(**N**on-**I**nvasive **M**odule for **B**iomonitoring **L**ive)

Final Design Review

Review Committee:

Dr. Sonali Das

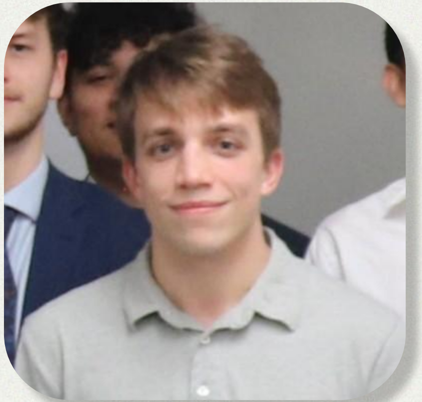
Dr. Xun Gong

Mark Maddox

Faculty Advisor:

Dr. Sreeram Sundaresh

Group Members



Ethan Denner
Electrical Engineering

Kai Ford
Electrical Engineering

Tyler Takimoto
Computer Engineering

Benjamin Will
Electrical Engineering

Project Motivation

- Simple biomonitoring can save or improve lives
- Create a low cost product that measures important vitals and transmits data through radio frequencies
- Other similar products in the market are expensive and uncommon

Project Goals & Objectives

Goals

- Offer safe, accurate, and noninvasive biomonitoring.
- Make the device versatile.
- Highly power efficient.
- Store data on an external base station.

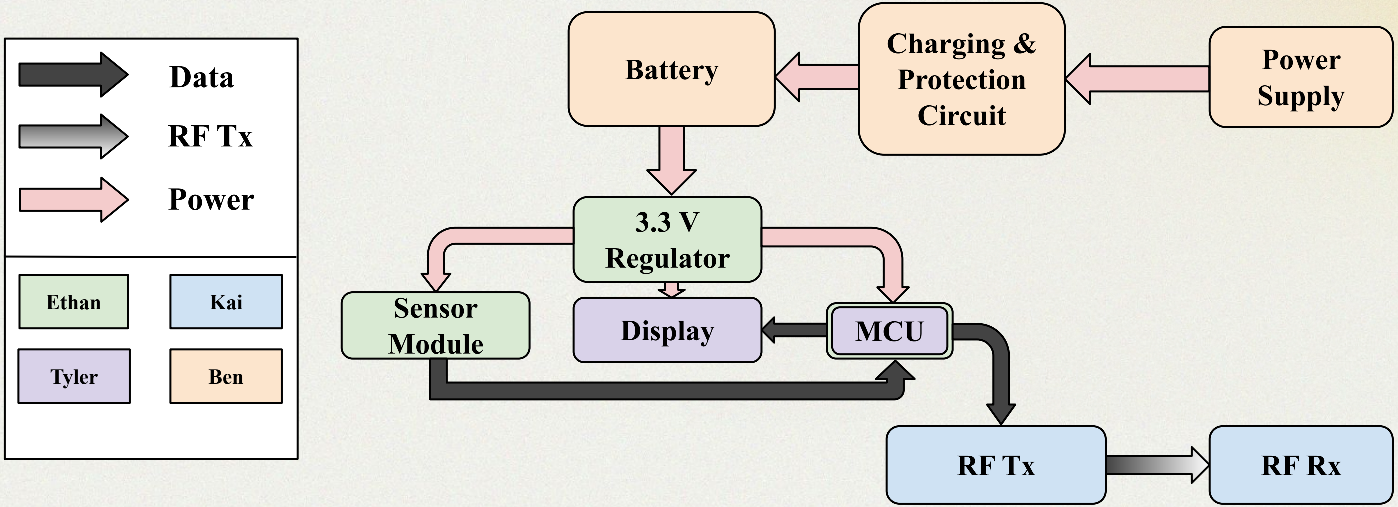
Objectives

- Isolate circuit elements from user.
- Accurately measure blood oxygenation and heart rate.
- Visually show data.
- Operate for 3+ hours.
- Communicate via RF.

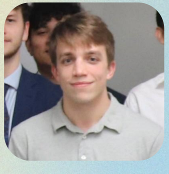
Engineering Requirements

Engineering Requirements	**Justification**
Pulse rate should be obtained *within 10 seconds* of contact.	There could be noise as we read data, so this time frame should give us an accurate measurement with fast responses.
Screen-on time should be ≥ *3 hours*.	Users should be able to read vital information for a long time without frequent charging.
Pulse readings should be within *10 BPM* of control reading.	Ensure accuracy of biometric readings.
We must *transmit between 902-928MHz*.	Compliance with FCC regulations (Part 15.247) on RF communications.
Wireless transmission should be successfully received from *at least 10 meters away*.	Being able to save data via wireless communication allows for further analysis of health patterns.

Hardware Block Diagram



Introduction to Pulse Oximetry



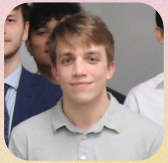
Heart Rate

- Hemoglobin in the blood absorbs light
- AC pulsatile signal vs DC signal
- Digital signal processing techniques used to identify the fundamental frequency of the AC signal

Blood Oxygen Saturation

- Oxygenated Hemoglobin absorbs more infrared light and Deoxygenated Hemoglobin absorbs more red light
- Modulation Ratio / Perfusion Index
- R-value (Ratios of Ratios)
- Empirical Calibration

How the Pulse Oximeter Works



MAX30101

- Integrates the low noise electronics, ambient light rejection, photodetector, infrared, red, and green LEDs in one IC.
- Pairs with MAX32664 which comes with embedded firmware and algorithms to take data from the MAX30101 and turn them into measurements a MCU can read.
- Both communicate using I^2C.

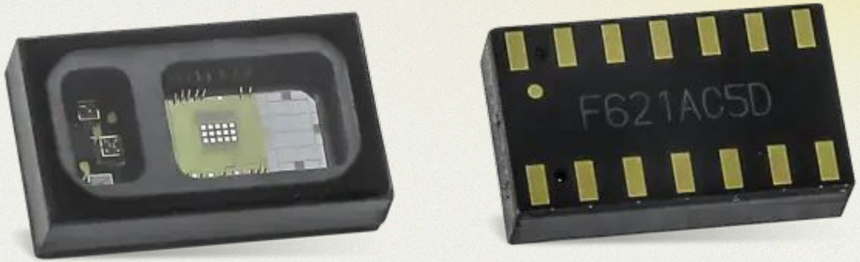
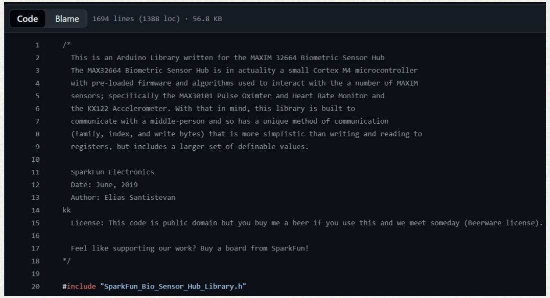


Image Source: Mouser Electronics

Pulse Oximeter Development Board

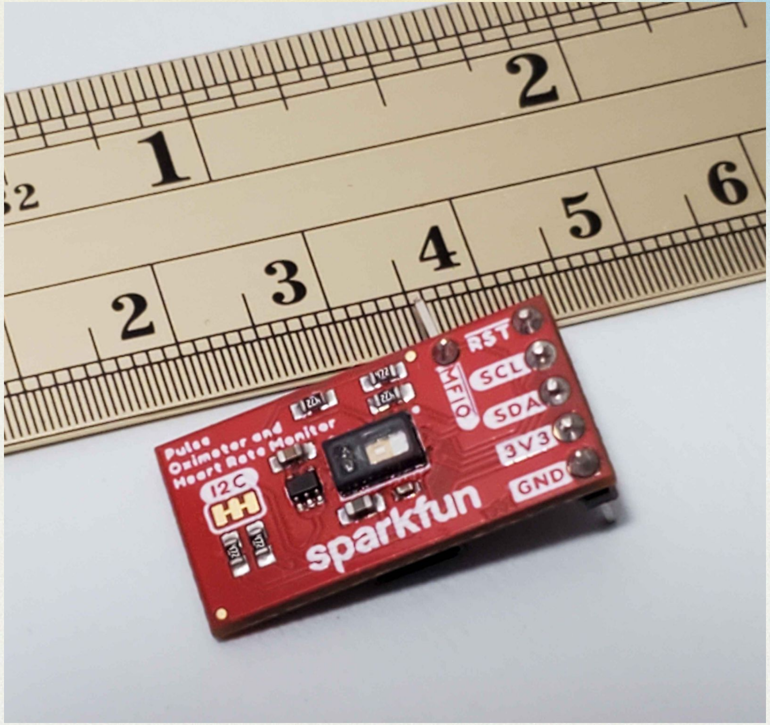
SparkFun Pulse Oximeter and Heart Rate Sensor - MAX30101 & MAX32664 (Qwiic)

- MAX30101 and MAX32664 would have been technically challenging to solder to a board with the equipment we have available.
- SparkFun provides ample documentation for the board.
- SparkFun also provides a public domain Arduino software to get the sensor running straight out of the box and provide a framework for us to program our MSP430.

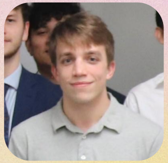


Code Blame 1694 lines (1388 loc) · 56.8 KB

```
/*
  This is an Arduino Library written for the MAXIM 32664 Biometric Sensor Hub
  The MAX32664 Biometric Sensor Hub is in actuality a small Cortex M4 microcontroller
  with pre-loaded firmware and algorithms used to interact with the a number of MAXIM
  sensors; specifically the MAX30101 Pulse Oximter and Heart Rate Monitor and
  the KX122 Accelerometer. With that in mind, this library is built to
  communicate with a middle-person and so has a unique method of communication
  (family, index, and write bytes) that is more simplistic than writing and reading to
  registers, but includes a larger set of definable values.

  SparkFun Electronics
  Date: June, 2019
  Author: Elias Santistevan
kk
  License: This code is public domain but you buy me a beer if you use this and we meet someday (Beerware license).

  Feel like supporting our work? Buy a board from SparkFun!
*/

#include "SparkFun_Bio_Sensor_Hub_Library.h"
```



Pulse Oximetry IC Part Selection



	Availability	LEDs	Package	Price for Dev Board
MAX30101	Excellent	Infrared, Red, Green	OLGA	$48.95
MAXM86161	Less	Infrared, Red, Green	OLGA	$234.18
MAX86916	Less	Infrared, Red, Green, Blue	OLGA	$48.00

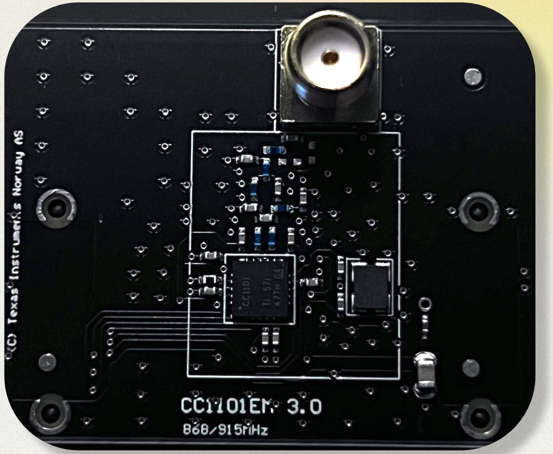
RF IC Part Selection

	Accessibility	Current Draw	Communication	Price
Ti CC1101	Excellent	Low	SPI	$4.87
HopeRF RFM69CW	Poor	Moderate	SPI	$9.95 (Breakout)
Linx HUM-900-Pro	Poor	Moderate	UART	$24.89 (Breakout)

RF Module

PCB leverages the Ti CC1101

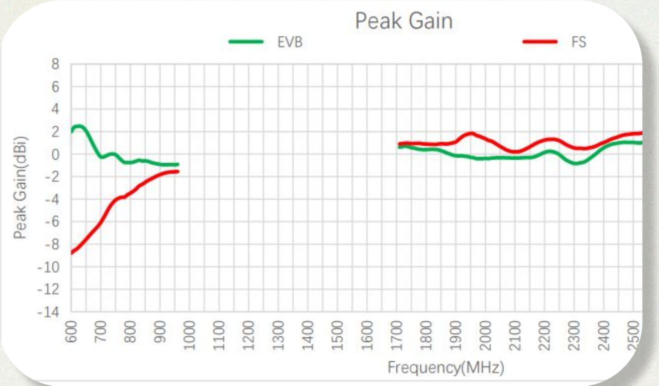
- The module itself is driven by 3.3V
- The RF module matches the differential energy ports of our IC to a 50Ω SMA connector using a balun network
- The drilling of many vias near the balun network reduce the parasitic inductance brought on at RF frequencies, as well as mitigating fringing fields
- Data is communicated to the IC over SPI, which will then leverage FHSS at 915MHz to communicate that data over RF
- For verification of reception, another transceiver will be placed nearby and communicate the demodulated results over SPI to an MCU development module.



Antenna

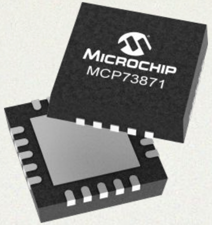
915MHz Monopole Whip

- We will be utilizing the Quectel YECT003AA, which is a monopole whip antenna that provides adequate gain at our center frequency of 915MHz



Battery Charging IC Selection

	Manufacturer	Control	Input Voltage	Max Charging Current	Price
MCP73871	Microchip	Linear	3.75-6V	1A	$2.41
TP4056	EVVO	Linear	4-8V	1A	$0.21
BQ25616	TI	Buck	4-13.5V	3A	$2.52



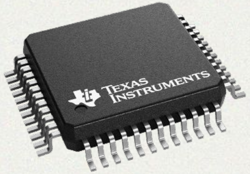
Battery Protection IC Selection

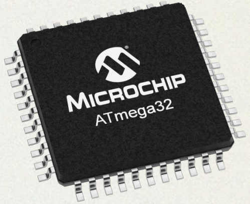
	Manufacturer	Overcharge & Overdischarge	Charge Overcurrent	Price
DW01	EVVO	Yes	Yes	$0.10
BQ2980	TI	Yes	Yes	$0.56
UCC3952	TI	Yes	No	$1.49

5V Charger IC Selection

	Manufacturer	Input Voltage	Output Voltage	Max Output Current	Price
LM2576	TI	4-40V	1.23-37V	3A	$1.79
TPS54202	TI	4.5-28V	0.596-28V	2A	$1.17

MCU Selection





	Power	Max Clock Speeds	Low Power Mode	Architecture	Price
MSP430FR2476	12mW	16MHz	Yes	16-bit RISC	$2.71
ATMEGA32	16mW	16MHz	Yes	8-bit AVR	$7.56
ESP8266	264mW	160MHz	Yes	32-bit Tensilica	$7.99

Display Selection

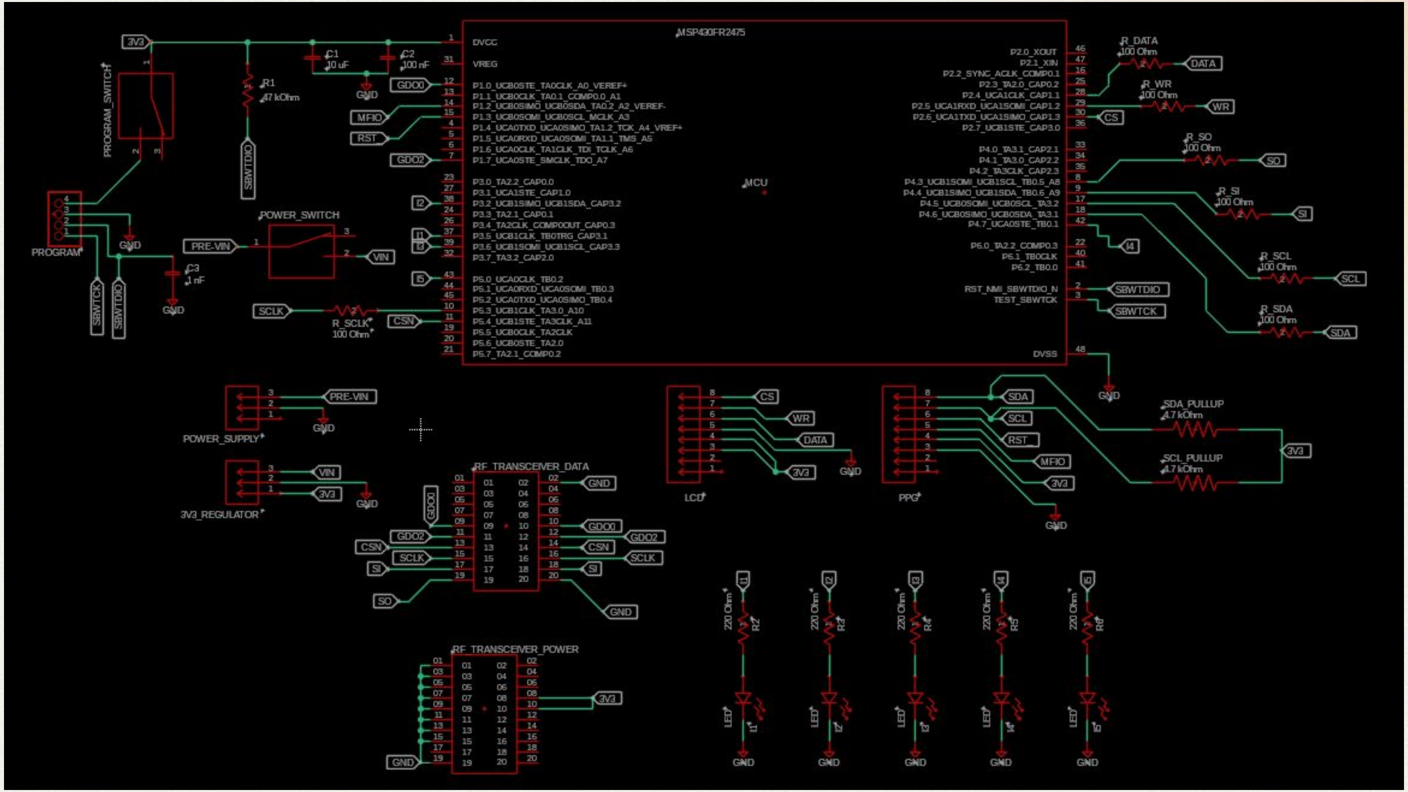
	Power	Resolution	Programmability	Lifespan	Price
HT1621 LCD	1mW	Segmented	Simple	Better	$2.49
NHD-0.95-9664G OLED	36mW	96 x 64 pixels	Complex	Short	$7.56

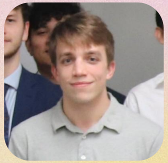
Hardware Design - Power Budget

- Battery charges off a 5V/1A supply
- 12V brick + 5V buck

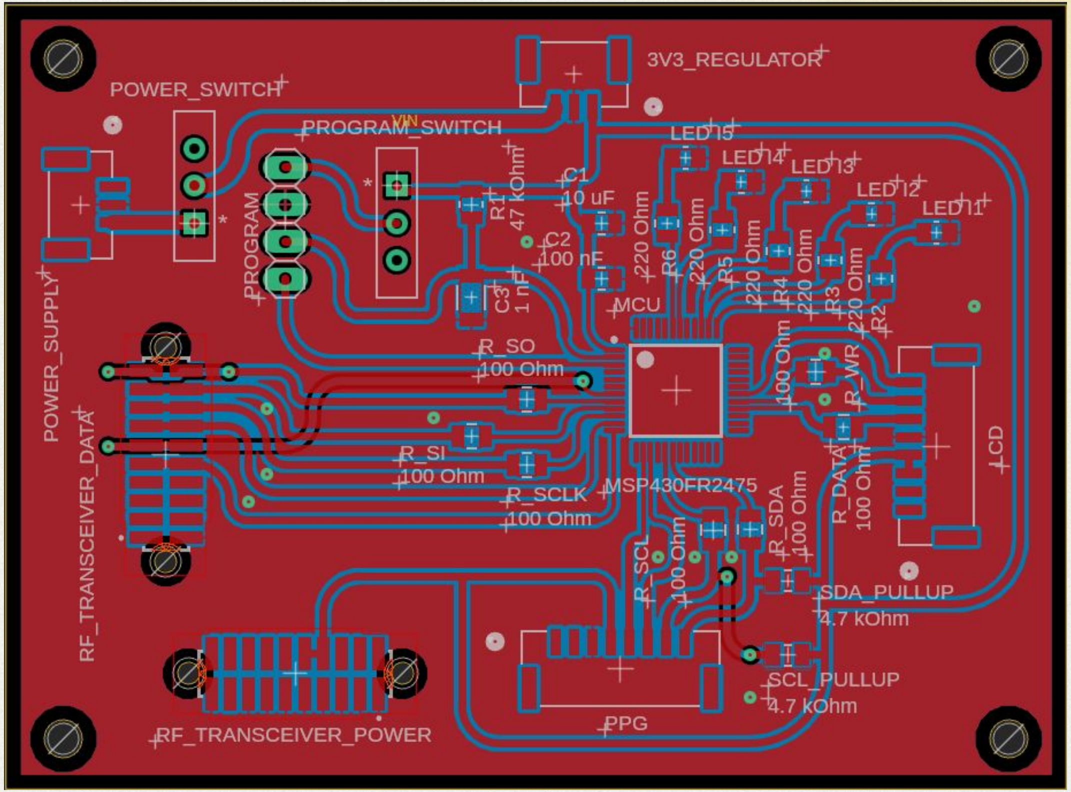
Component	Voltage	Current
MSP430	3.3V	3.75mA
PPG Sensor	3.3V	51.1mA
LCD Screen	3.3V	0.3mA
Transceiver	3.3V	34.2mA
Total		89.35mA

Main Circuit

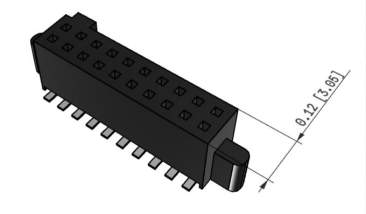




Main PCB

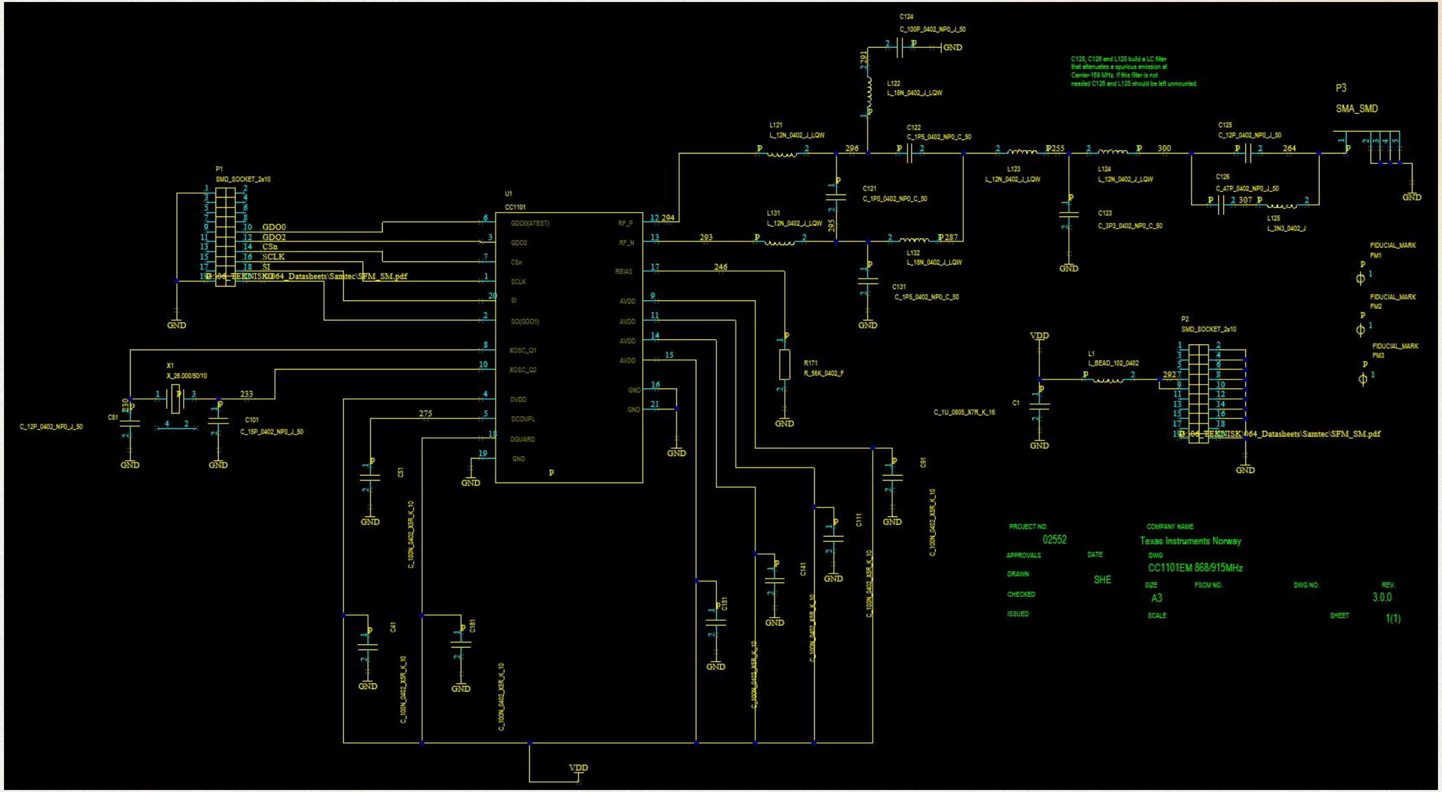


JST GH Connector
Image Source: JST

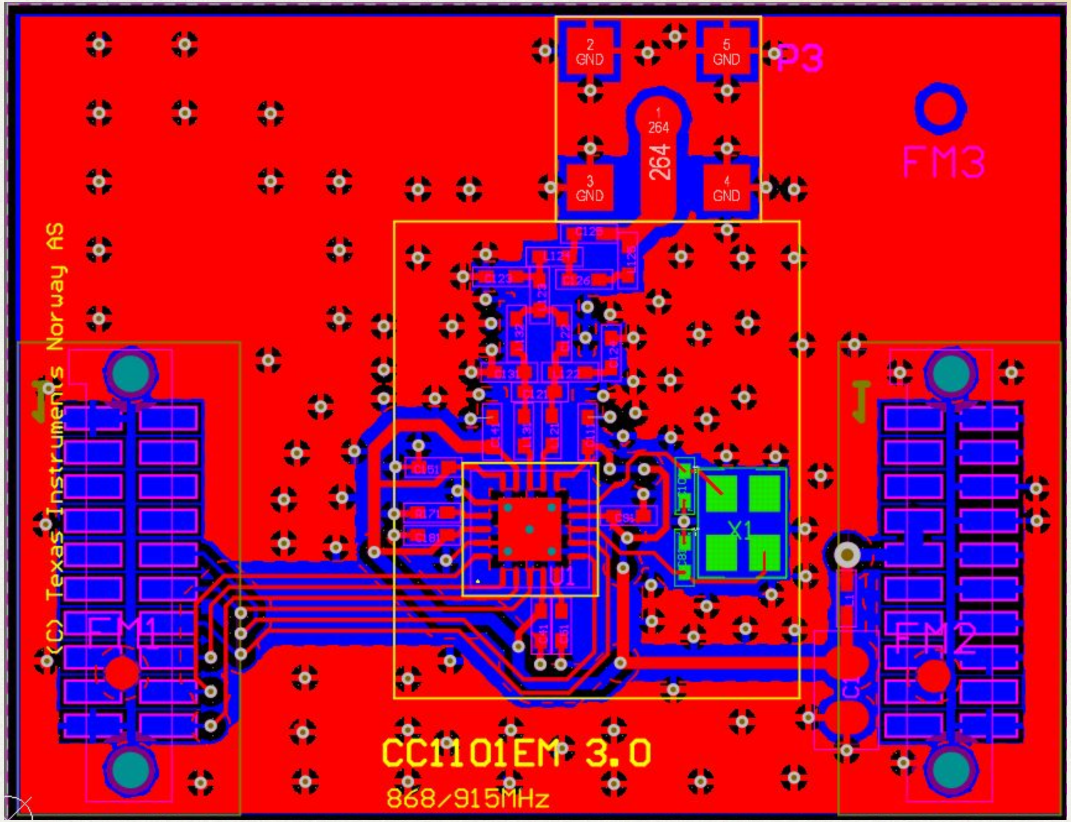


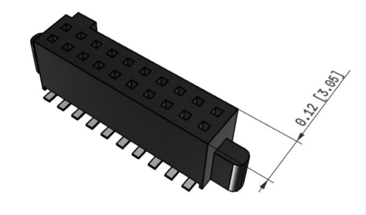
SFM Socket
Image Source: Samtec

RF Module Circuit



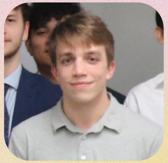
RF Module PCB

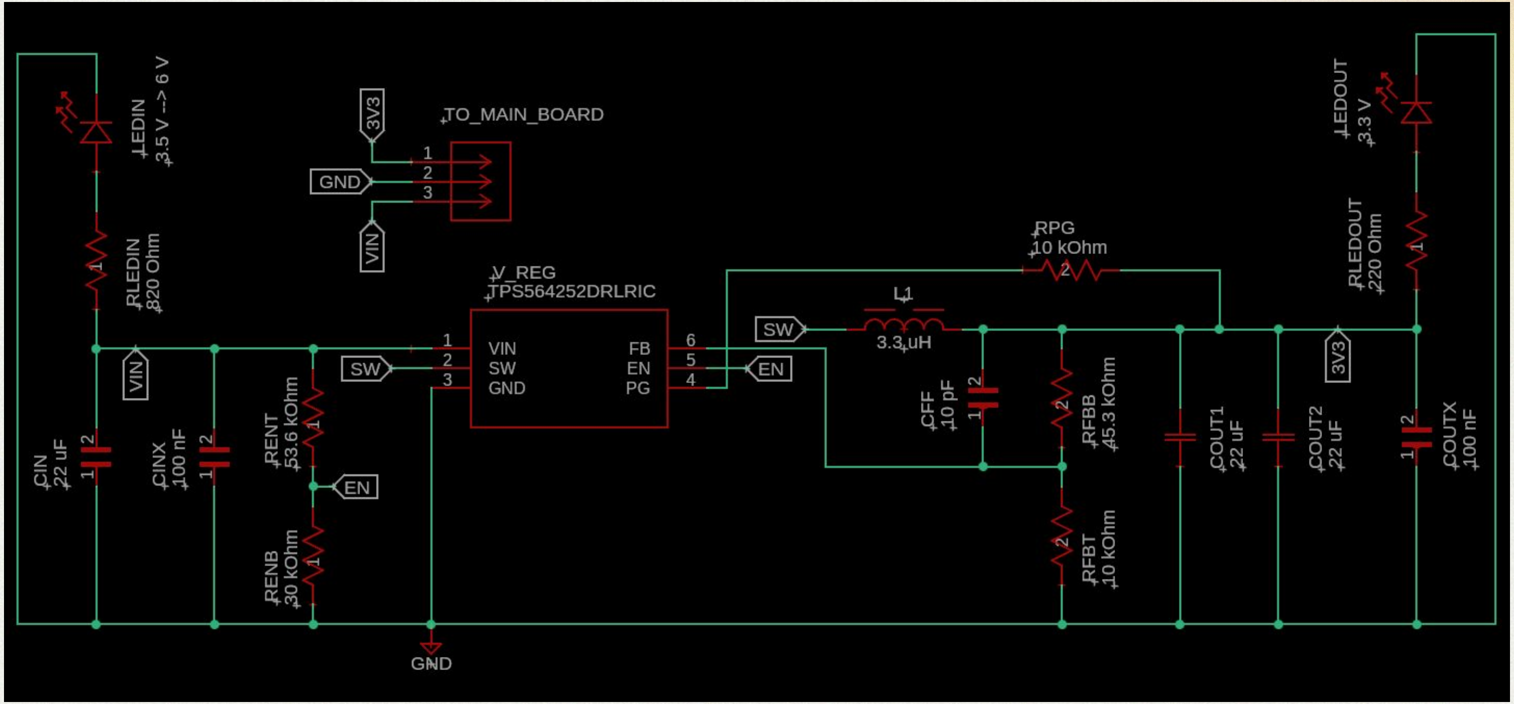




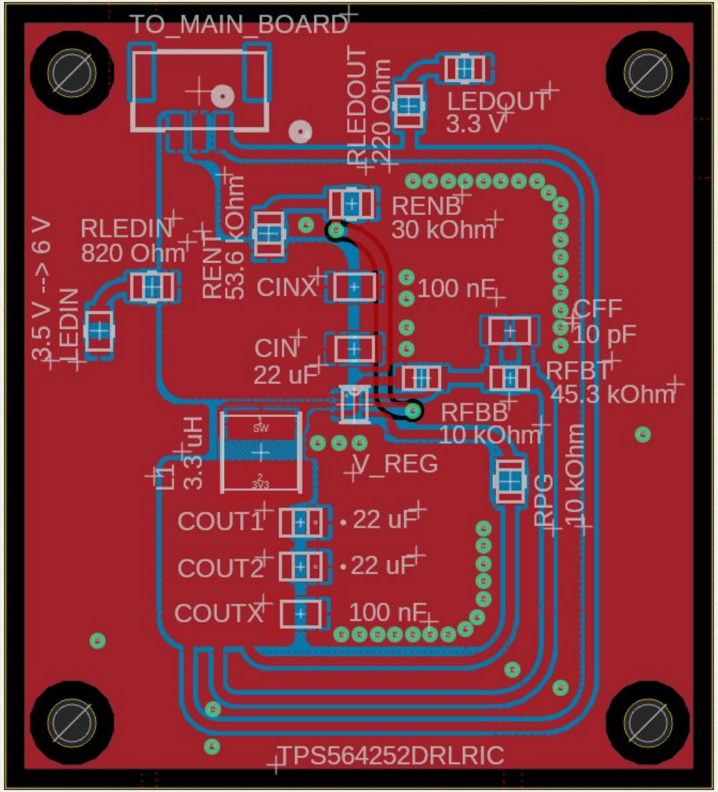
SFM Socket
Image Source: [Samtec]

3.3 Volt Regulator Circuit

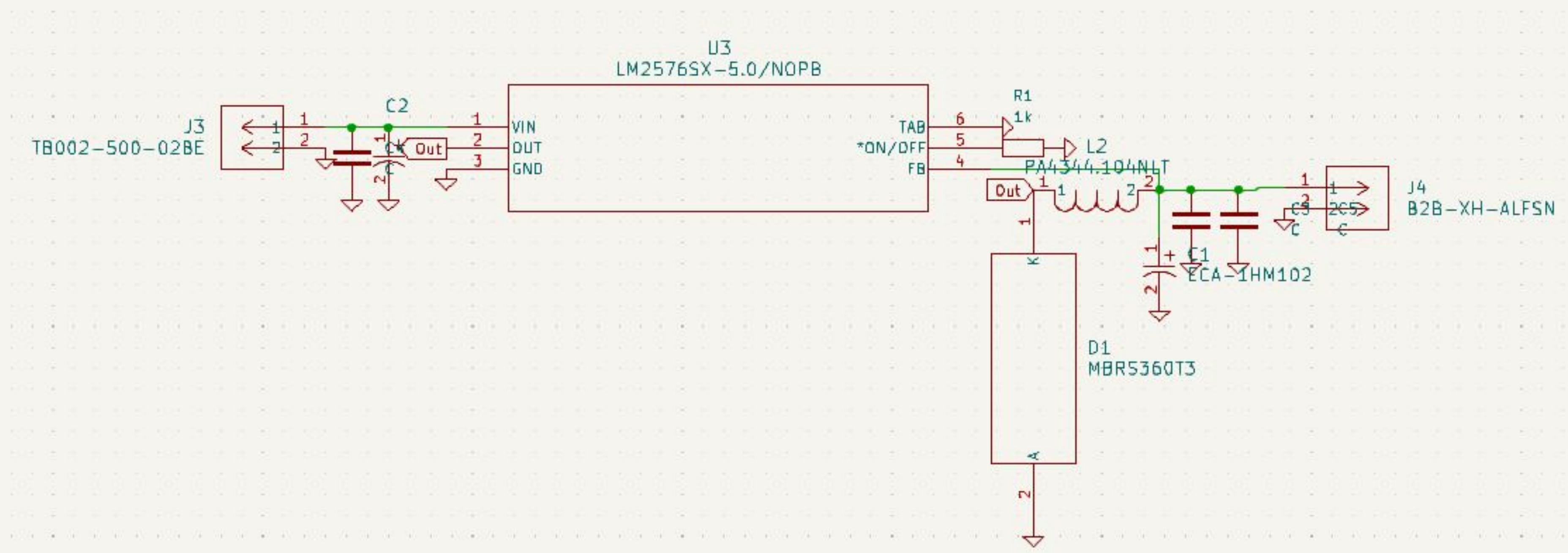




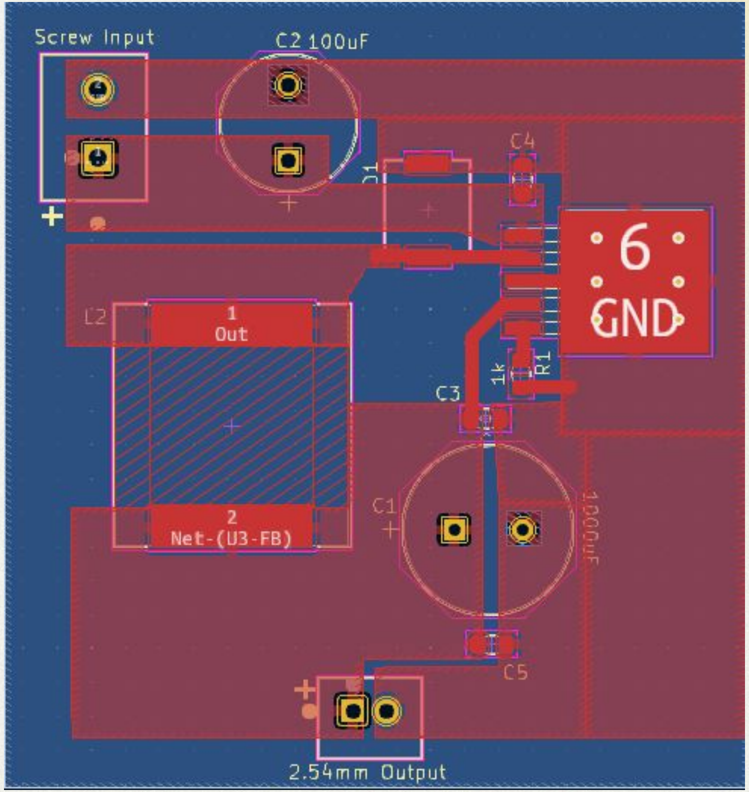
3.3 Volt Regulator PCB



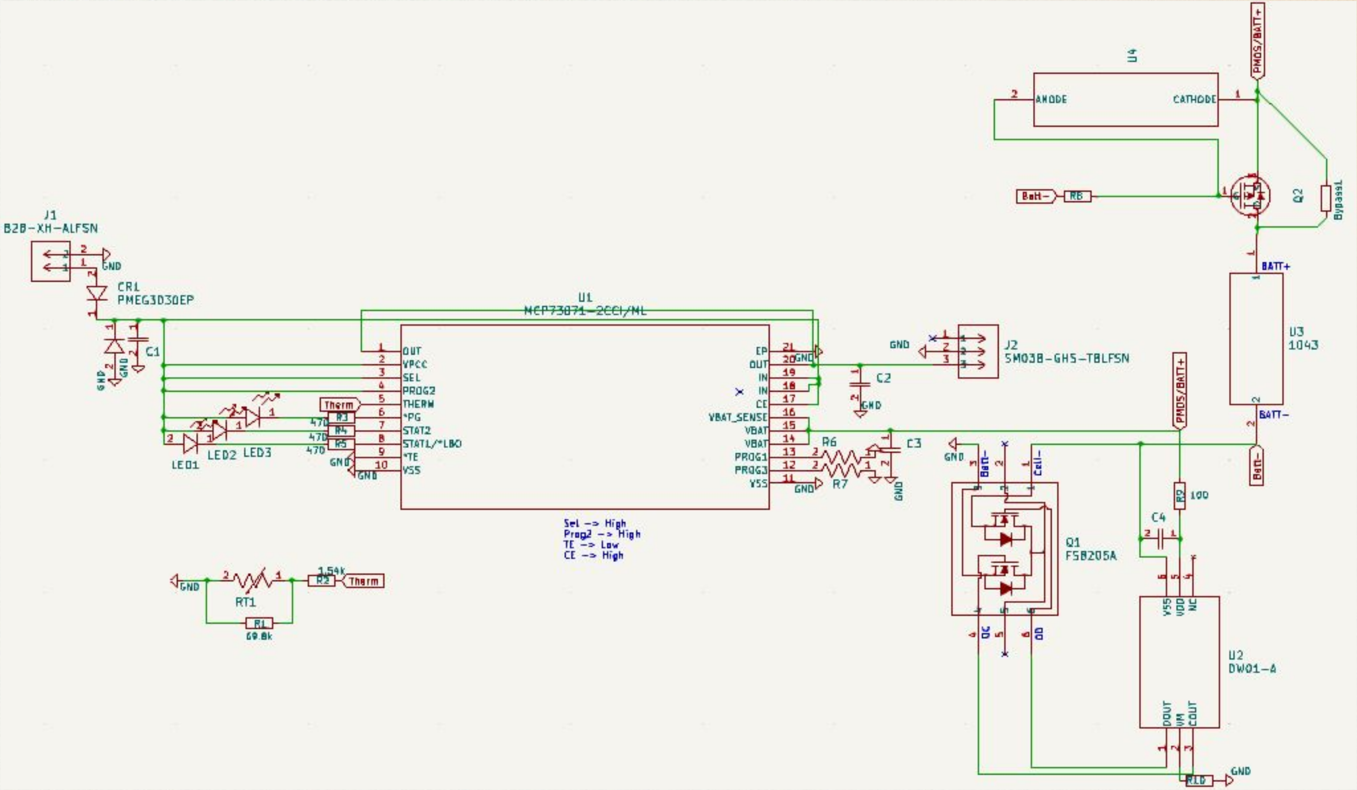
5V Charger Schematic



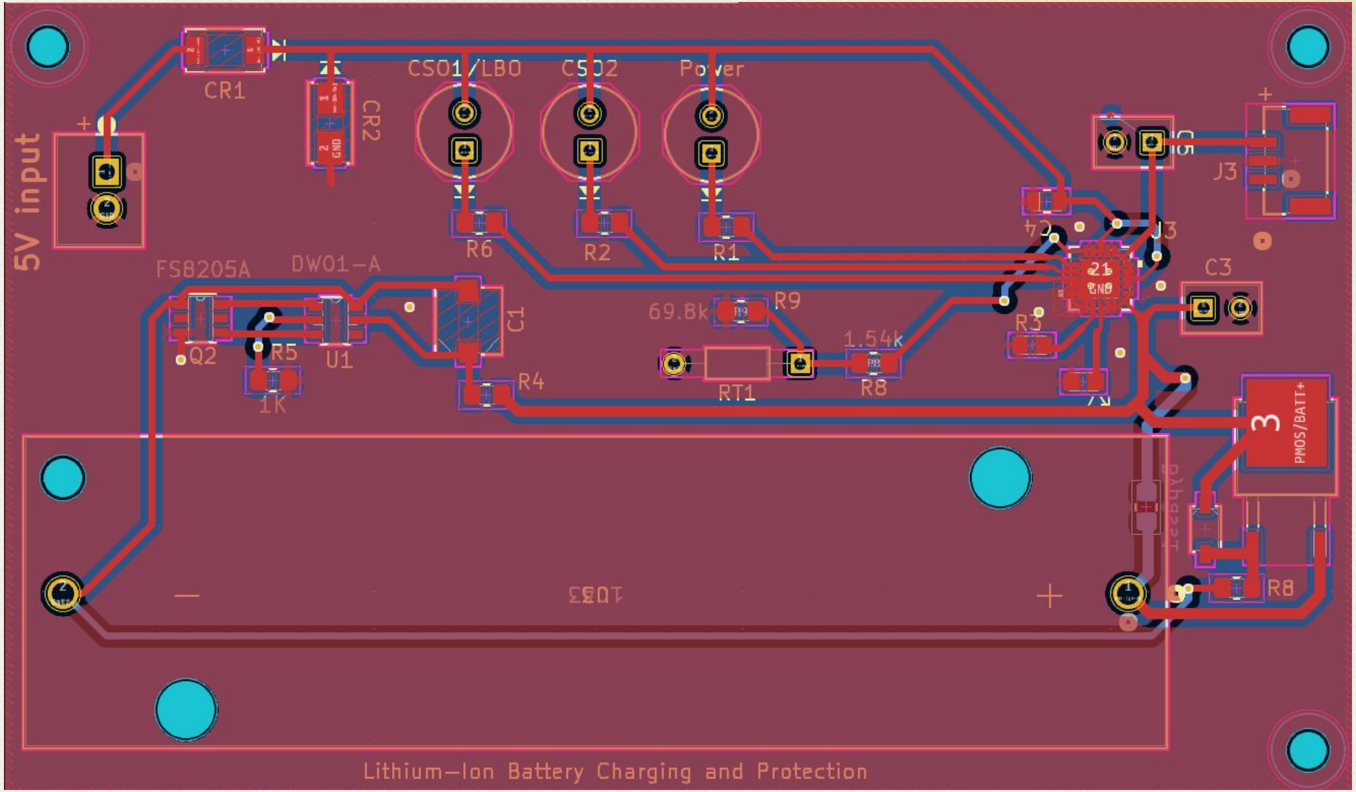
5V Charger PCB



Battery Schematic



Battery PCB



CR1
CR2
CSO1/LBO
CSO2
Power
5V input
J3
R6
R2
R1
C4
U3
C3
FS8205A
DW01-A
C1
69.8k
R9
1.54k
R3
Q2
R5
U1
R4
RT1
R8
1K
PMOS/BATT+
Lithium-Ion Battery Charging and Protection

Software Development

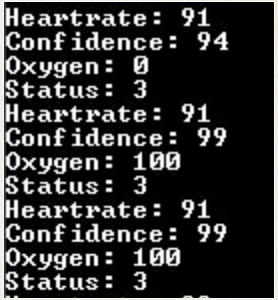
- Language: **C++**
- Dev Environment: **VSCode**
- Implementation: **TI CCS**
- Debugging: **Tera Term**
- Publicly available on GitHub

Tera Team

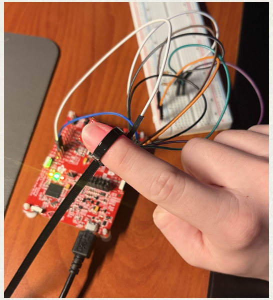
TI Code Composer Studio

Sensor Library

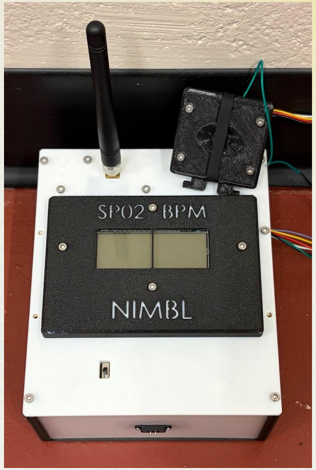
- I2C Communication
- Reads & writes data
- Configures the sensor
- Enables the sensor to read our vitals



Heartrate: 91
Confidence: 94
Oxygen: 0
Status: 3
Heartrate: 91
Confidence: 99
Oxygen: 100
Status: 3
Heartrate: 91
Confidence: 99
Oxygen: 100
Status: 3



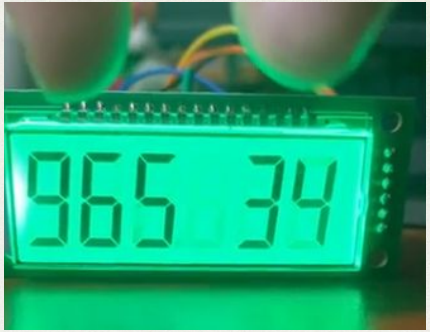
Early Tests



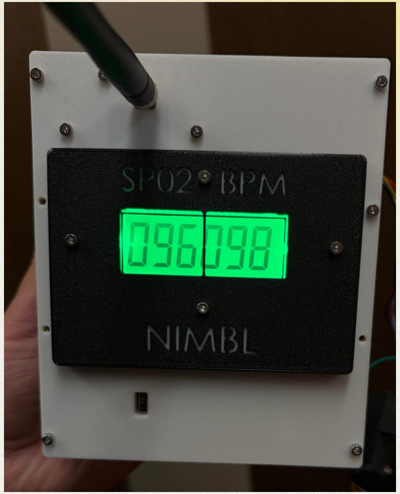
Top-right part is the new design

LCD Library

- Specialized communication protocol
- Similar to SPI, but only 3 wires
- Treat the display as two, 3-digit partitions



Testing partitions



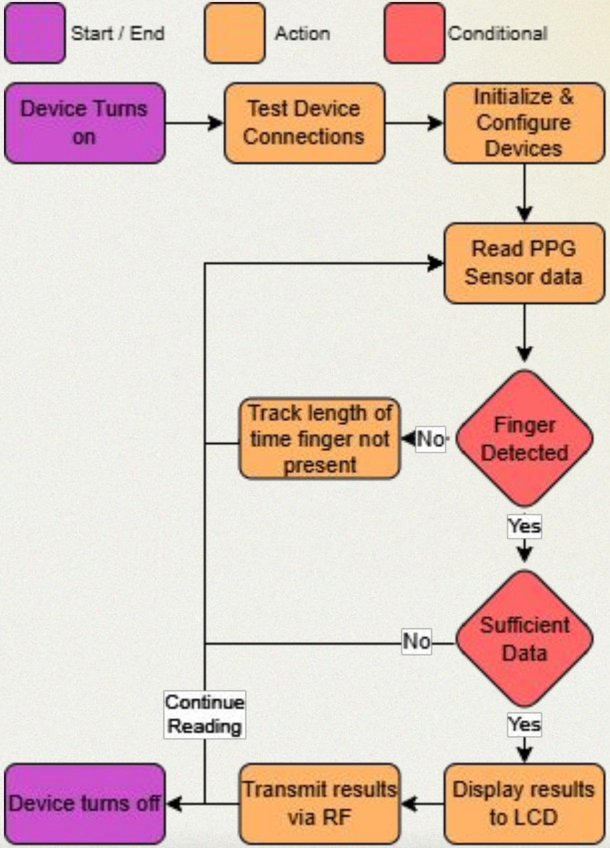
Finalized design

RF Library

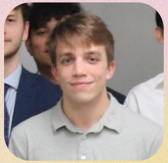
- SPI Communication
- Configure via SmartRF
- Store data onto transceiver
- Send command to transmit
- Receiver polls once given the receive command

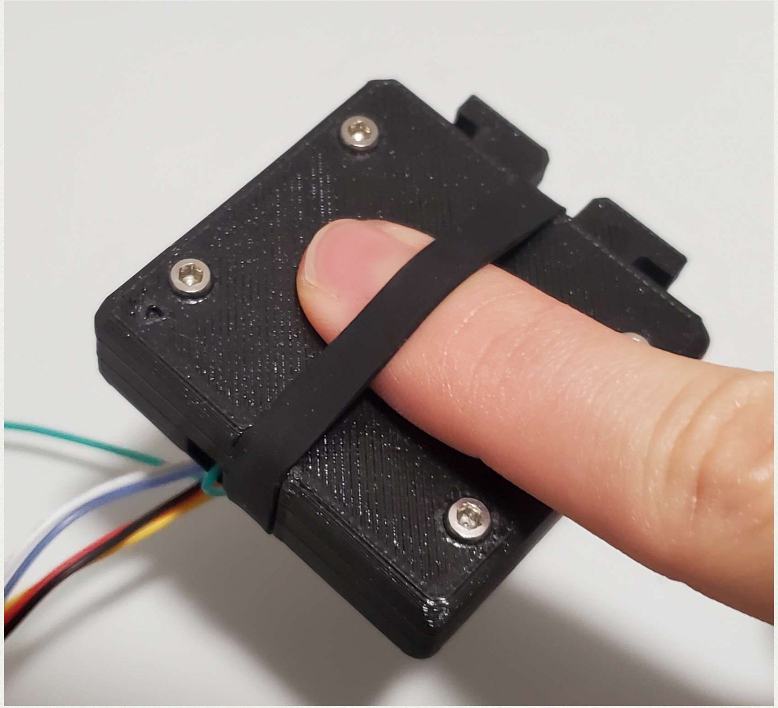
Receiving Vitals

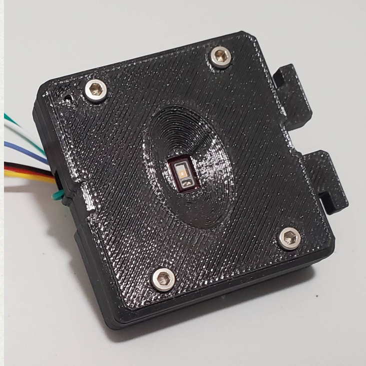
Software Flowchart

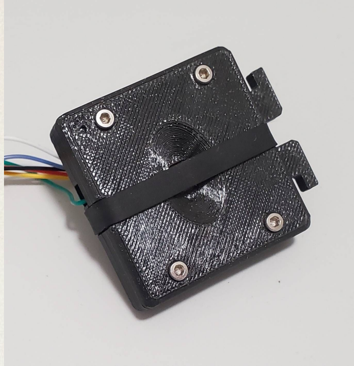


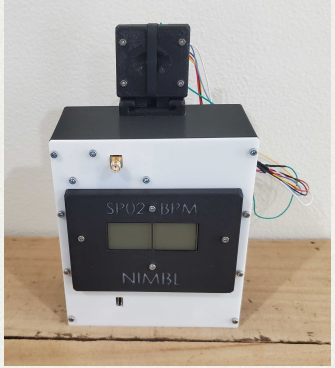
Mechanical Design











Mechanical Design

Main Device Body

Charging Station

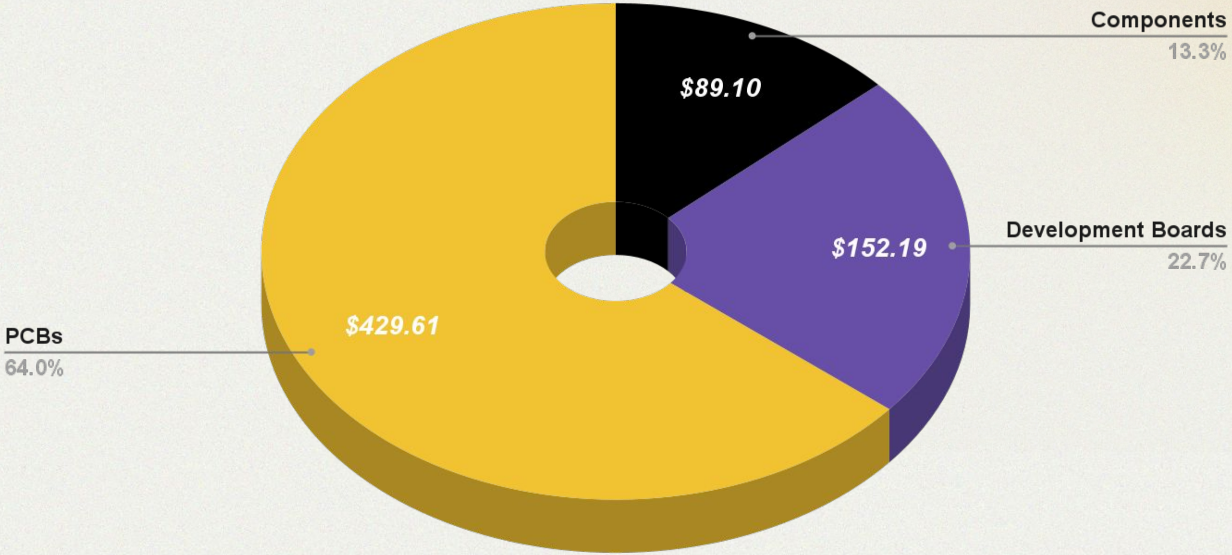
Project Challenges

- Choosing a regulator IC for the 3.3V regulator
- Cheap version of the RF breakout module did not utilize advertised IC
- Tolerances with the 3D printer
- Communicating with the RF & PPG sensor modules
- Transmitting & Receiving with the RF

Distribution of Work

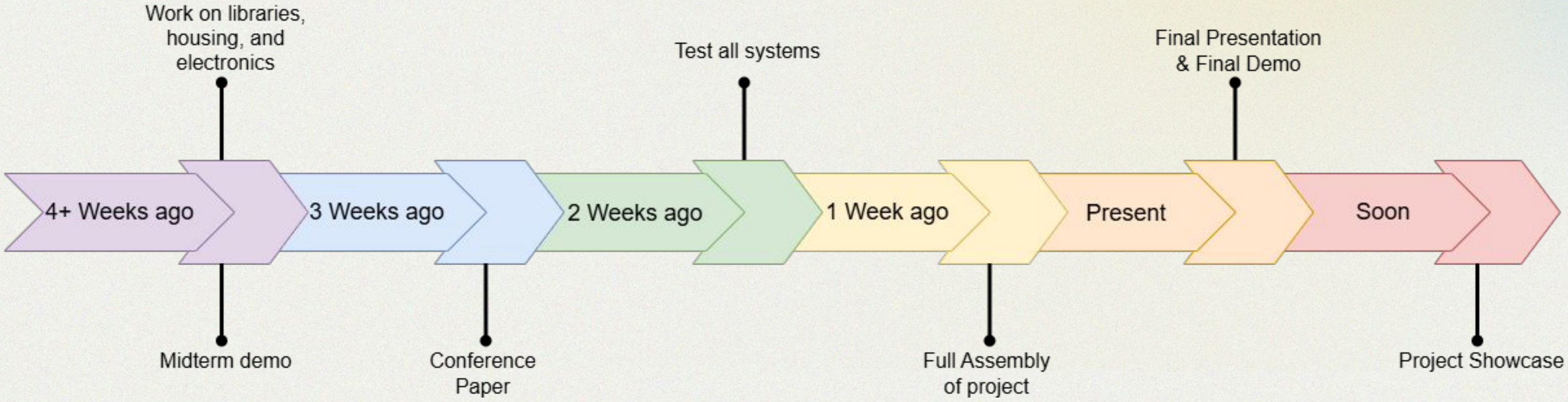
	PCB	Power	RF	PPG	Software	Mechanical
Ethan	✔			✔		✔
Kai	✔		✔		✔	
Tyler				✔	✔	
Benjamin	✔	✔				

Budget Breakdown



Total: $670.90

Project Timeline



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Final Presentation

Thank you for attending!