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

Critical Design Review

Review Committee:

Dr. Sonali Das

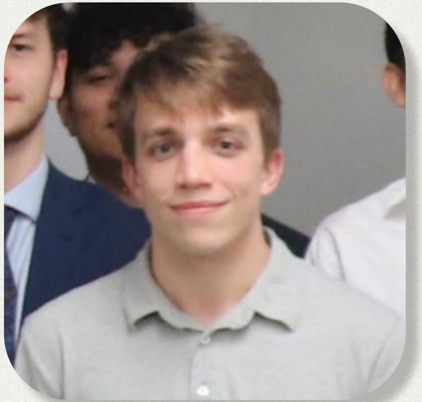
Dr. Xun Gong

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

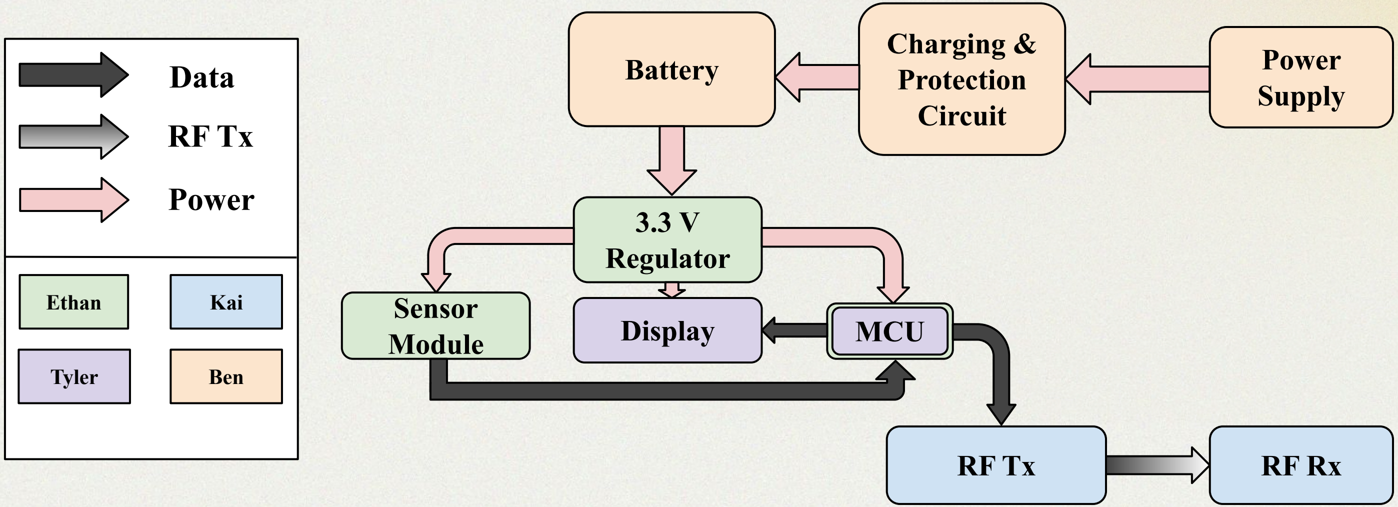
Project Goals & Objectives

- Design sensor housing to prioritize user comfort and preserve light signal integrity
- Build safe electrical components that are separated from the user
- System must transmit, display, and accurately read vital data
- Select affordable and low power peripherals

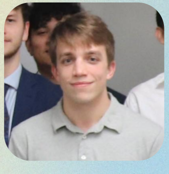
Engineering Requirements

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.
We must *transmit* a *maximum of 36 dBm EIRP.*	Compliance with FCC regulations (Part 15.247) on RF communications.
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



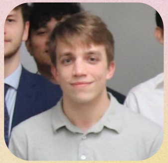
Heart Rate

- 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.

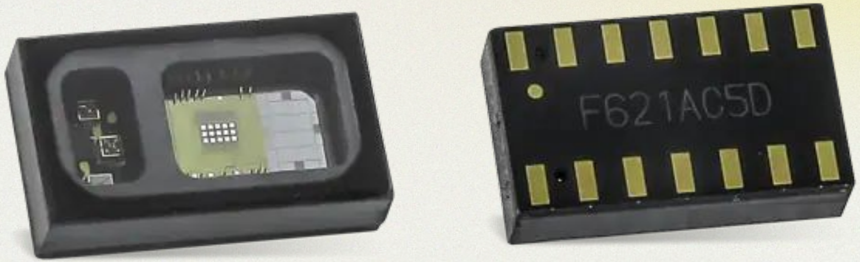
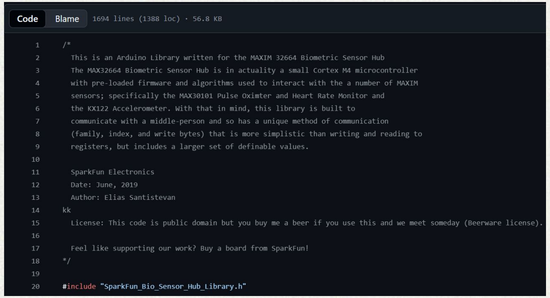


Image Source: [Mouser Electronics]

Pulse Oximeter Development Board

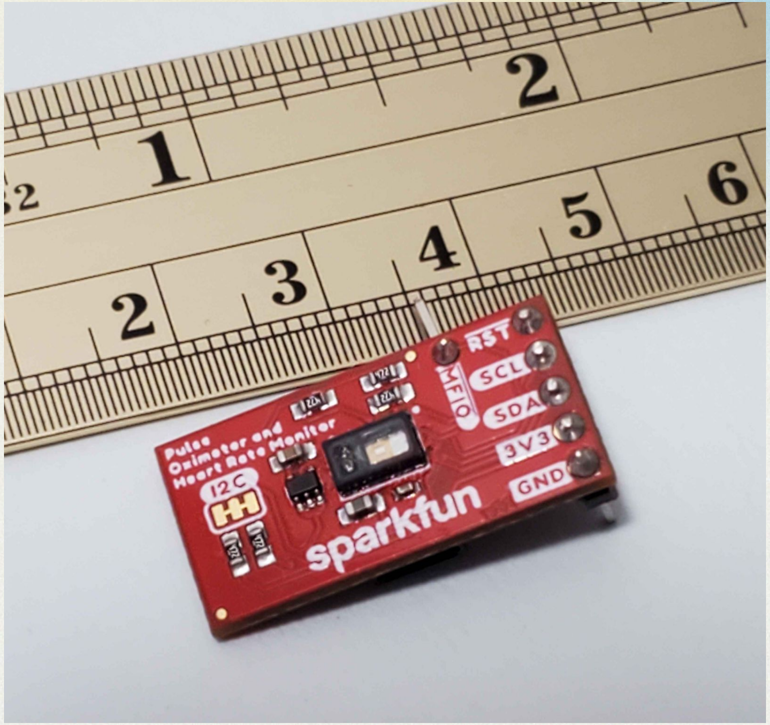
SparkFun Pulse Oximeter and Heart Rate Sensor - MAX30101 & MAX32664 (Qwiic)

- 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.

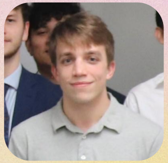


Code Blame 1694 lines (1388 loc) · 56.8 KB

```
/*
  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

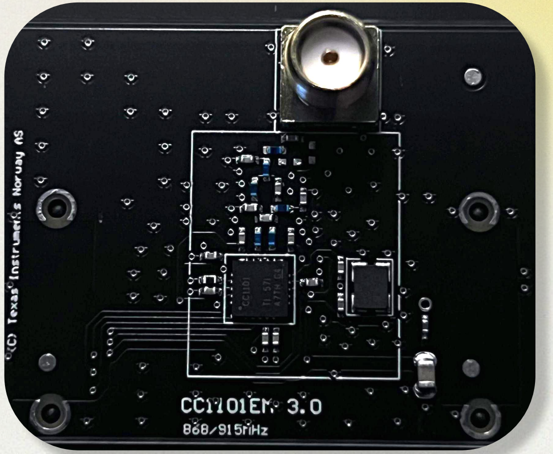
RF IC Part Selection

	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

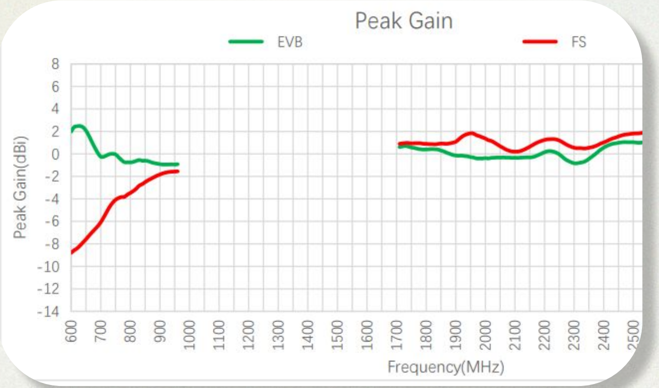
- The module itself is driven by 3.3V
- The RF module matches the differential energy ports of our IC to a 50Ω SMA connector using a balun network
- The drilling of many vias near the balun network reduce the parasitic inductance brought on at RF frequencies, as well as mitigating fringing fields
- Data 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

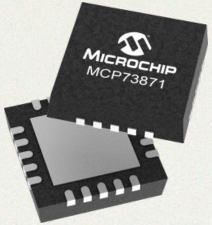
915MHz Monopole Whip

- 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

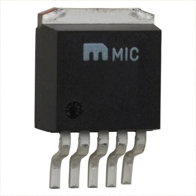


Battery Protection IC Selection

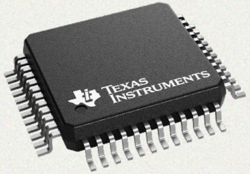
	Manufacturer	Overcharge & Overdischarge	Charge Overcurrent	Price
DW01	EVVO	Yes	Yes	$0.10
BQ2980	TI	Yes	Yes	$0.56
UCC3952	TI	Yes	No	$1.49

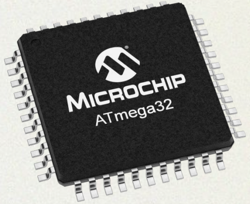
5V Charger IC Selection

	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

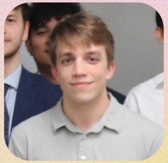
	Power	Resolution	Programmability	Lifespan	Price
HT1621 LCD	1mW	Segmented	Simple	Better	$2.49
NHD-0.95-9664G OLED	36mW	96 x 64 pixels	Complex	Short	$7.56

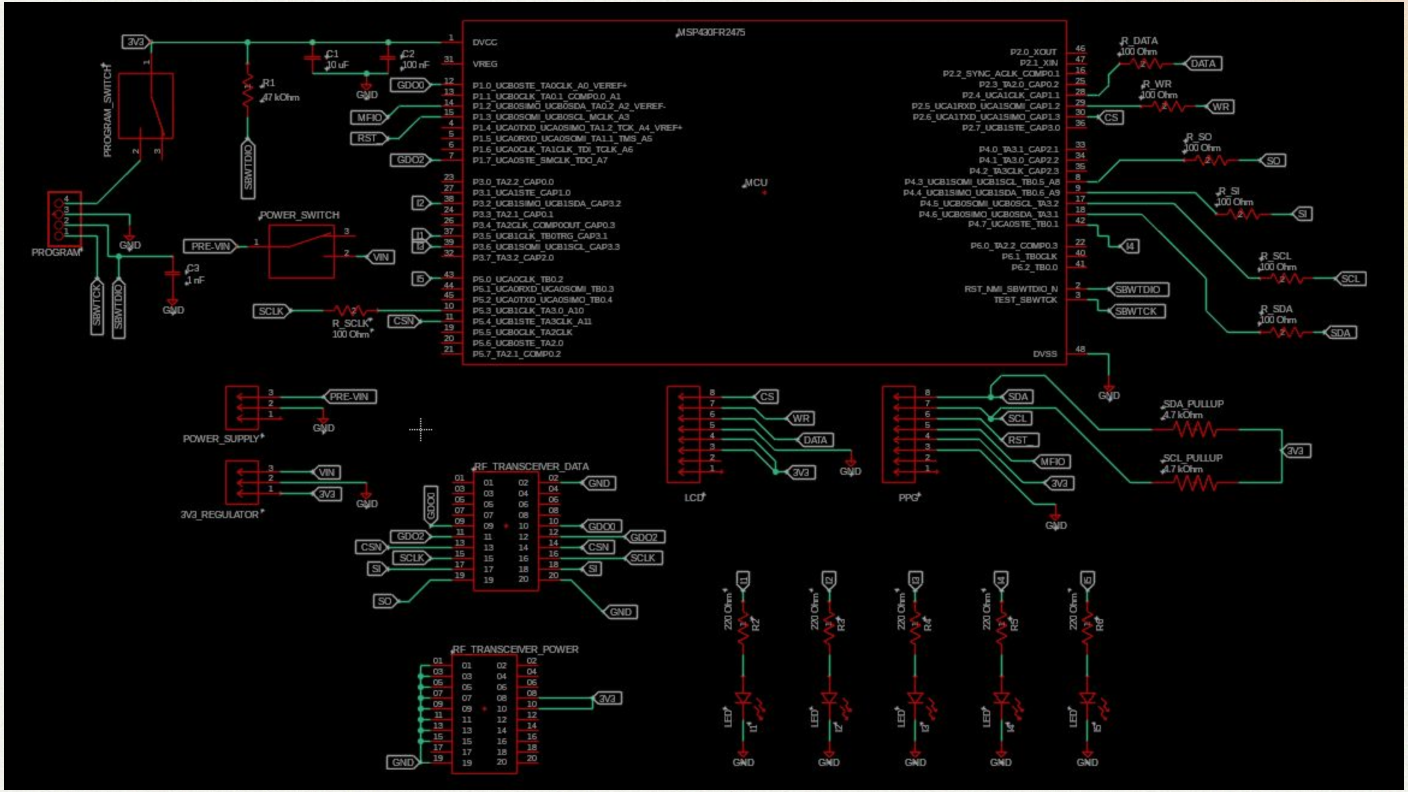
Hardware Design - Power Budget

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

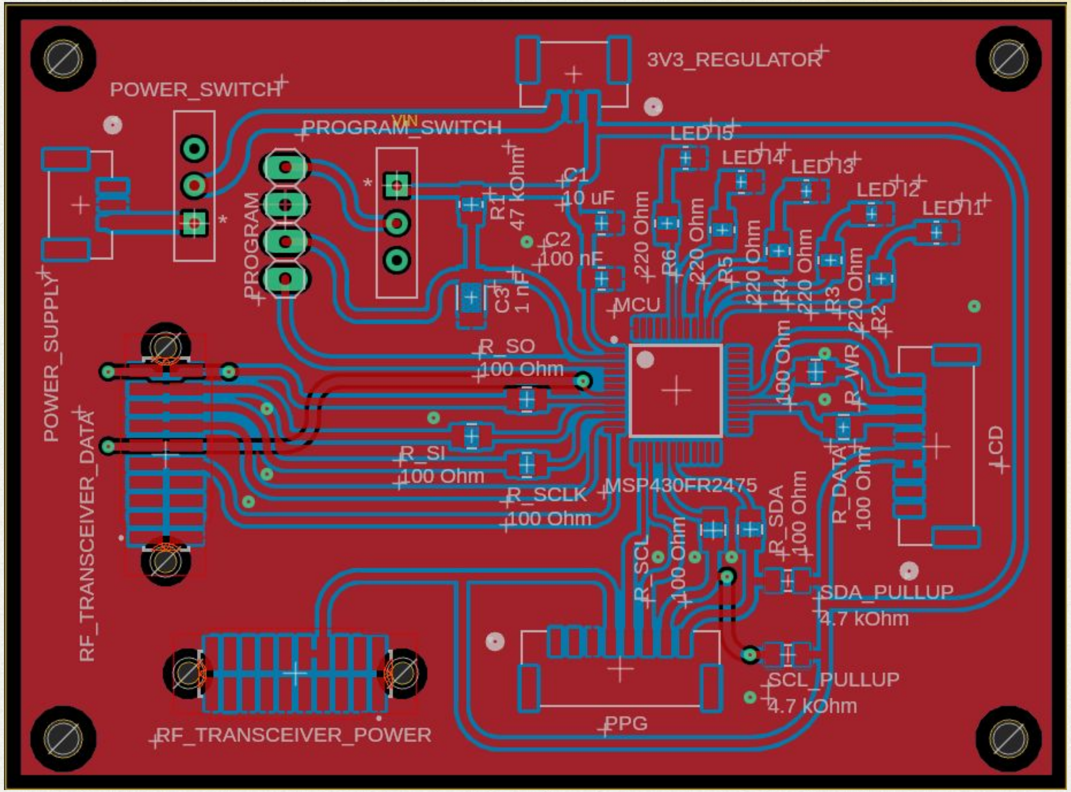
Component	Voltage	Current
MSP430	3.3V	3.75mA
PPG Sensor	3.3V	51.1mA
LCD Screen	3.3V	0.3mA
Transceiver	3.3V	34.2mA
Total		89.35mA

Main Circuit

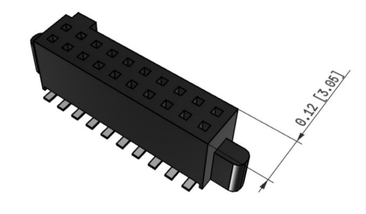




Main PCB

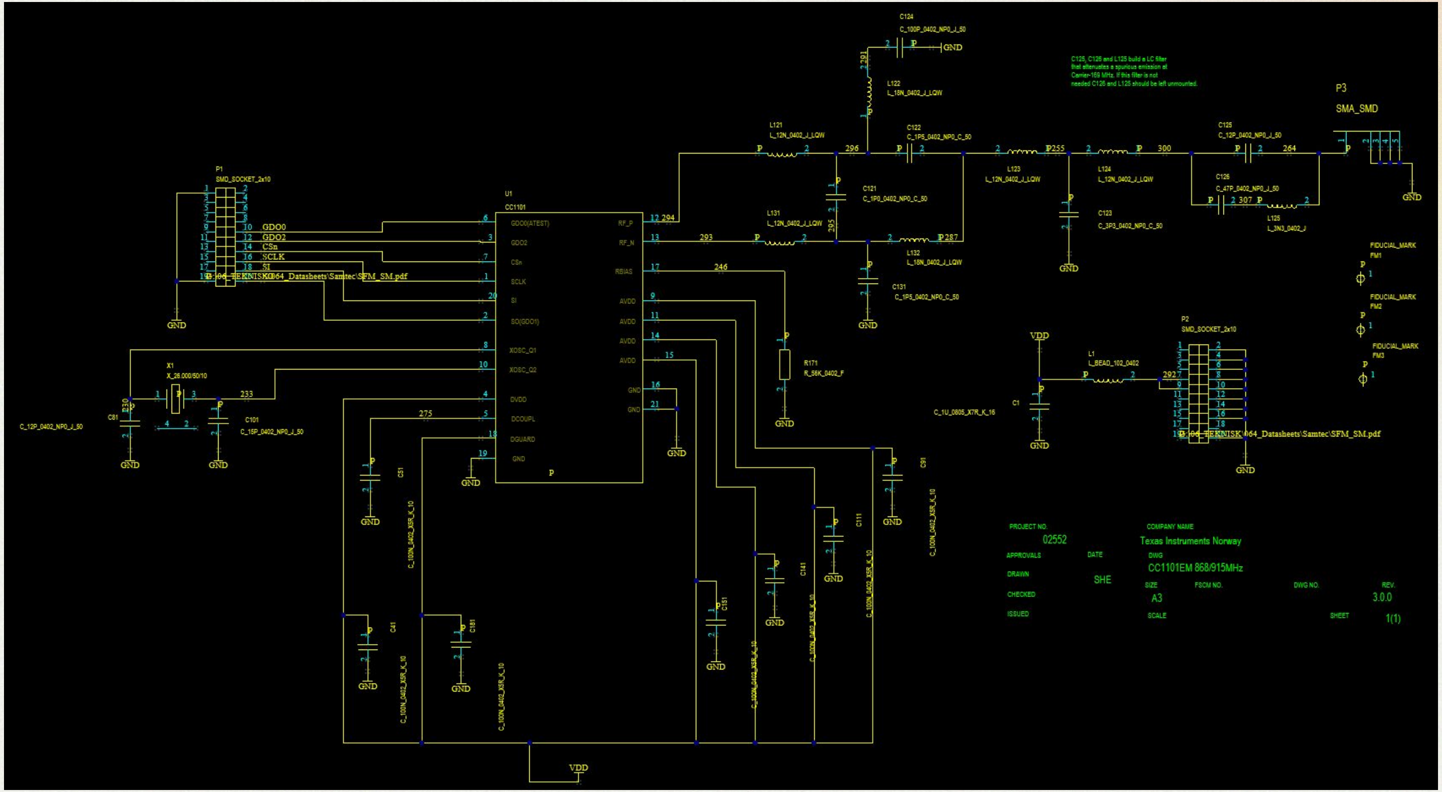


JST GH Connector
Image Source: JST

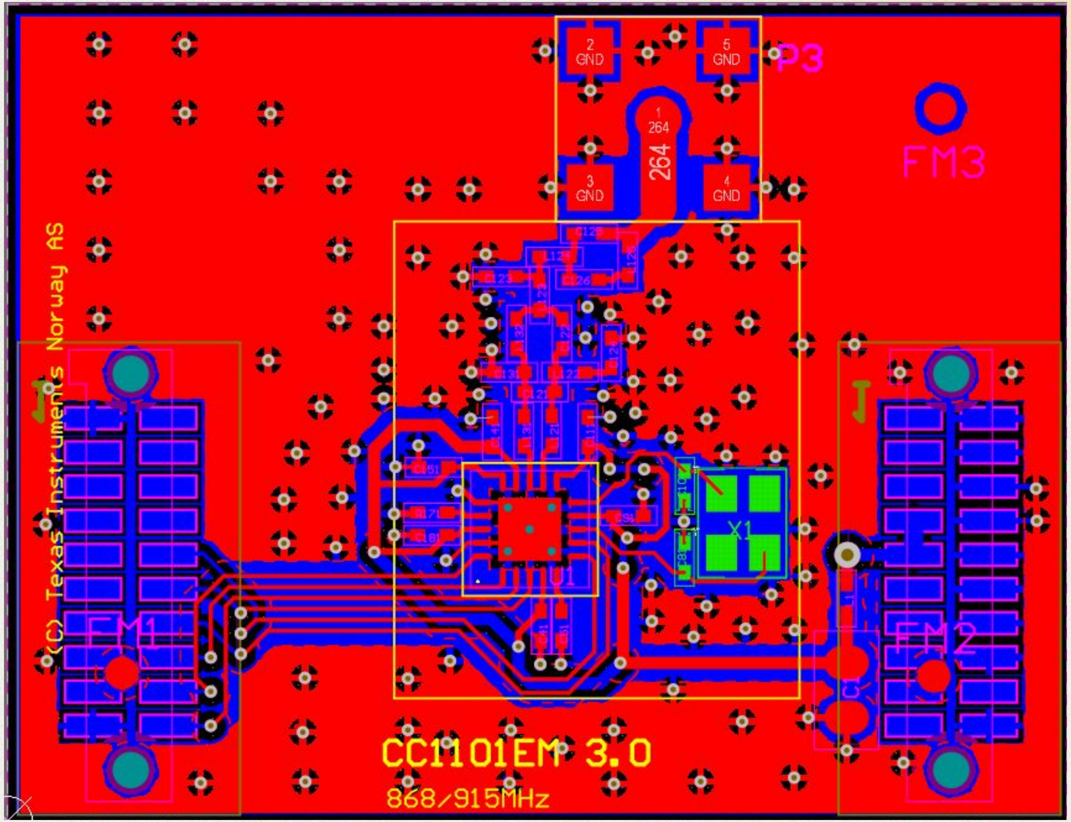


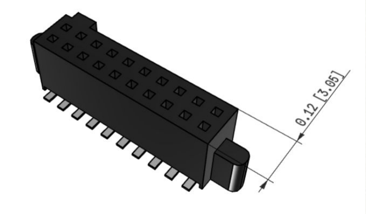
SFM Socket
Image Source: Samtec

RF Module Circuit



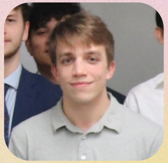
RF Module PCB

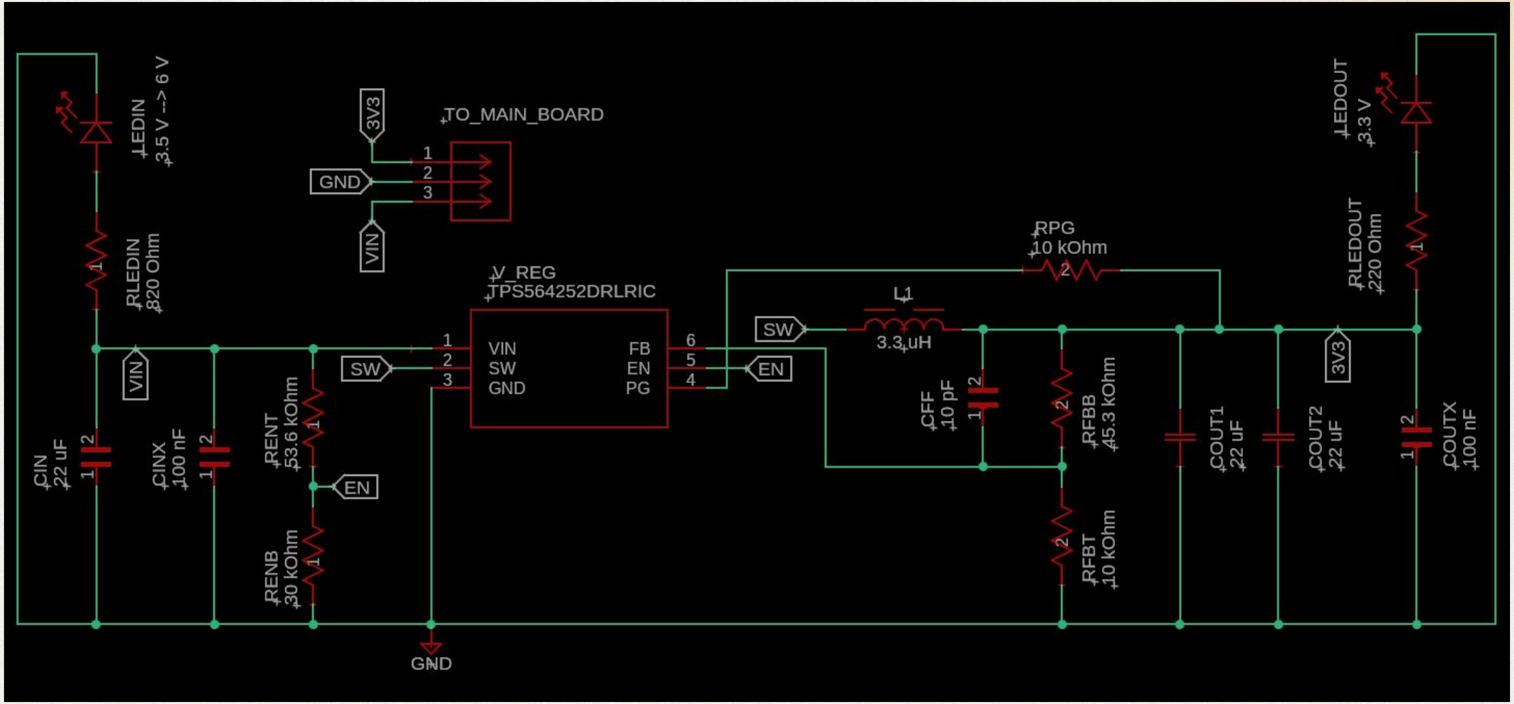




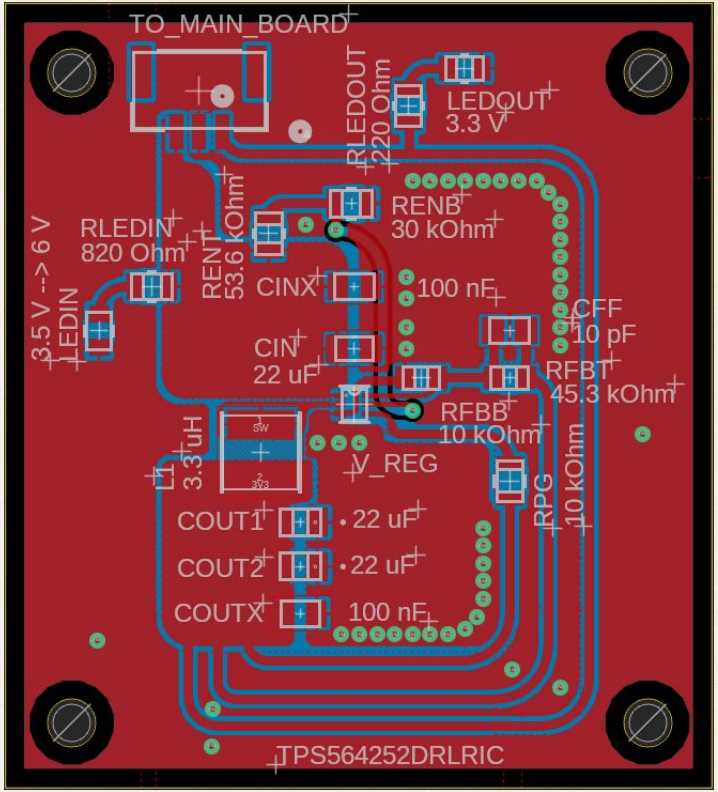
SFM Socket
Image Source: [Samtec]

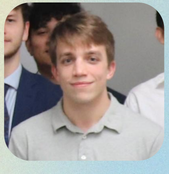
3.3 Volt Regulator Circuit



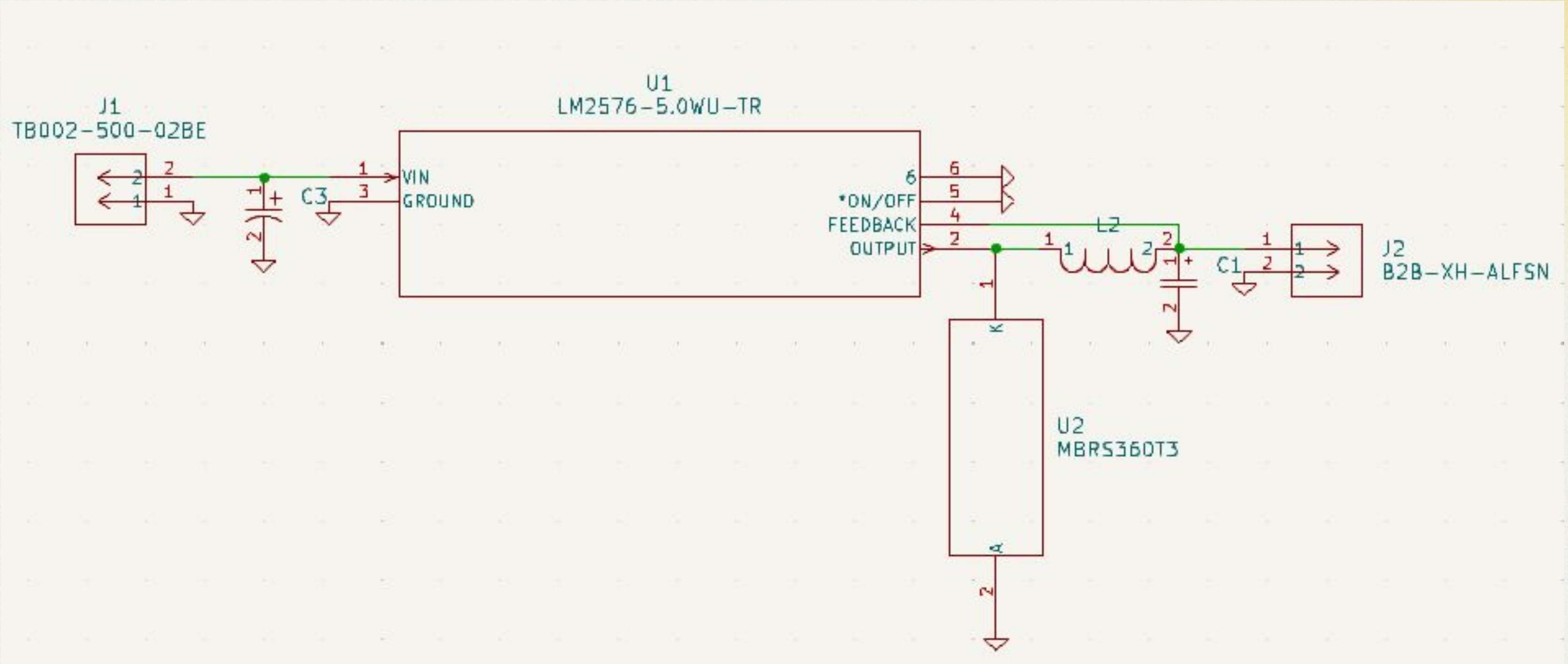


3.3 Volt Regulator PCB

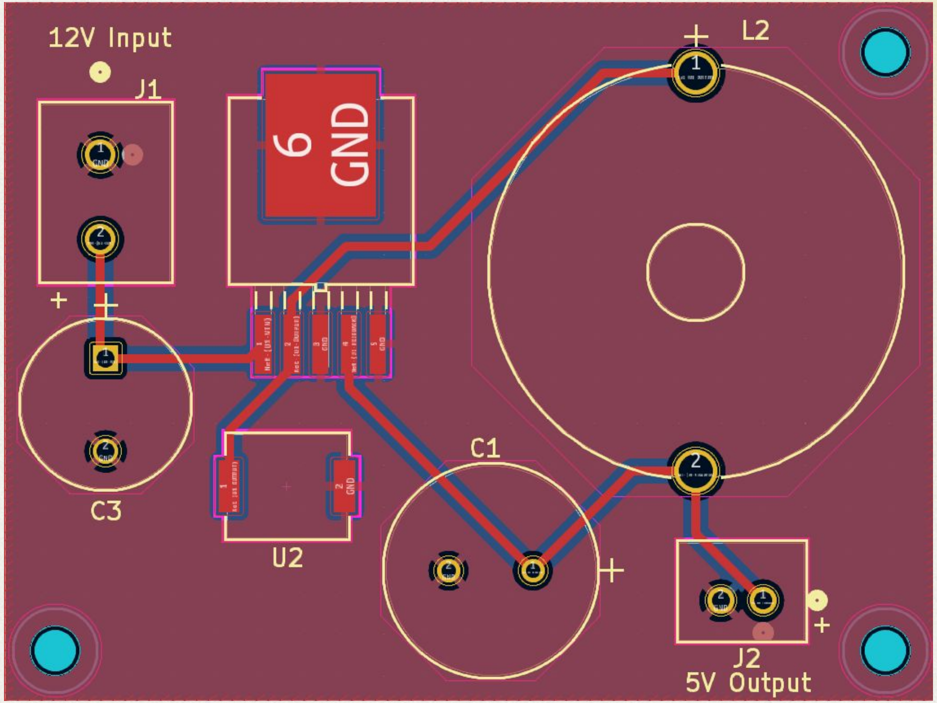




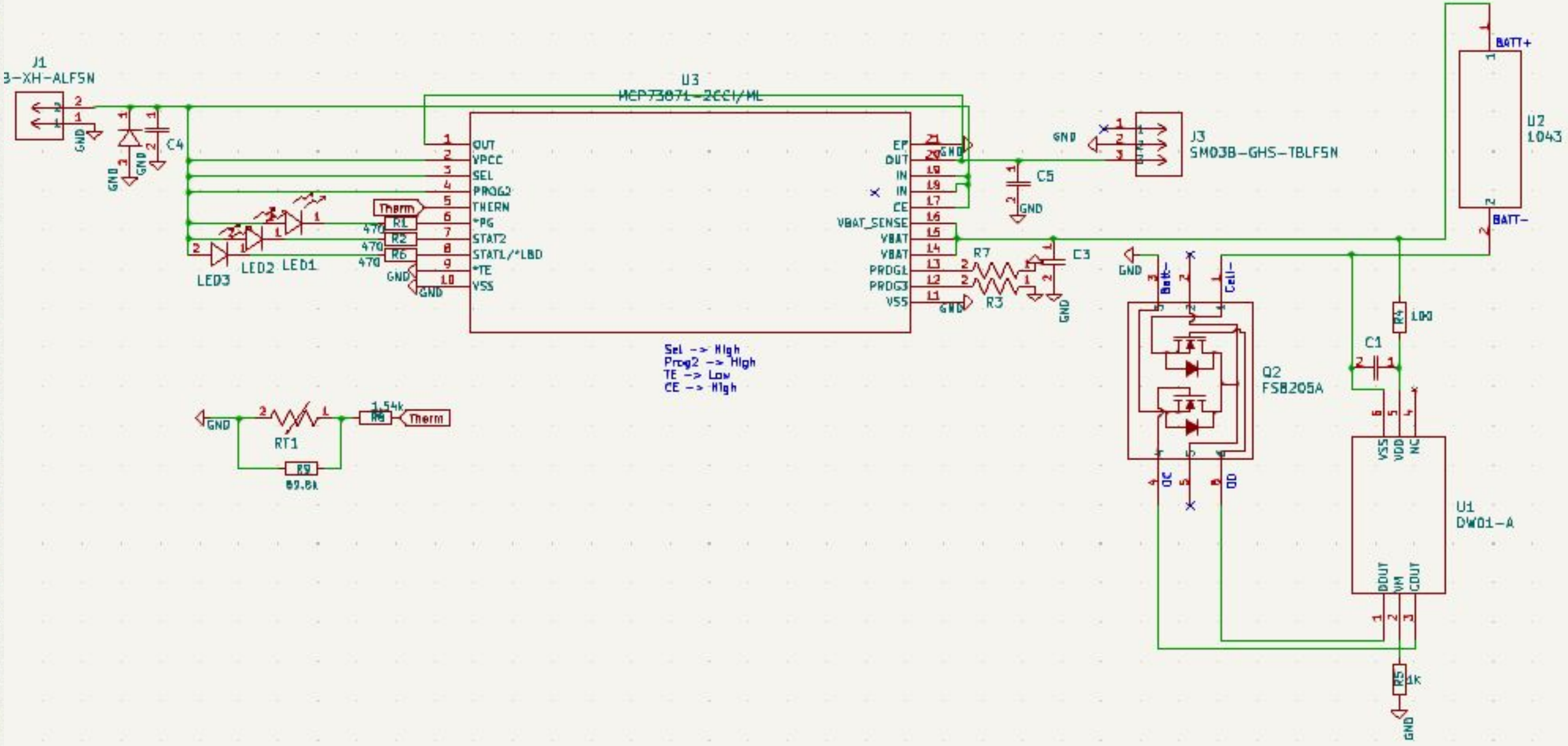
5V Charger Schematic



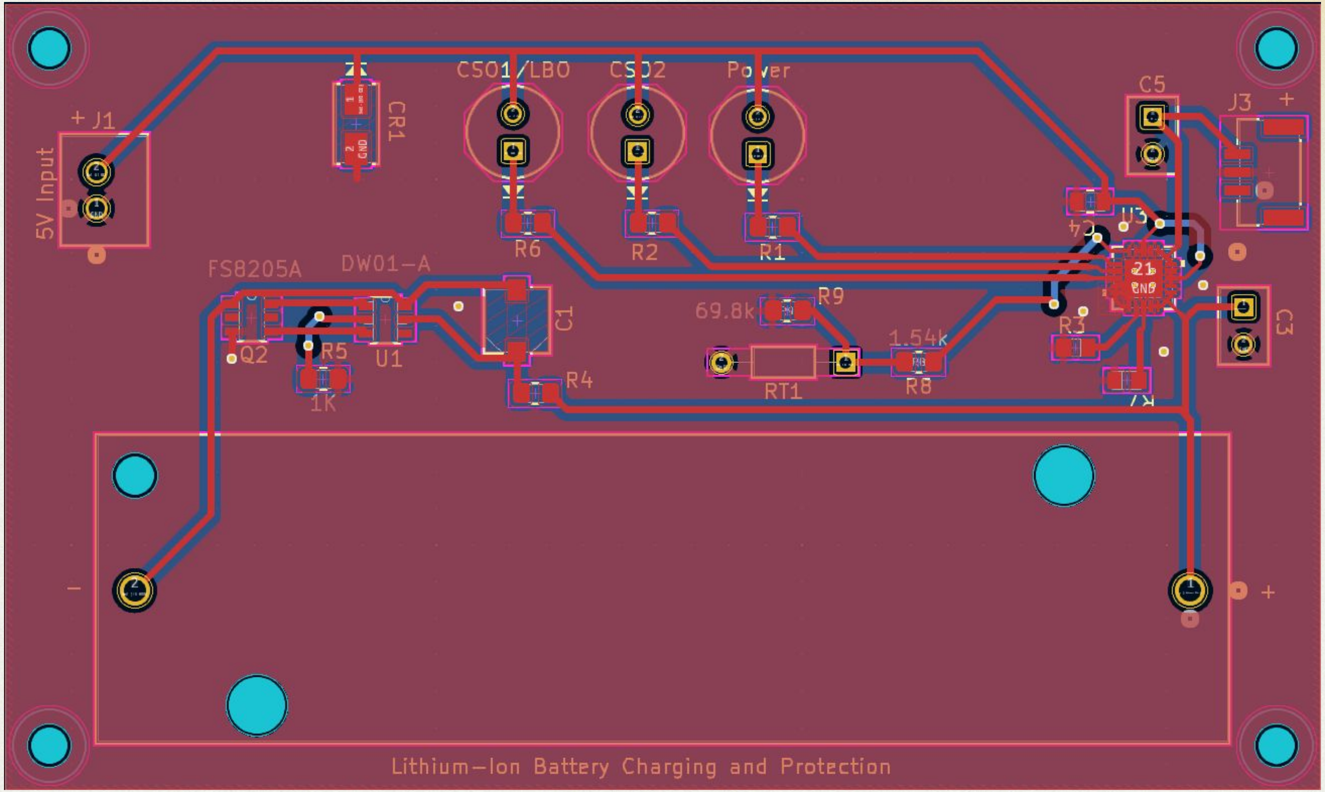
5V Charger PCB



Battery Schematic



Battery PCB

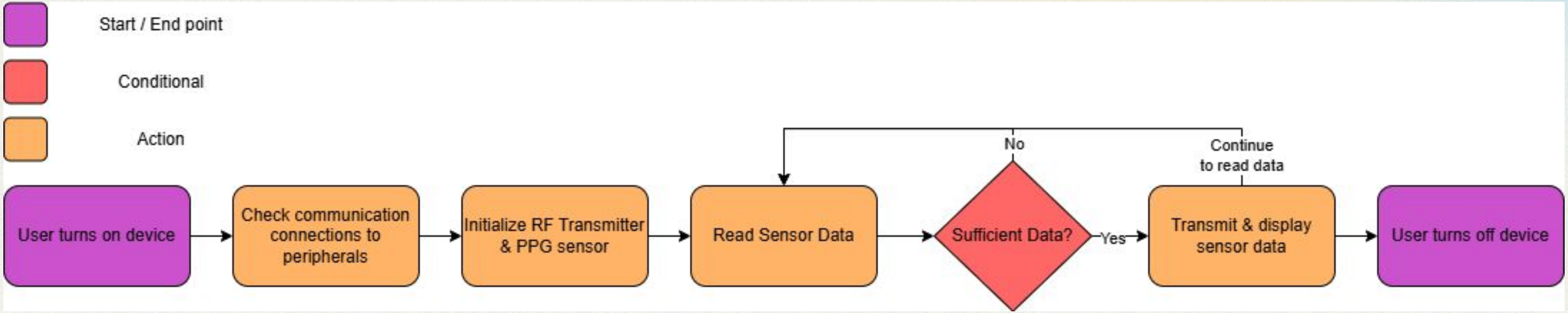


J1
5V Input
CR1
CSO1/LBO
CSO2
Power
C5
J3
R6
R2
R1
U5
C4
FS8205A
DW01-A
C1
69.8k
R9
1.54k
R3
C3
Q2
R5
U1
R4
RT1
R8
1K
Lithium-Ion Battery Charging and Protection

Software Development

- Language: C++
- Dev Environment: VSCode
- Implementation: TI CCS
- Debugging: Tera Term

Software Flowchart

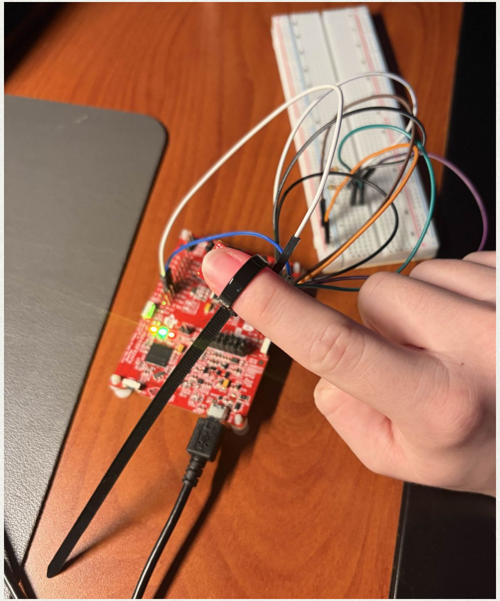


Sensor Testing

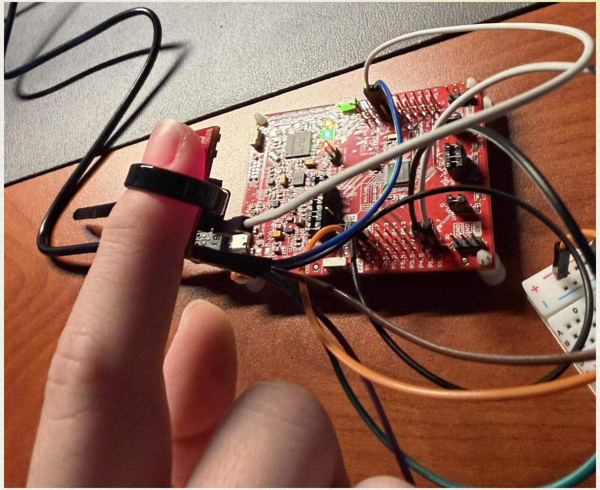
Sensor Readings

```
Heartrate: 91
Confidence: 94
Oxygen: 0
Status: 3
Heartrate: 91
Confidence: 99
Oxygen: 100
Status: 3
Heartrate: 91
Confidence: 99
Oxygen: 100
Status: 3
Heartrate: 92
Confidence: 99
Oxygen: 100
Status: 3
Heartrate: 92
Confidence: 99
Oxygen: 100
Status: 3
```

Sensor Testing

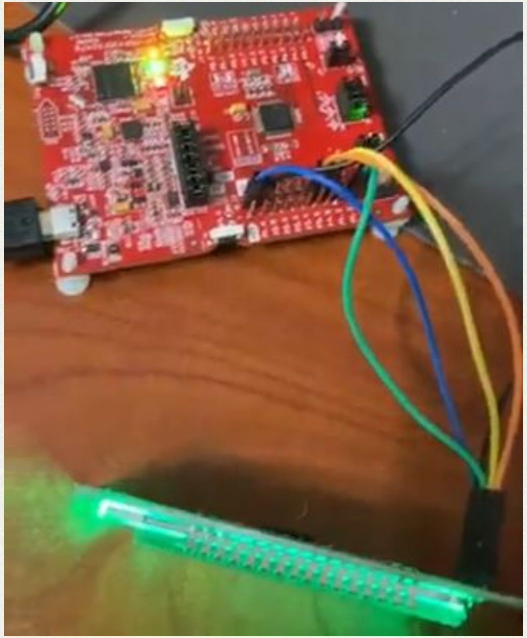


Sensor Testing

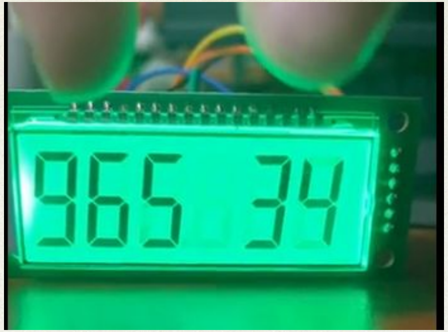


LCD Testing

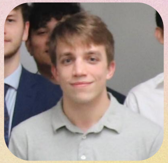
Wiring to the MSP



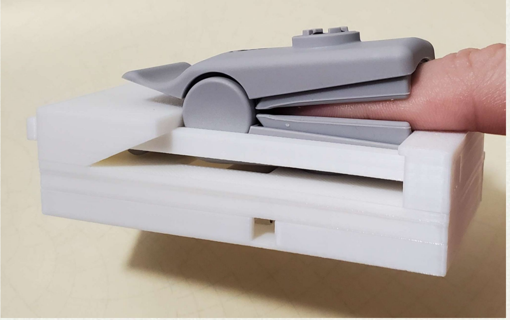
Clear picture of display



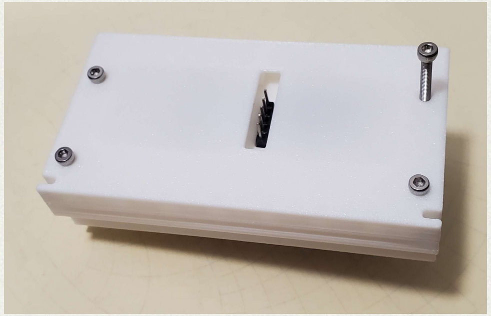
Mechanical Design



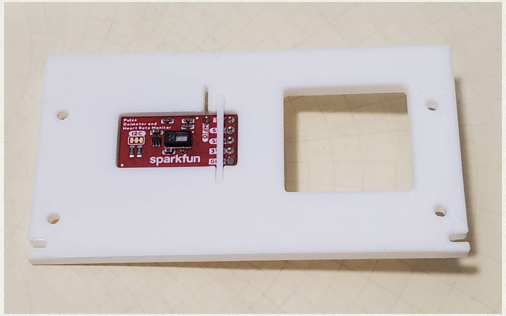
Full Adapter



Clip Adapter

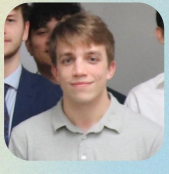


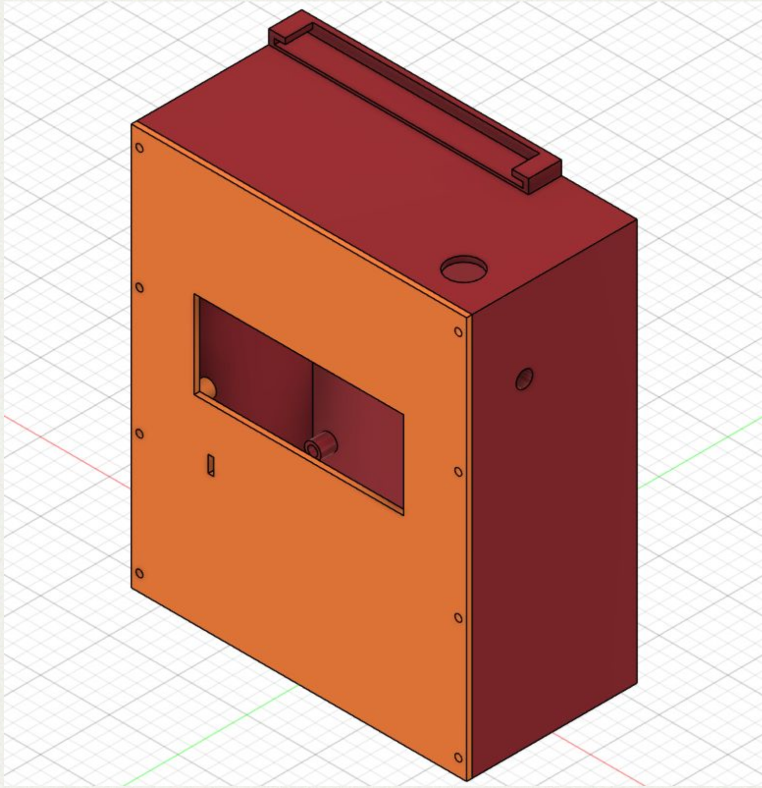
Bottom of Full Adapter



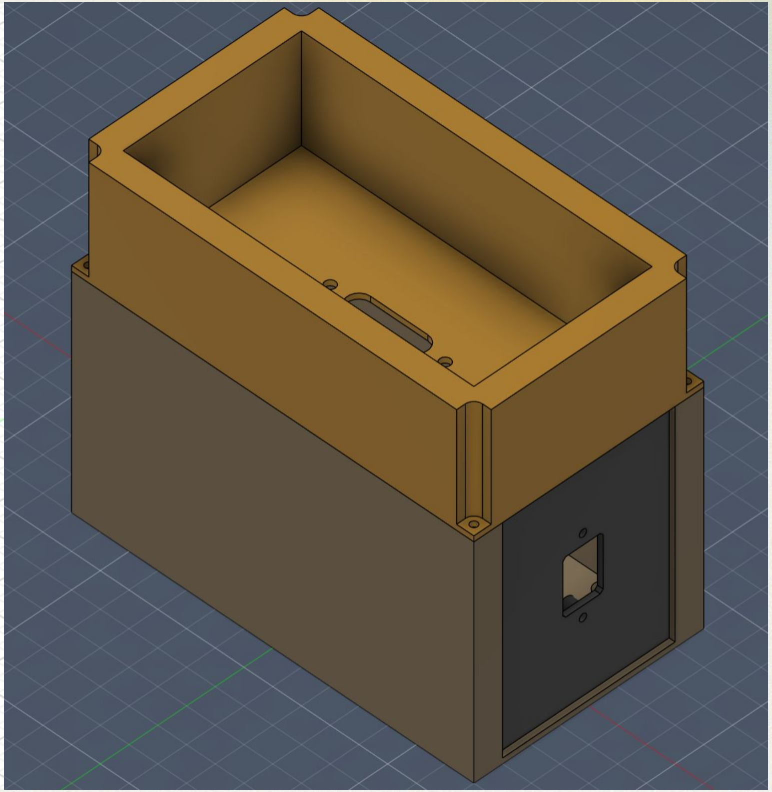
Dev Board Adapter

Mechanical Design





Main Device Body



Charging Station

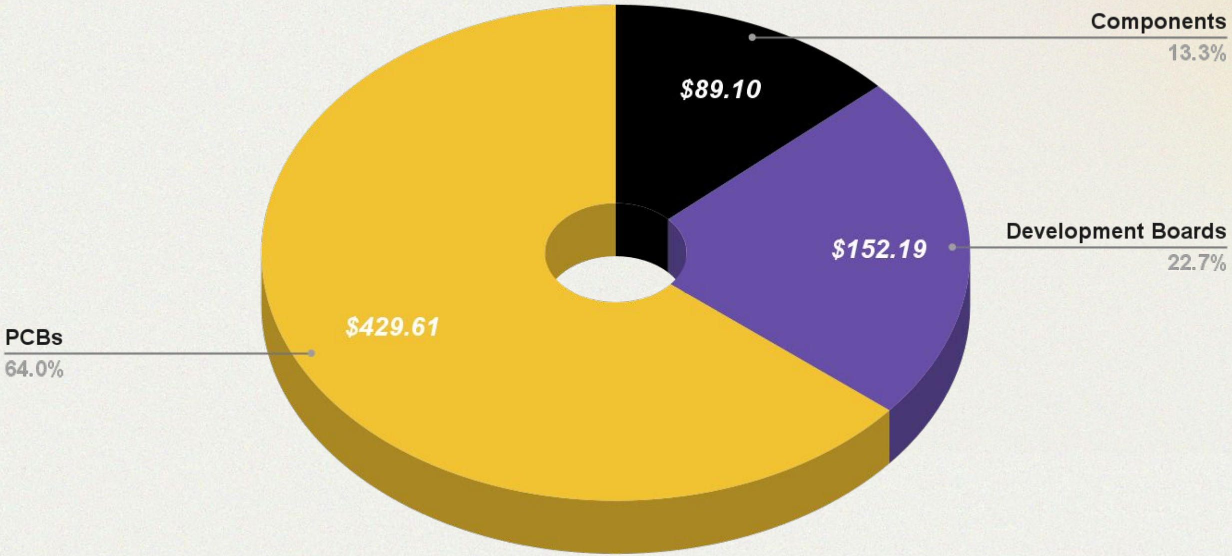
Project Challenges

- 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

Distribution of Work

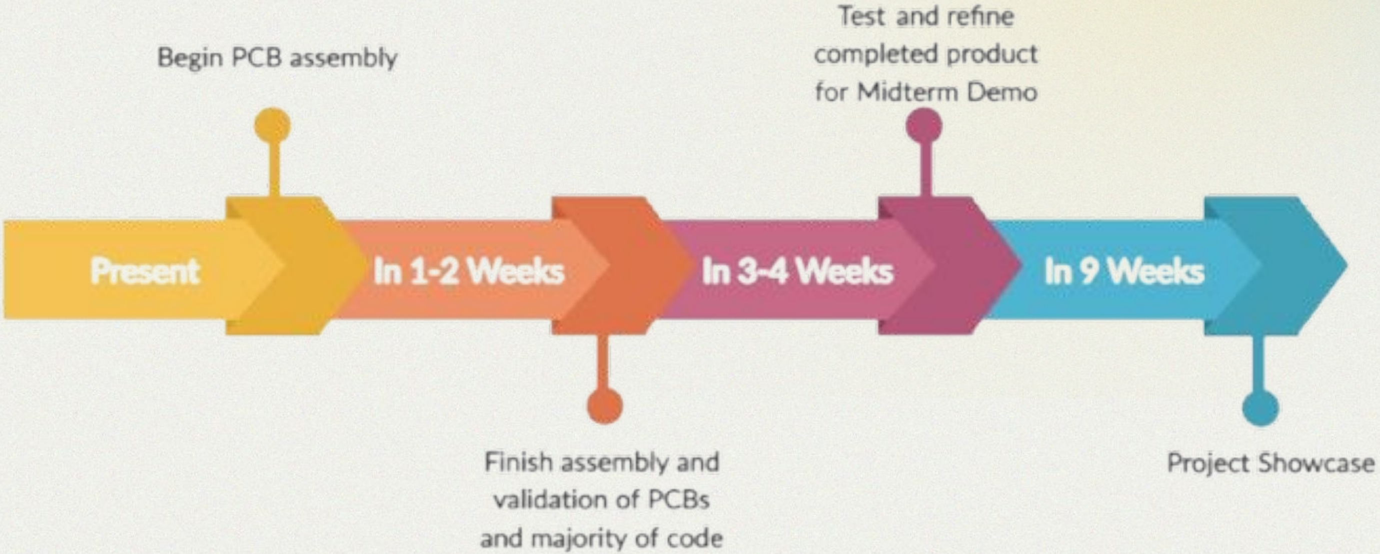
	PCB	Power	RF	PPG	Software	Mechanical
Ethan	✔			✔		✔
Kai	✔		✔		✔	
Tyler				✔	✔	
Benjamin	✔	✔				

Budget Breakdown



Total: $670.90

Project Timeline



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

Critical Design Review

Thank you for attending!