electrical hardware and software will all be done by the electrical and computer engineering team. The mechanical engineering team is responsible for making the housing where the PCB, battery, and screen will fit in. They will be making the housing rigid and waterproof in order to not cause any harm to the user and following the IEEE code of ethics health and safety regulations [3]. The idea was proposed by the track coach from Rhode Island.

The major safety concern in our project is the li-ion polymer battery. Li-ion polymer batteries are dangerous when handled incorrectly because they are extremely flammable and react chemically with water. Proper precautions need to take place (don' want to pull a Samsung) in order to mitigate any hazardous situations especially since our device will be used by athletes in both outdoor and indoor environments.

Since the battery is a safety vulnerability, the housing that will be designed to hold the circuit board needs to be robust and rigid in order to protect the PCB and battery. This will be taken care of by the mechanical engineering students who will design the housing for the device using cadence. Not only will the housing be rigid, but it will also have to be waterproof as to prevent any sort of humidity reaching the circuit and battery. Having water leak into the housing can cause the board to short circuit and possibly cause harm to the user. The water can also adversely affect the battery and cause a short causing it to heat up and potentially blow up.

In order to avoid the battery from causing any harm, to a user or device itself, the following precautions should be taken as to satisfy the IEEE code of ethics [3]:

- The battery and device should not be exposed to fire, water, or any sort of physical shock. During charging, the polarity of the battery should not be reversed.
- Do not charge battery for over 24 hours. The charging current should not surpass 2000mA at 4.2V.
- When charging, the temperature of the battery should be within the range of [0, 45]celsius.
- The discharge current should not reach more than 2000mA with end voltage of 3V. When discharging, the temperature of the battery should be within [-20, 60]celsius
- The cutoff current for charging and discharging battery is less than 20mA.
- Battery deteriorates over time when the batter is not being used. If battery does not last for long periods of time it may indicate that the battery needs to be changed.

References

[1] " Maxim Integrated", 2005. Available: https://datasheets.maximintegrated.com/en/ds/MAX1920-MAX1921.pdf . [Accessed: Feb. 24, 2017].

[2] Maxim Integrated "MAX30100 DataSheet", 2014. [Online]. Available: https://datasheets.maximintegrated.com/en/ds/MAX30100.pdf. [Accessed: February 2017].

[3] Ieee.org,"IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 8- Feb- 2017].

[4] "Li-Polymer Battery Technology Specification", 2014. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/LiIon2000mAh37V.pdf. [Accessed: February 2017].

[5] Spark Fun Electronics[Online] https://www.sparkfun.com/datasheets/Components/MAX1551-MAX1555-1.pdf. [Accessed: Feb 2017]

[6] ST Electronics "STM32F030x4/x6/x8/xC DataSheet", 2017. [Online]. Available: http://www.st.com/content/ccc/resource/technical/document/datasheet/a4/5d/0b/0e/87/c4/4d/71/DM00088500.pdf/files/DM00088500.pdf/jcr:content/translations/en.DM00088500.pdf. [Accessed: February 2017].

[7] Texas Instruments "RF30CL330H DataSheet", 2014. [Online]. Available: http://www.ti.com/lit/gpn/rf430cl330h. [Accessed: February 2017].

[8] Hitachi "HD447880 DataSheet", 1999. [Online]. Available: https://www.sparkfun.com/datasheets/LCD/HD44780.pdf. [Accessed: February 2017]