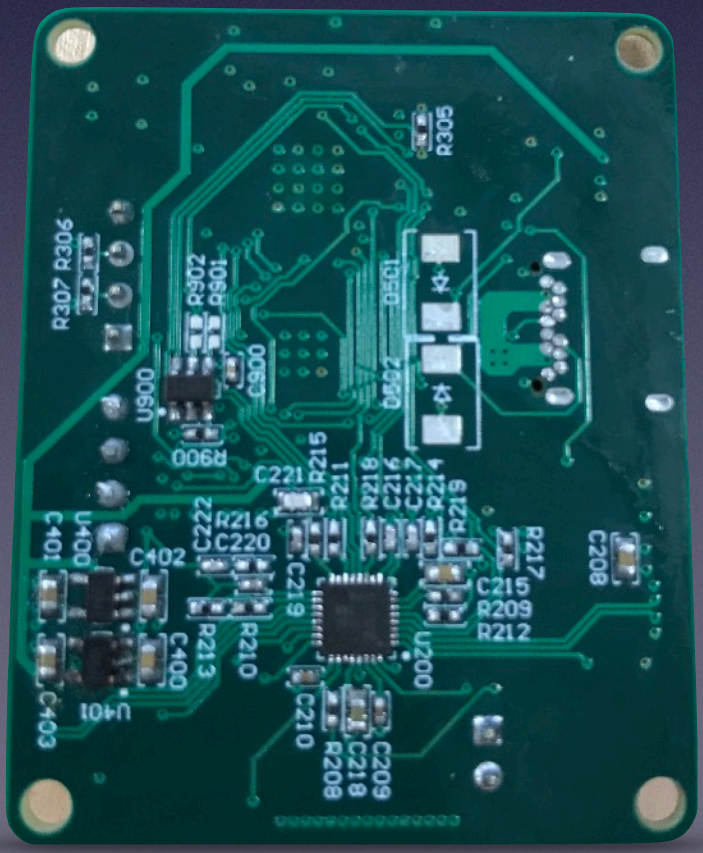
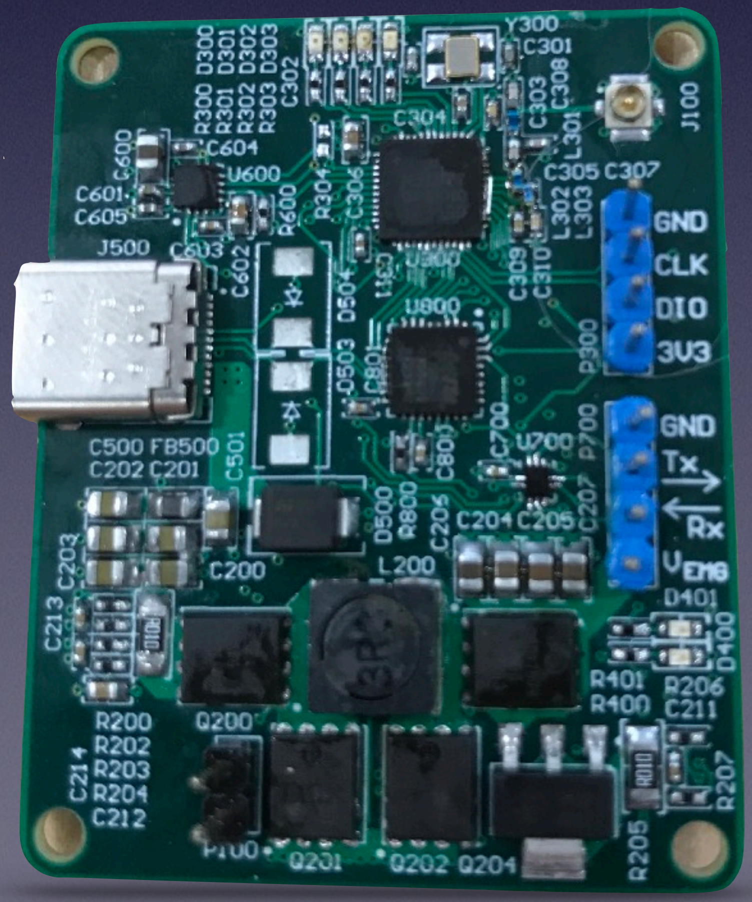
I/O System for the PSYONIC Advanced Bionic Hand

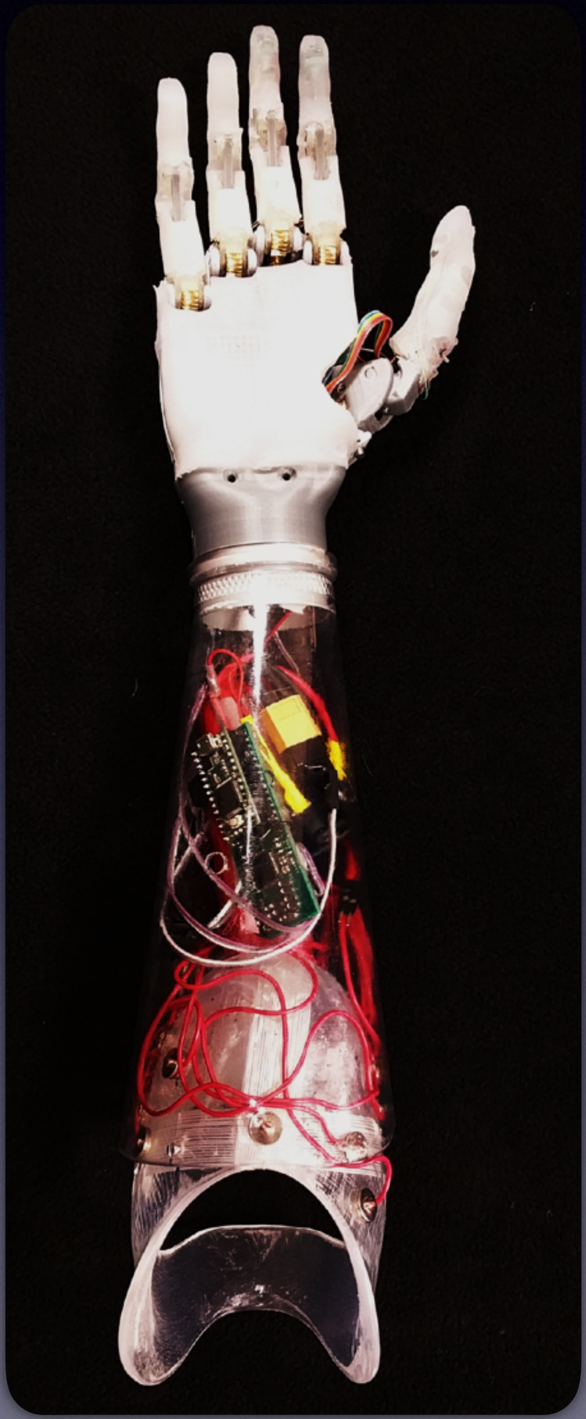


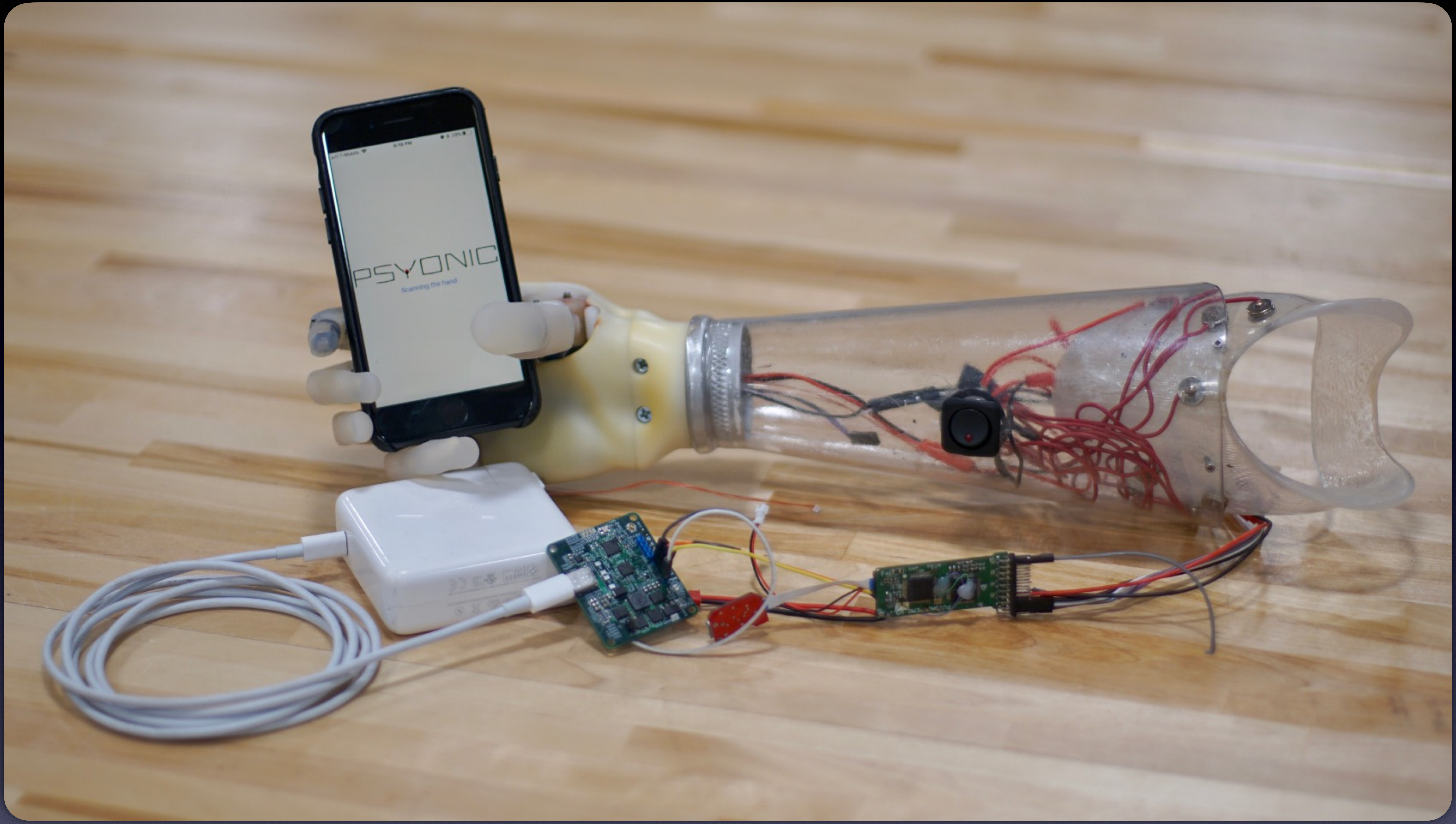
Team 28
Byron Hopps and Steven Sun
ECE 445 Senior Design
Fall 2017



Background

- PSYONIC is a startup at the University of Illinois creating low-cost prosthetics
- Their product is the PSYONIC Advanced Bionic Hand
- Current prototypes contain all core functionality
- User interfaces are lacking





I/O System

Bluetooth Wireless Communications
USB Wired Communications
Fast Charging with USB Power Delivery

High-Level Requirements

- The I/O System shall be capable of powering the prosthetic hand from both an external power source and an internal battery of at least 2.2Ah
- The I/O System shall be capable of communicating with external devices using Bluetooth or USB
- The I/O System shall be capable of sending commands and data to the EMG board at a baud rate of at least 115200 symbols per second

Battery Charging Procedure

Without the I/O System

1. Disassemble the hand
2. Remove the battery
3. Charge the battery with a lithium-ion battery charger
4. Wait for the battery to charge
5. Put the battery back in the hand
6. Reassemble the hand

Battery Charging Procedure

With the I/O System

1. Attach hand to a USB charger

2. Wait for hand to charge

Hand Configuration Procedure

Without the I/O System

1. Disassemble the hand
2. Change configuration constants in the source code
3. Recompile the hand’s source code
4. Attach JTAG programmer to hand
5. Reprogram hand with updated code
6. Reassemble the hand

Hand Configuration Procedure

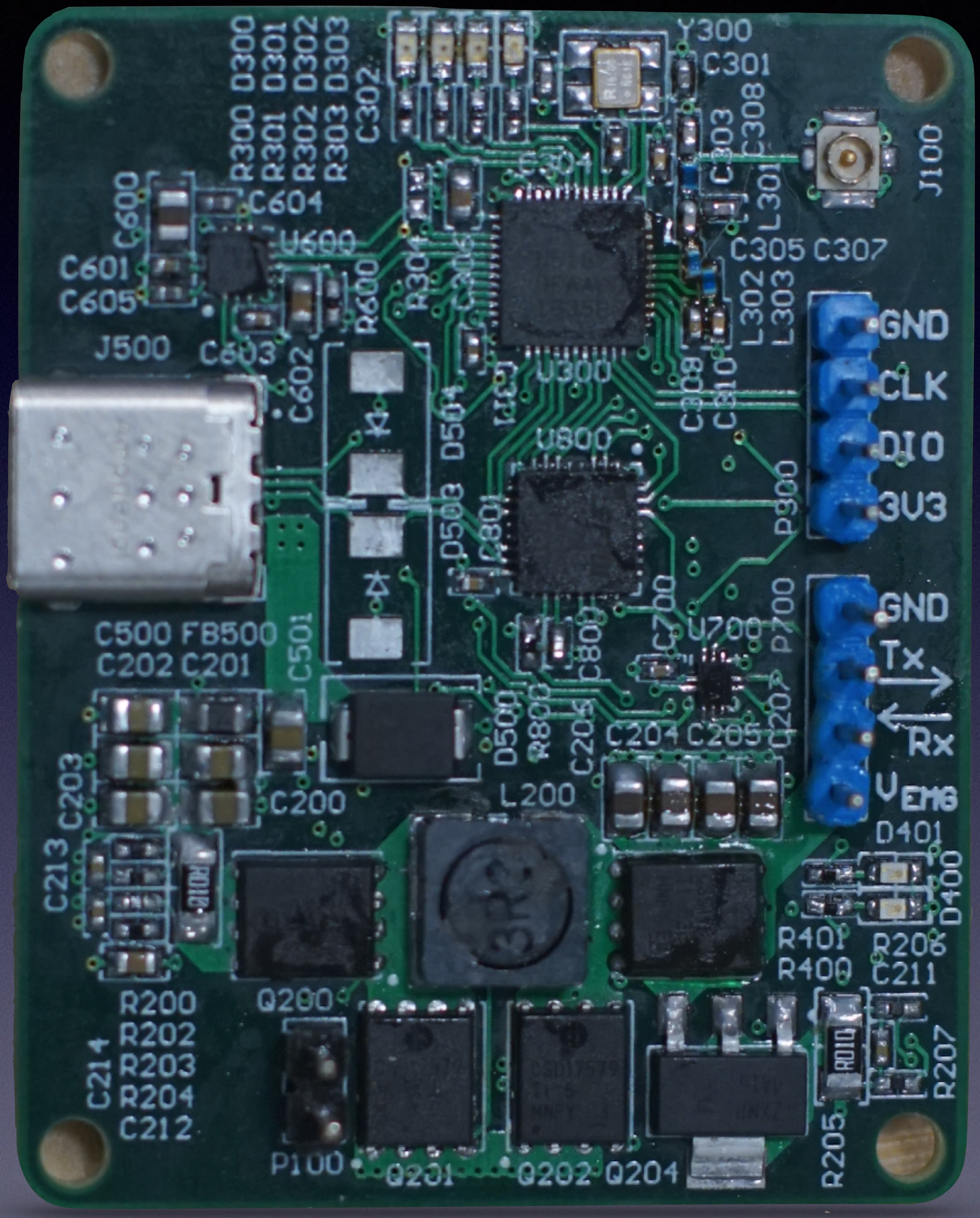
With the I/O System

1. Connect to hand with Bluetooth or USB

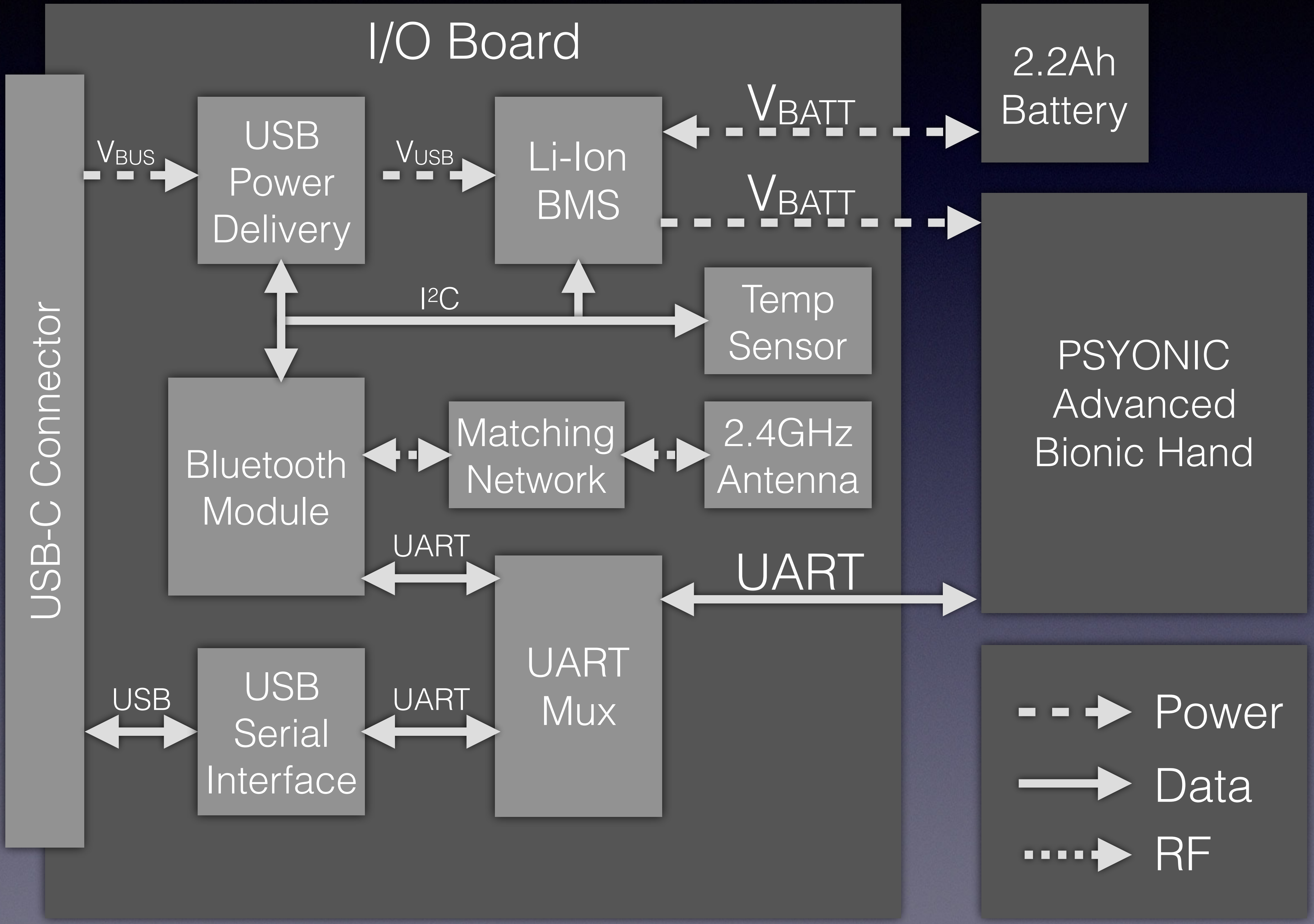
2. Use smartphone app or desktop software to reconfigure hand settings

Hardware

Byron Hopps

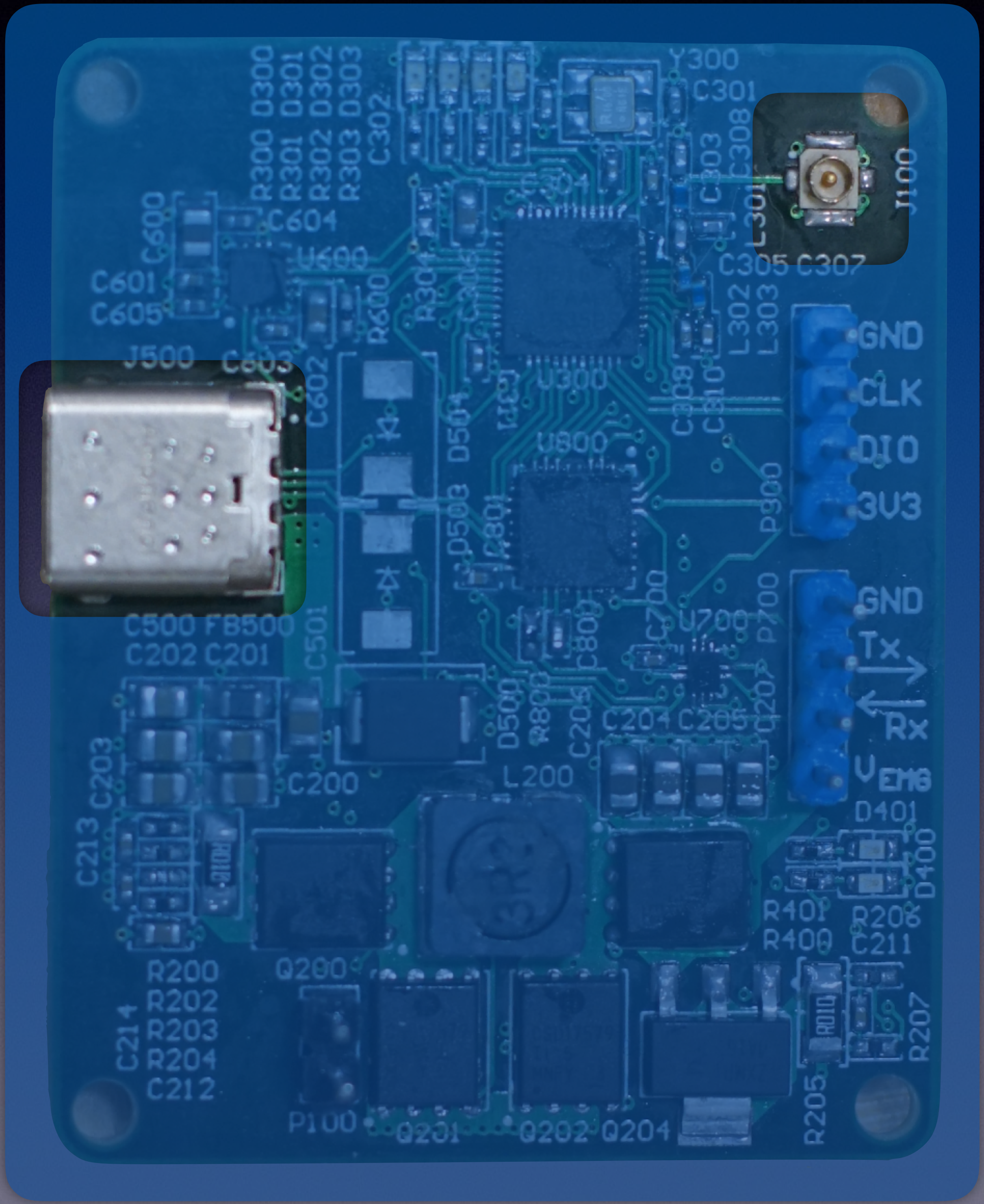


System Architecture

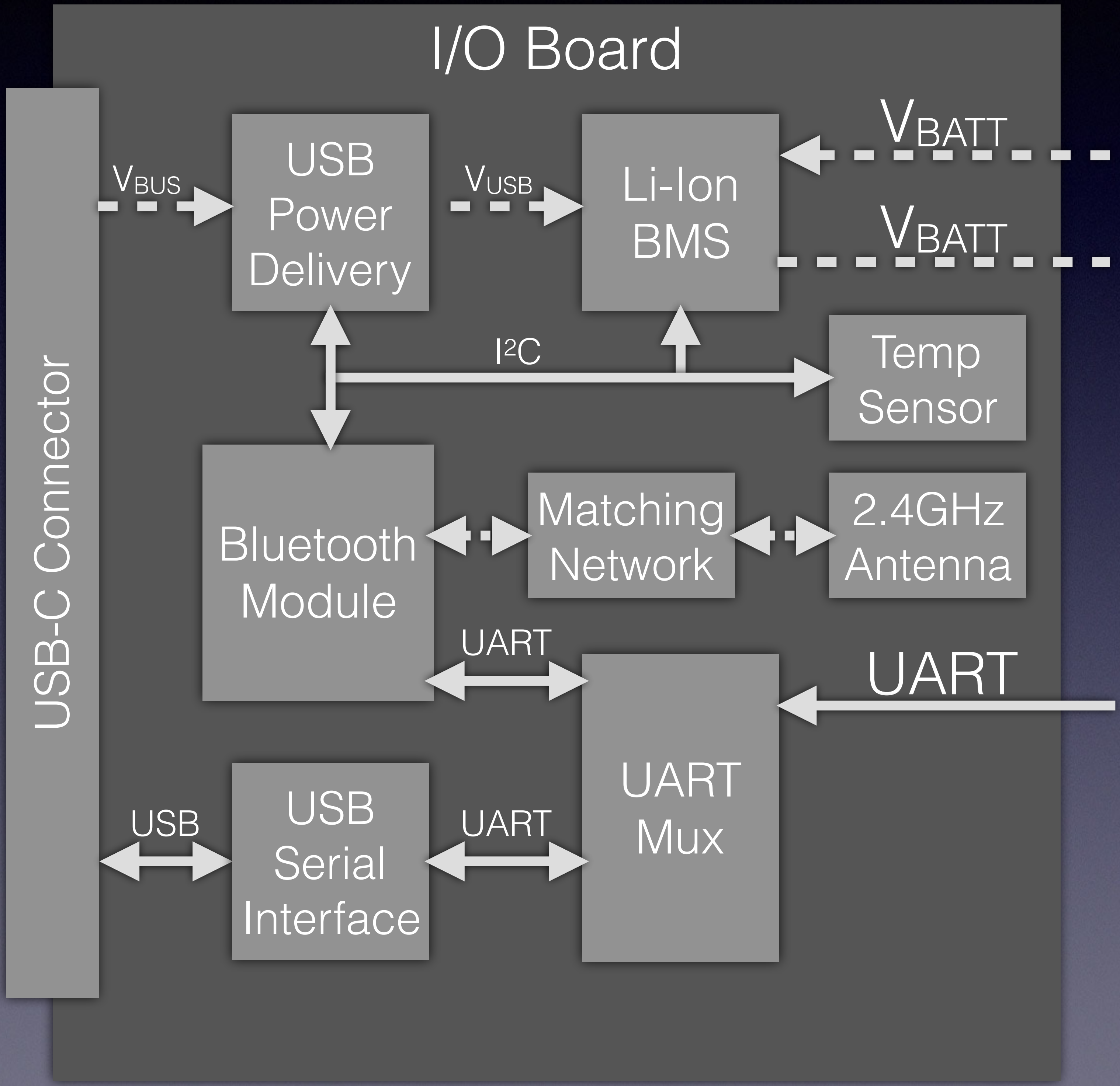


I/O System Interfaces

- Wireless communications using Bluetooth Low Energy
- USB Type-C Port
  - Wired communications using USB 2.0
  - Rapid Charging via USB Power Delivery 2.0

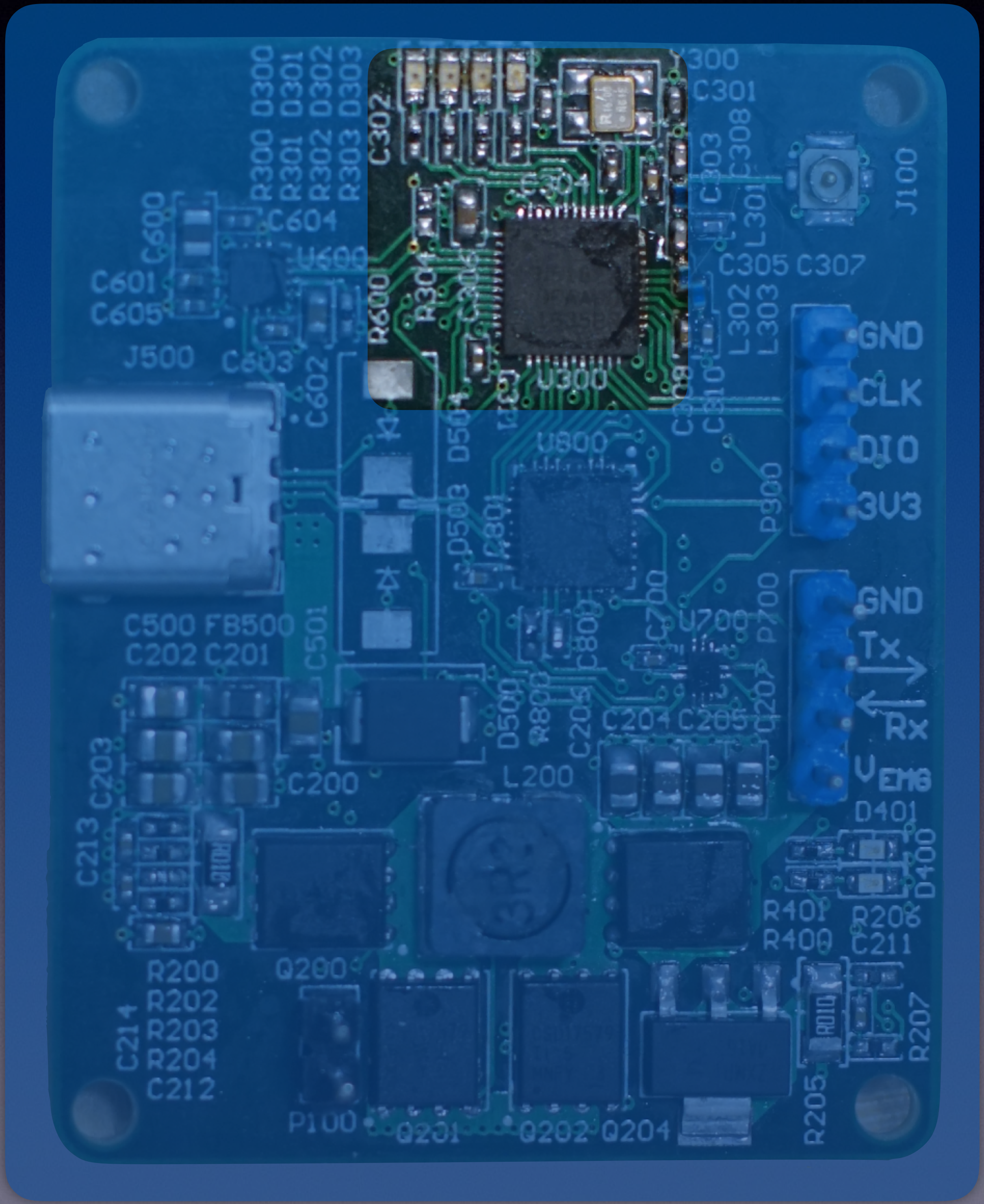


Bluetooth Module

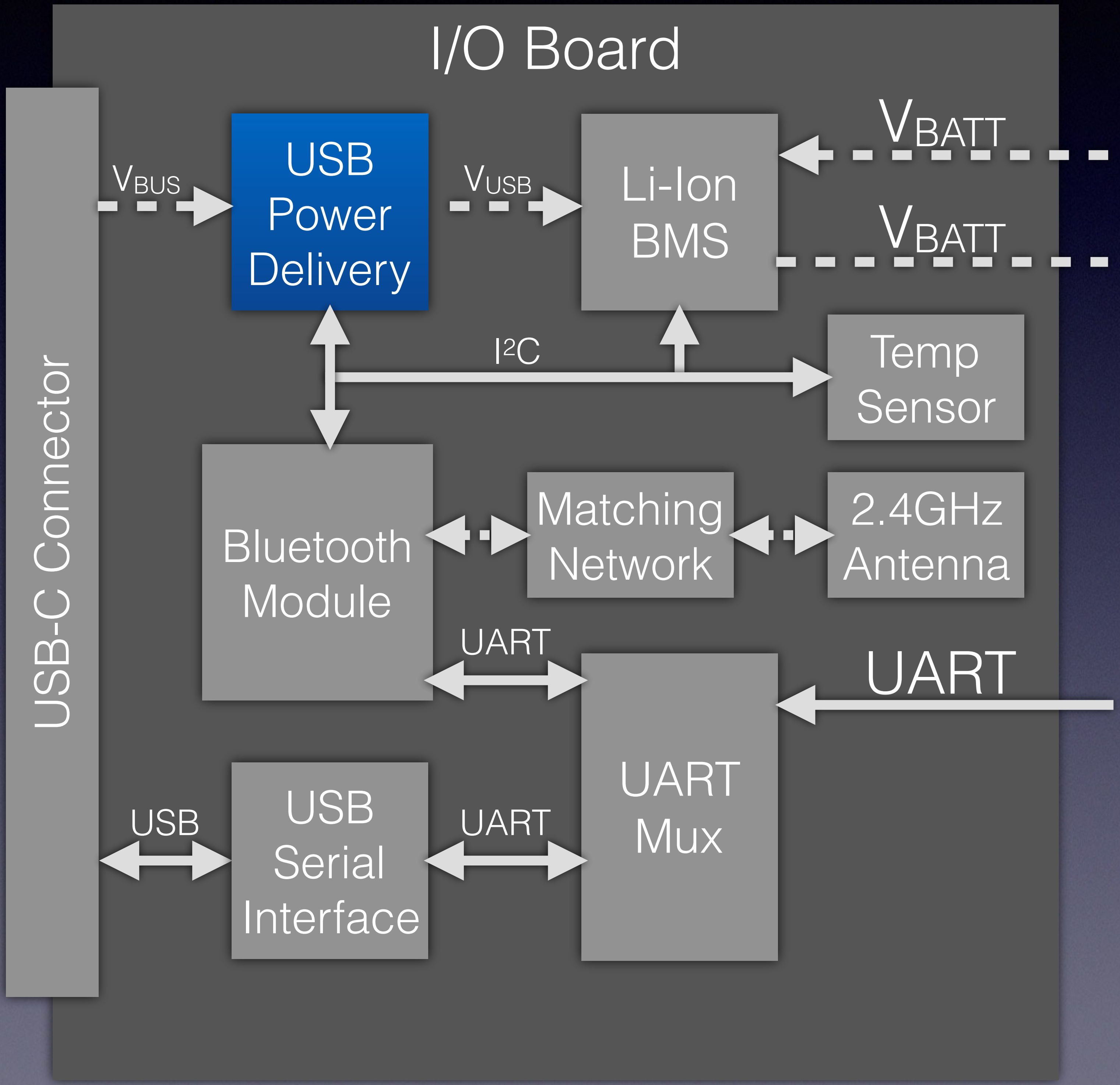


Bluetooth Module

- The brains of the I/O Board
- Executes code with an embedded microcontroller
- Very efficient wireless communications with Bluetooth Low Energy
- Controls the other peripherals on the I/O Board

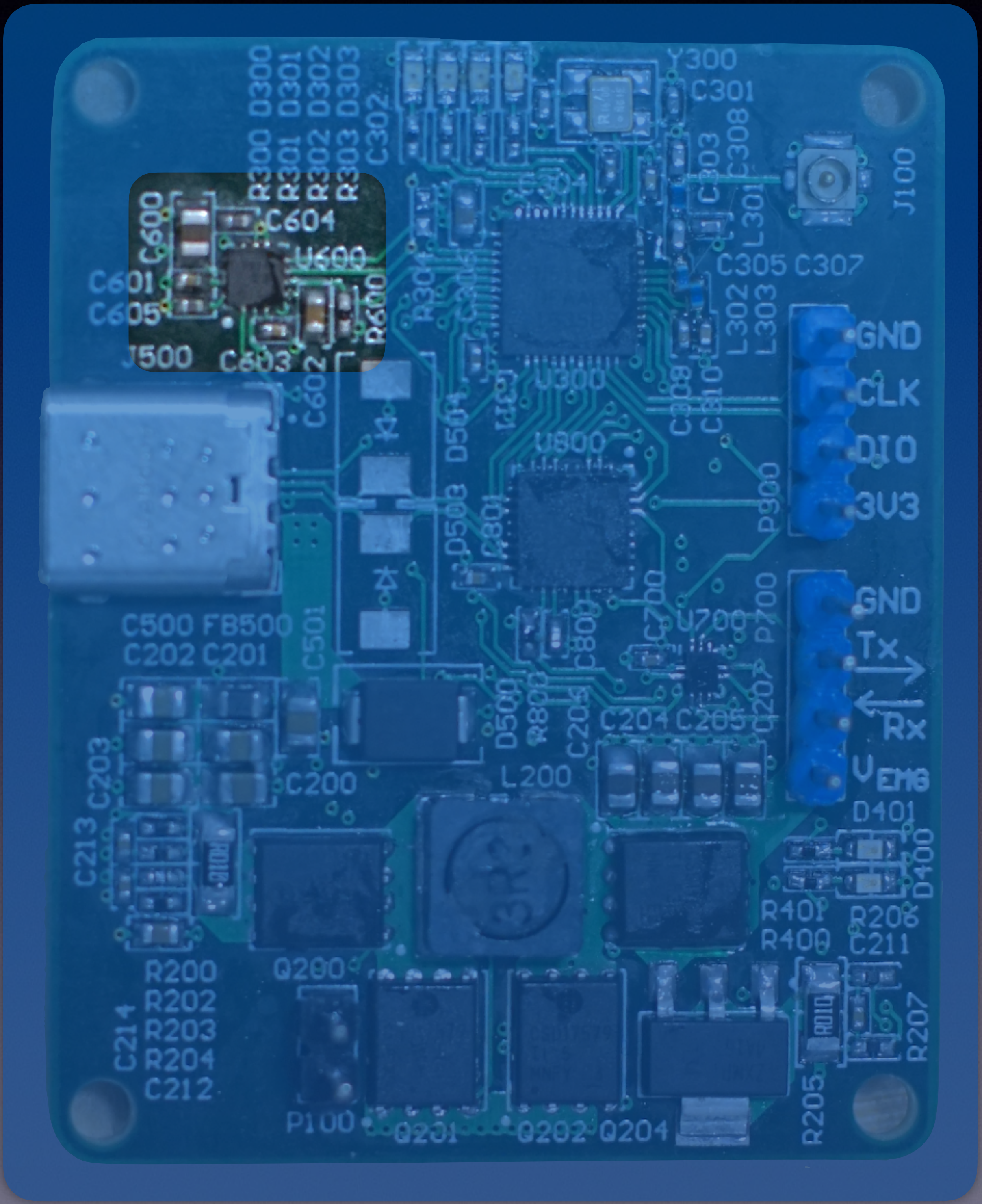


USB Power Delivery

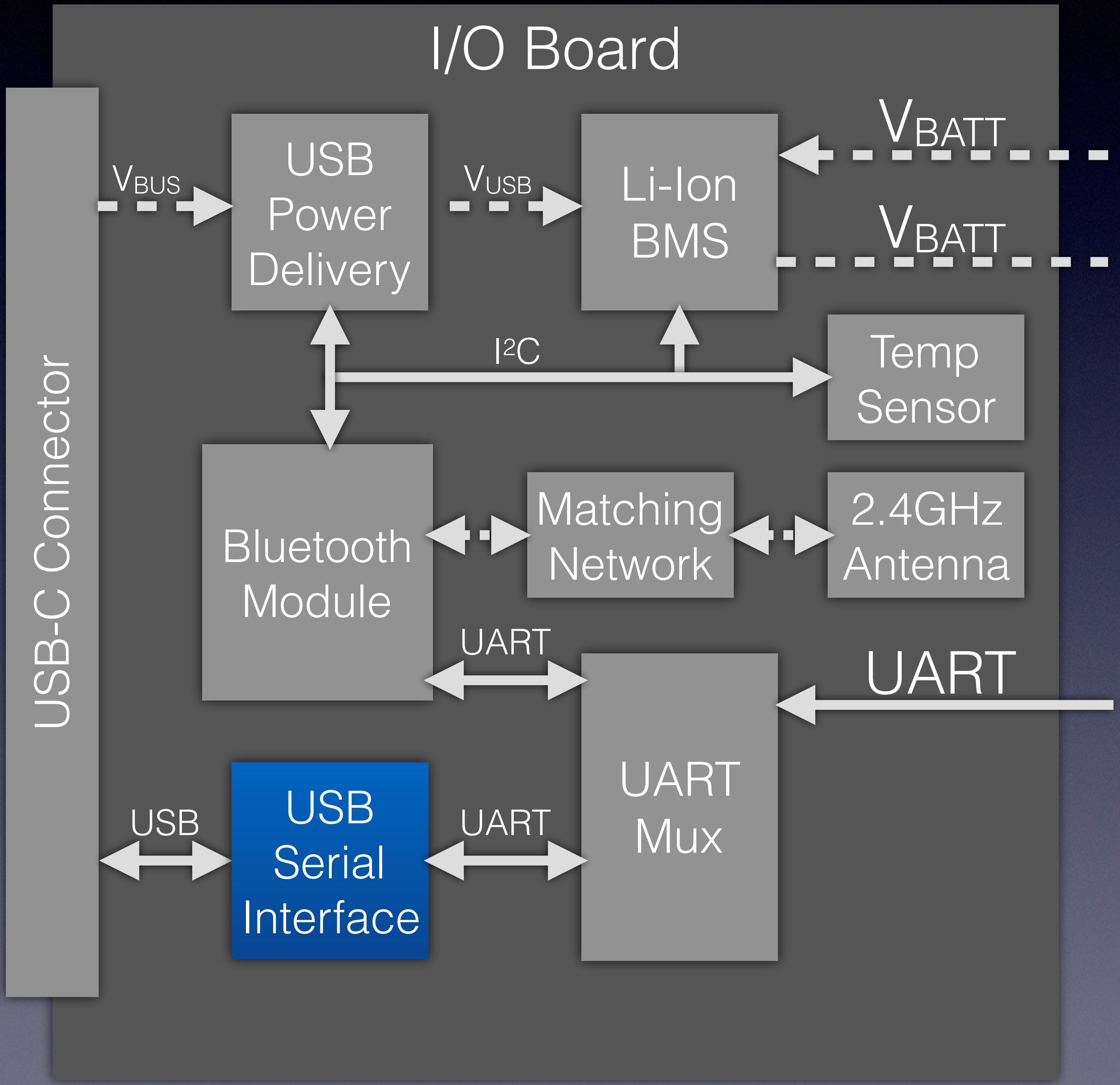


USB Power Delivery

- Allows the I/O Board to draw more power from USB chargers
- More input power reduces battery charging times
- Controlled by the Bluetooth Module

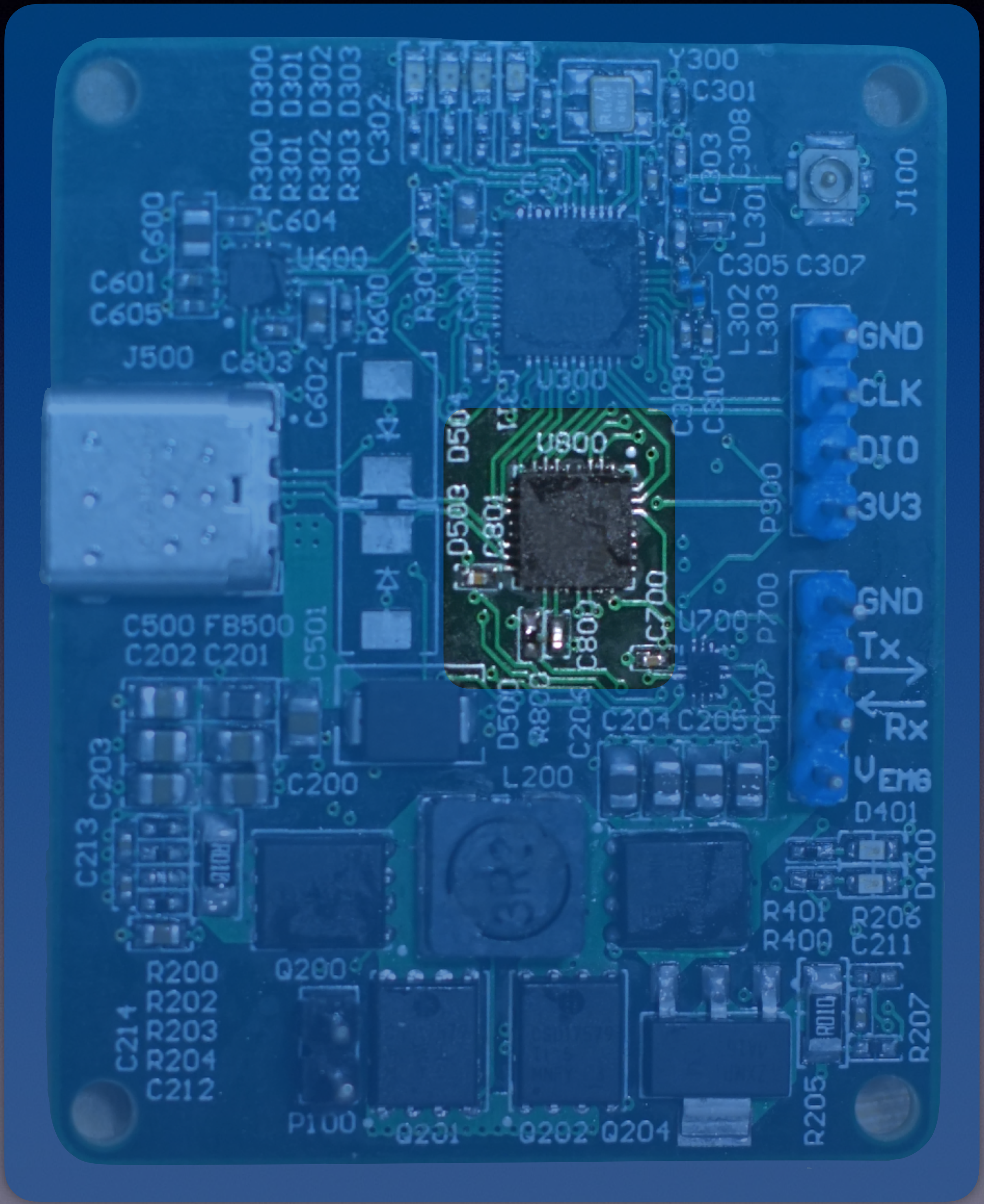


USB Serial Interface

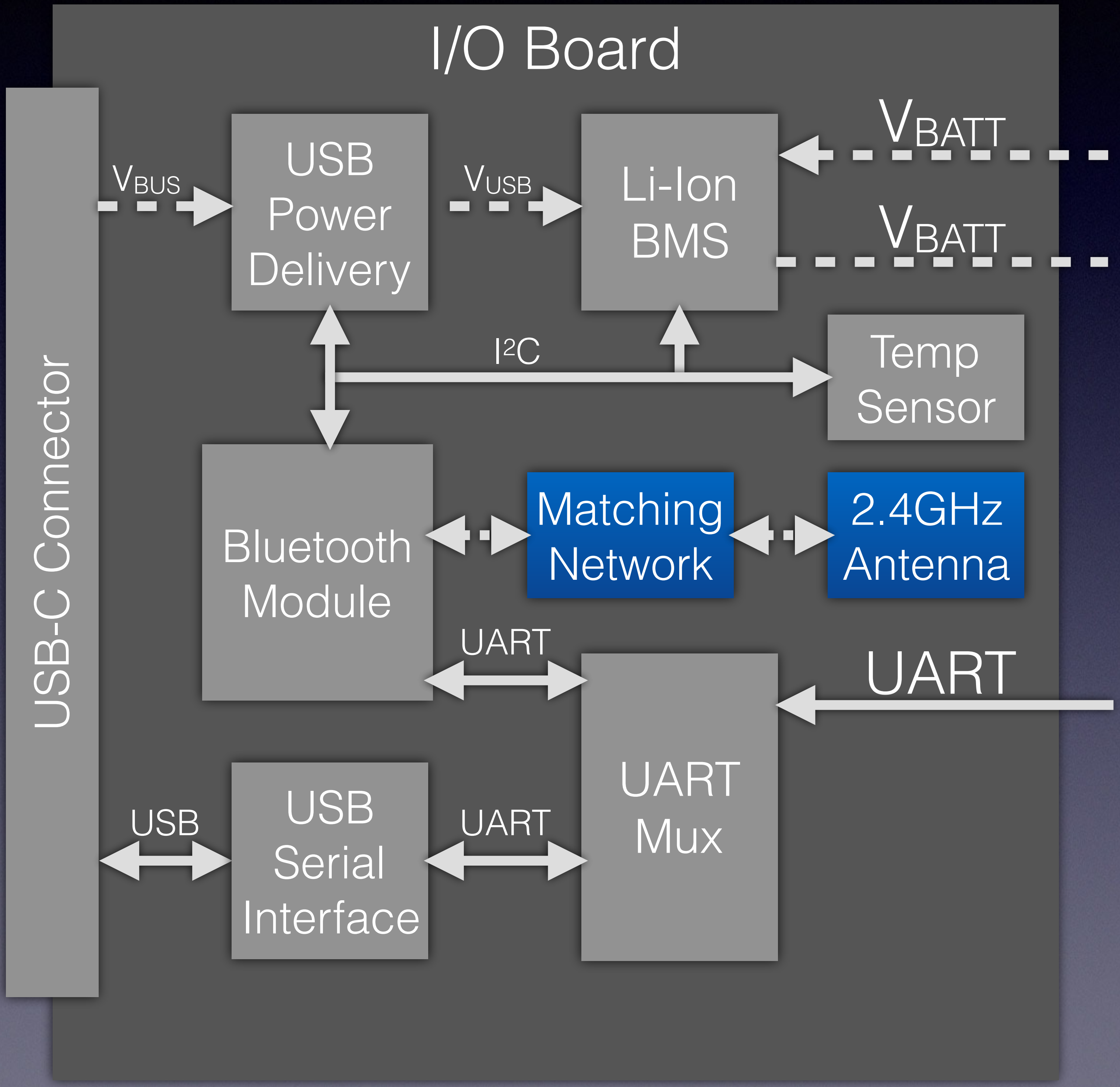


USB Serial Interface

- Converts USB data into a serial format
- Allows the I/O Board to communicate over USB

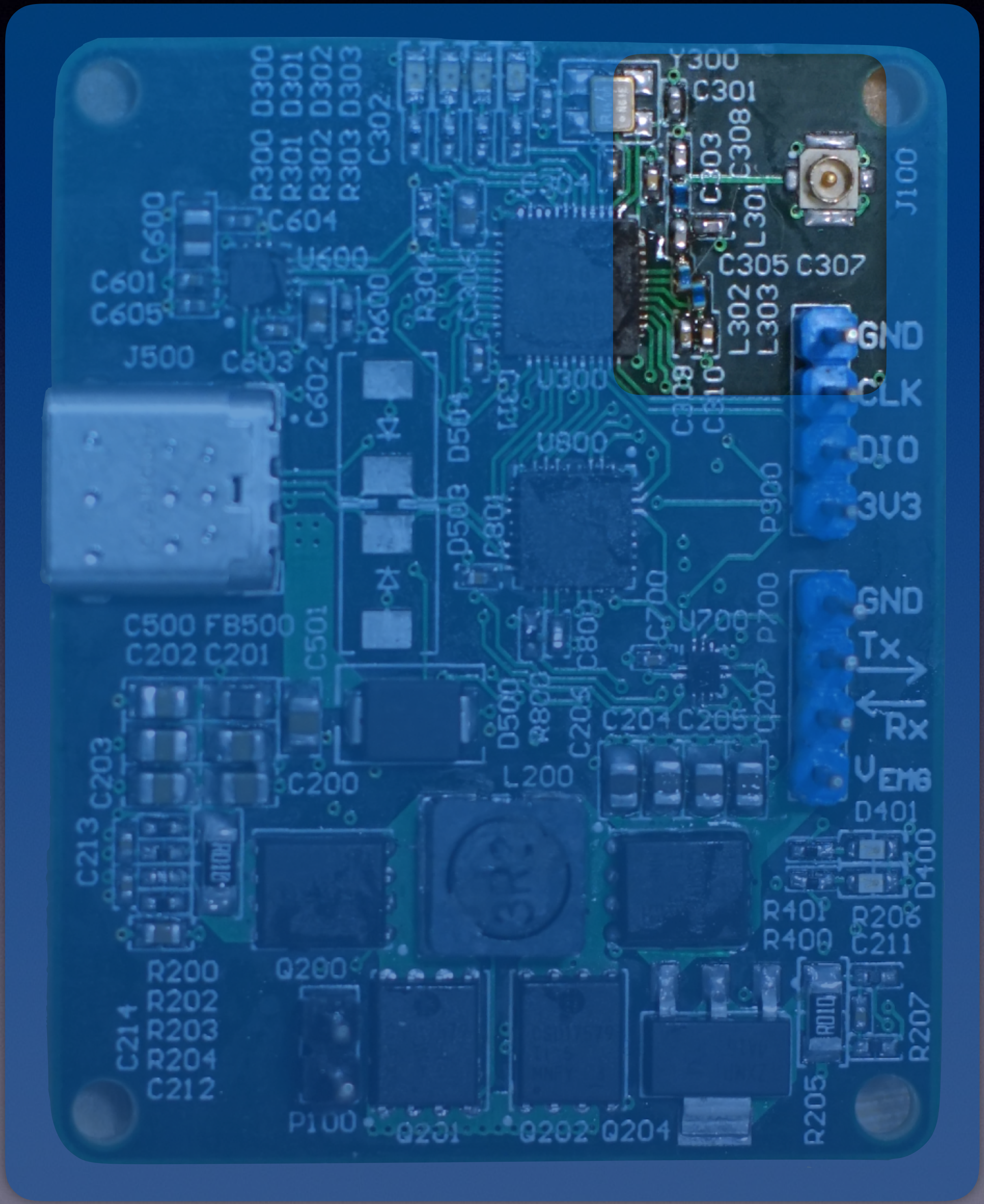


Radio-Frequency Front End

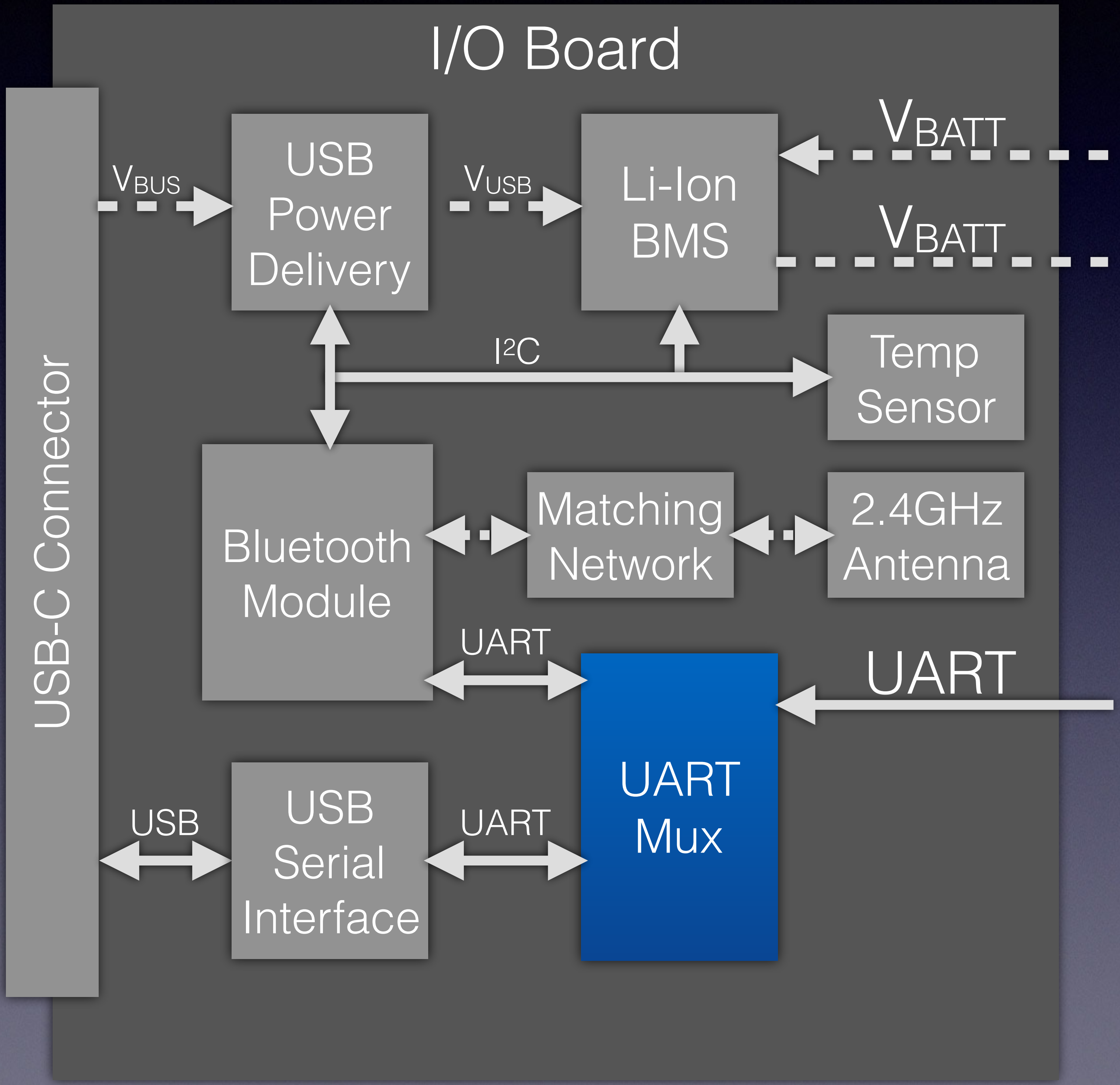


Radio-Frequency Front End

- Allows the Bluetooth module to drive an antenna
- Consists of a lumped-element matching network
- An external antenna is connected to the UMC jack

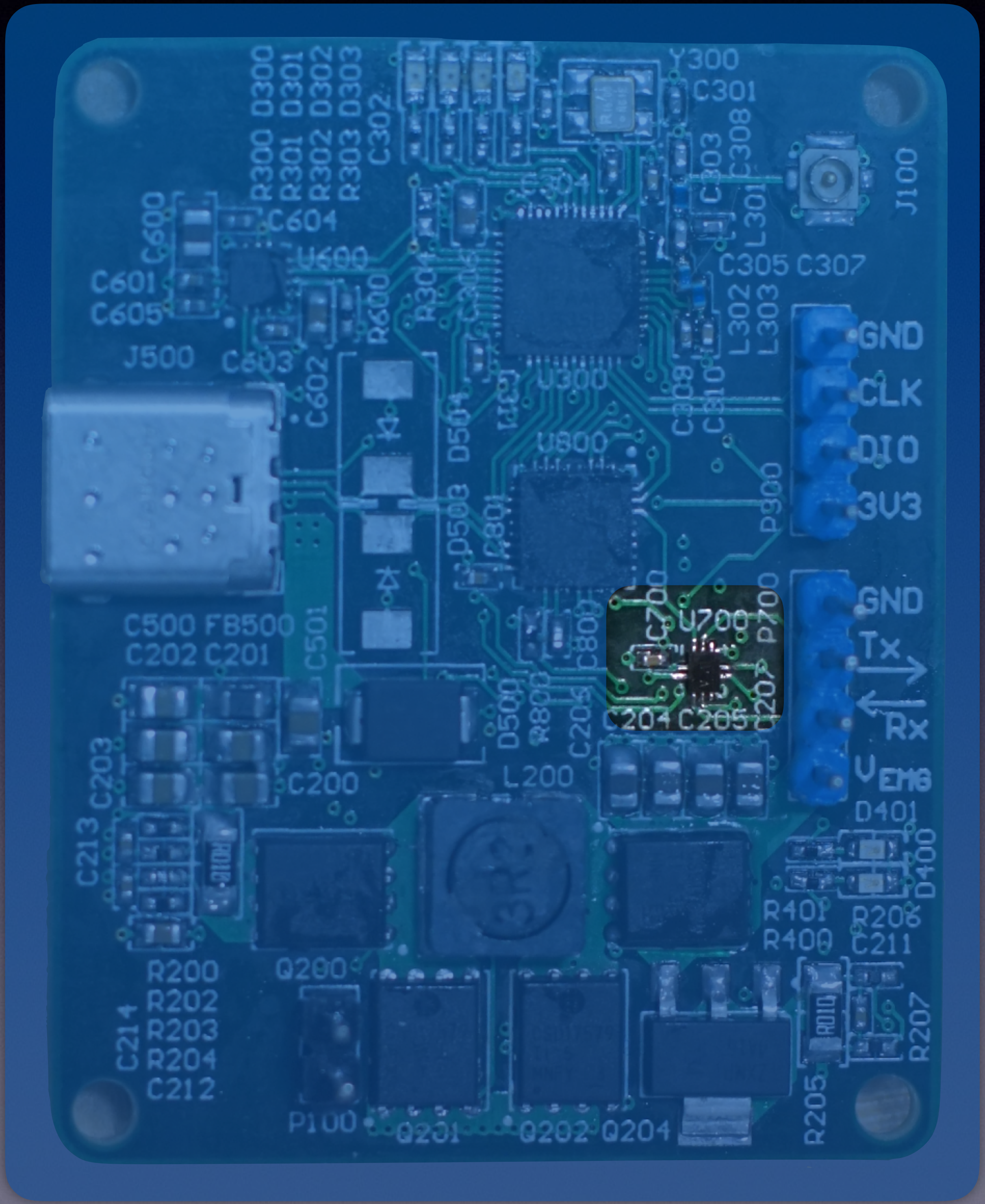


Serial Multiplexer

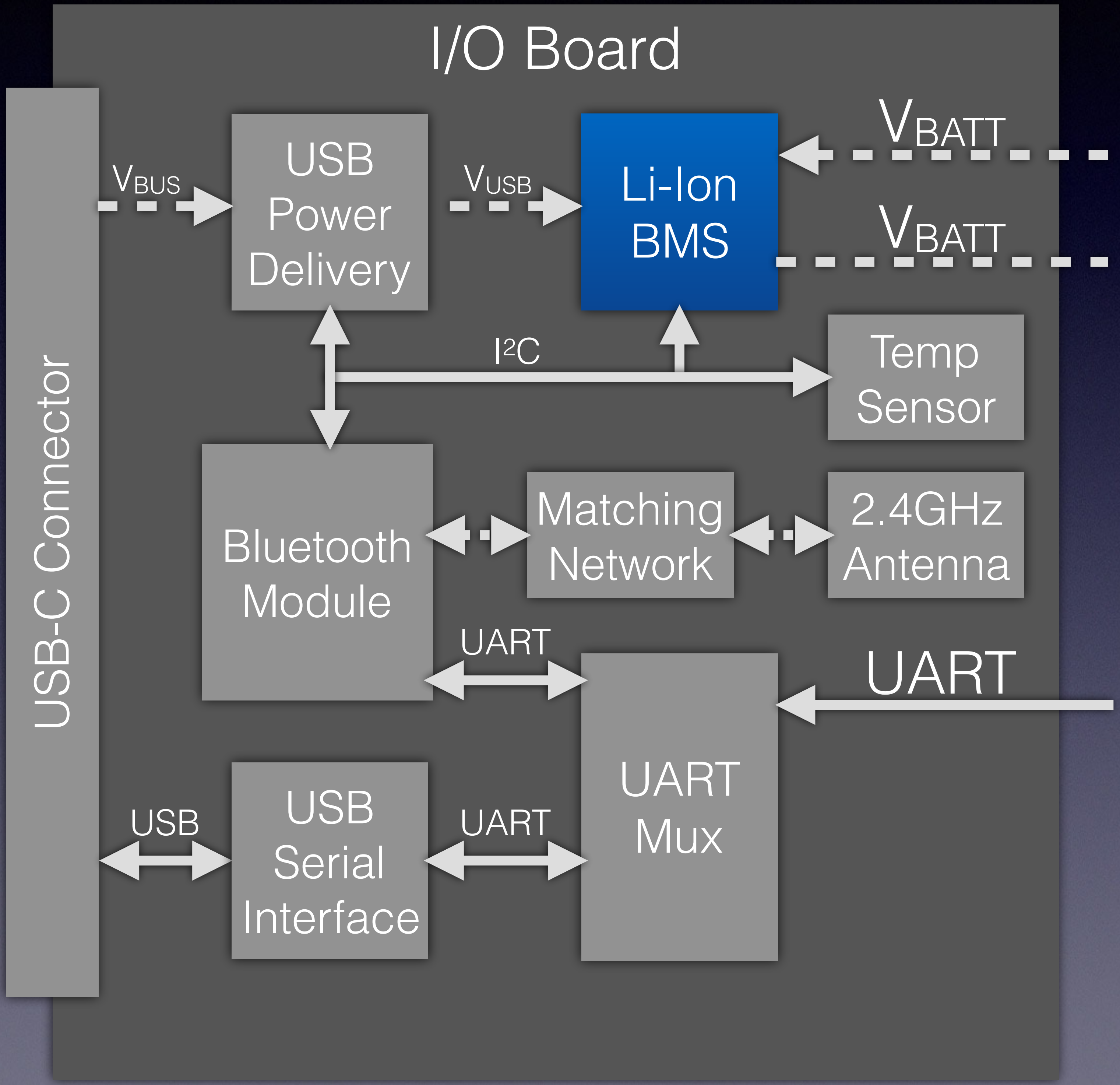


Serial Multiplexer

- Selects if the hand is controlled by USB or Bluetooth
- Controlled by the Bluetooth Module

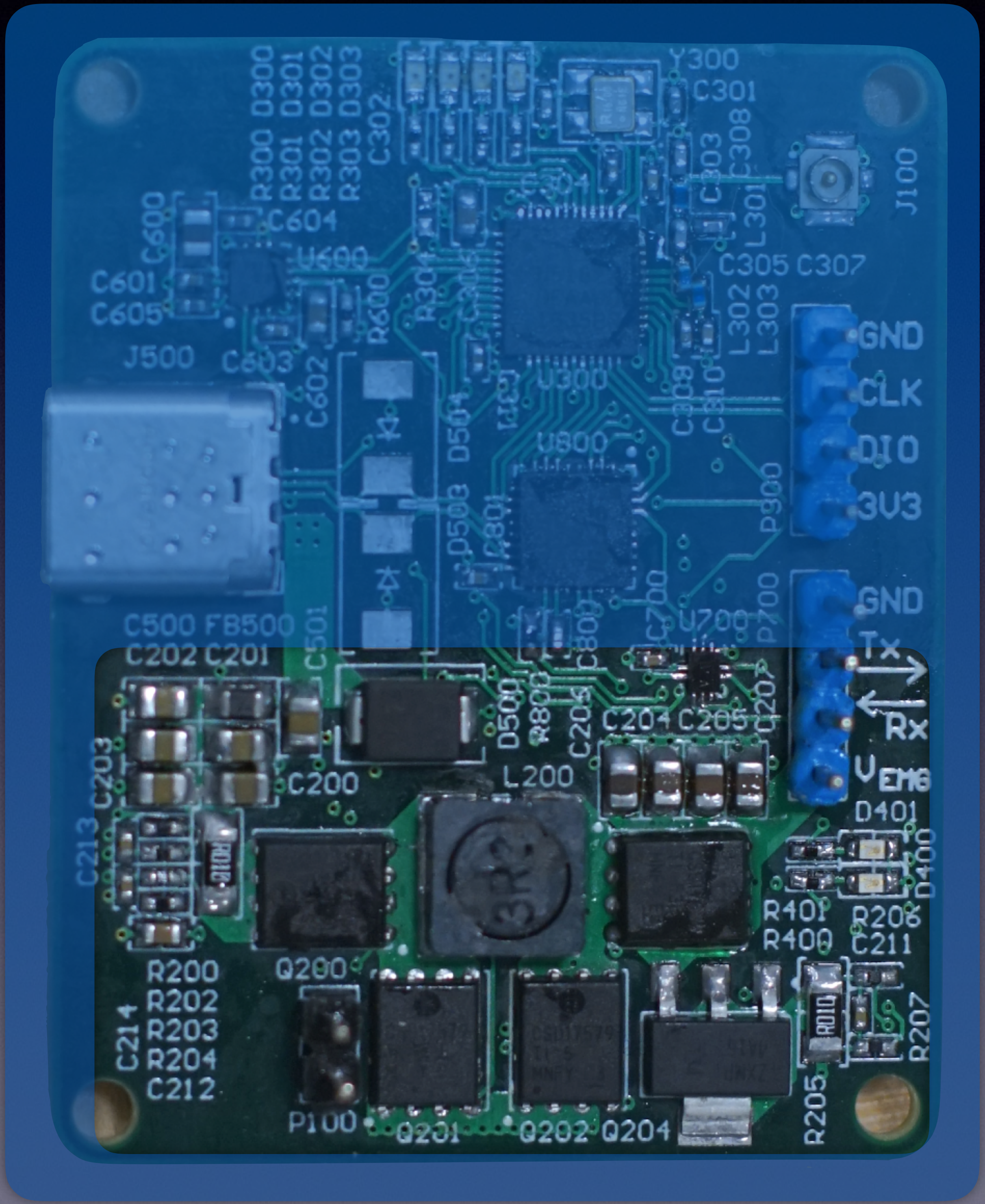


Battery Management System



Battery Management System

- Charges and discharges the battery
- Keeps the batteries from catching fire
- Monitors the battery's operating condition
- Controlled by the Bluetooth Module



Battery Management System

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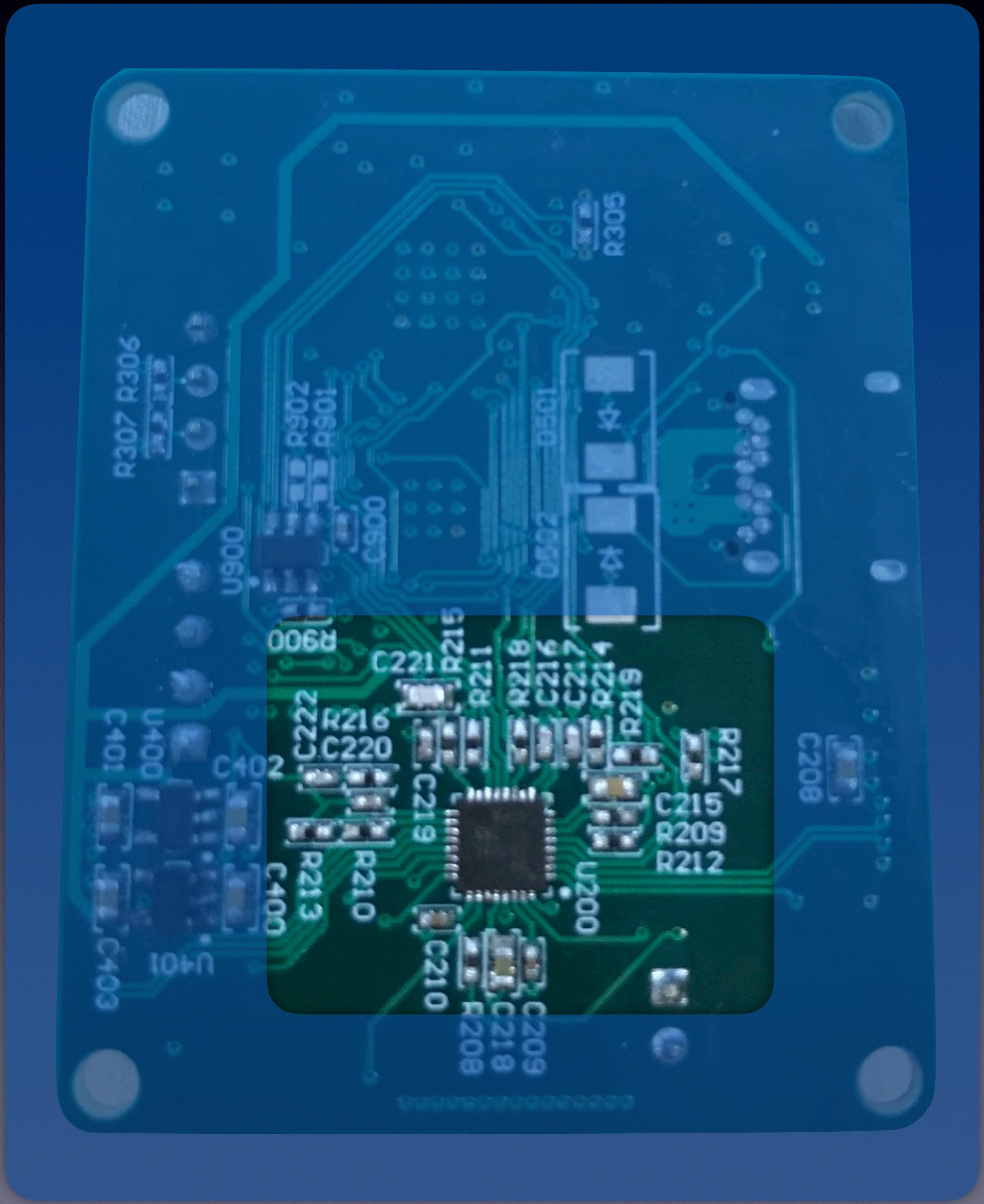
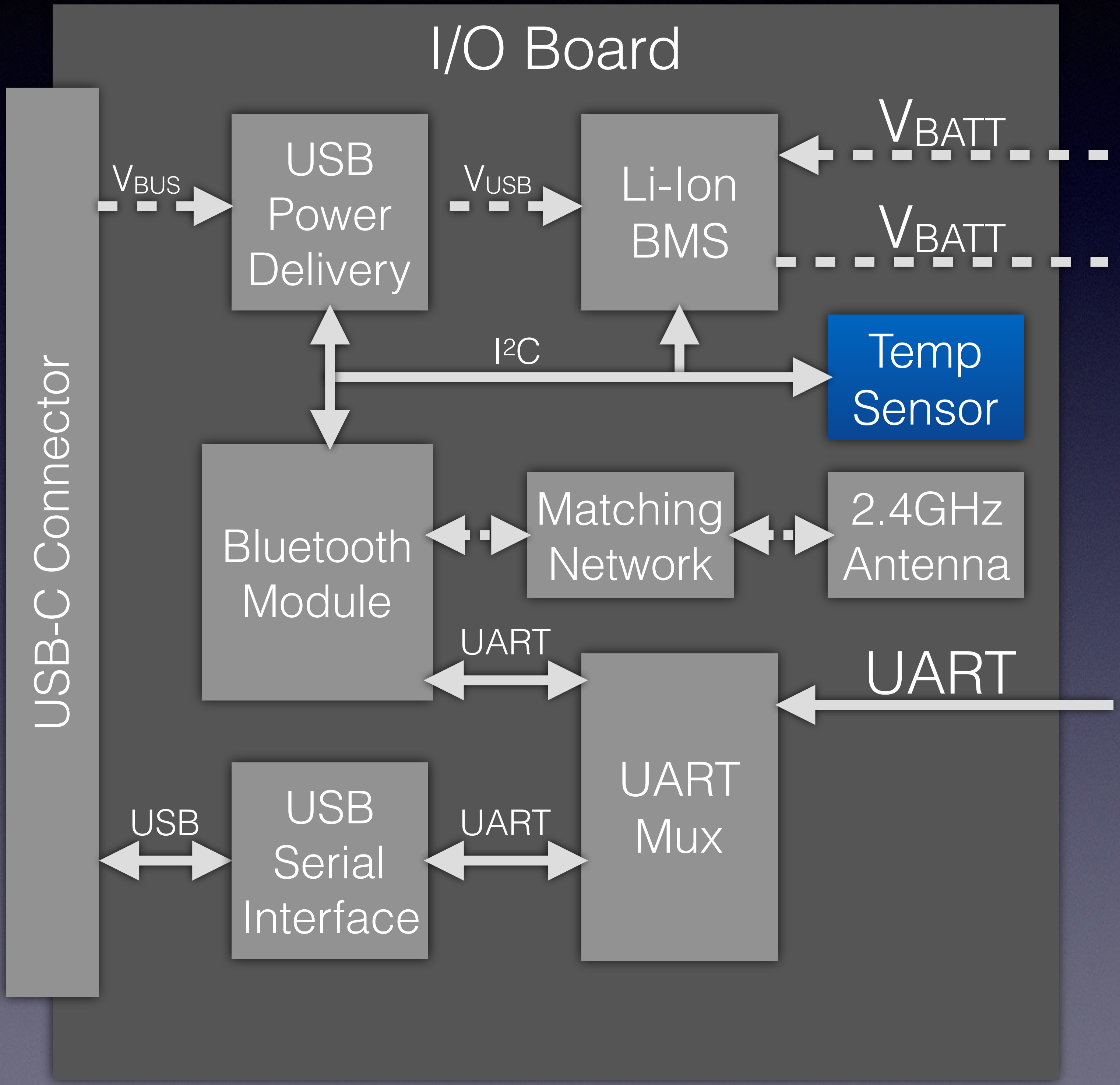


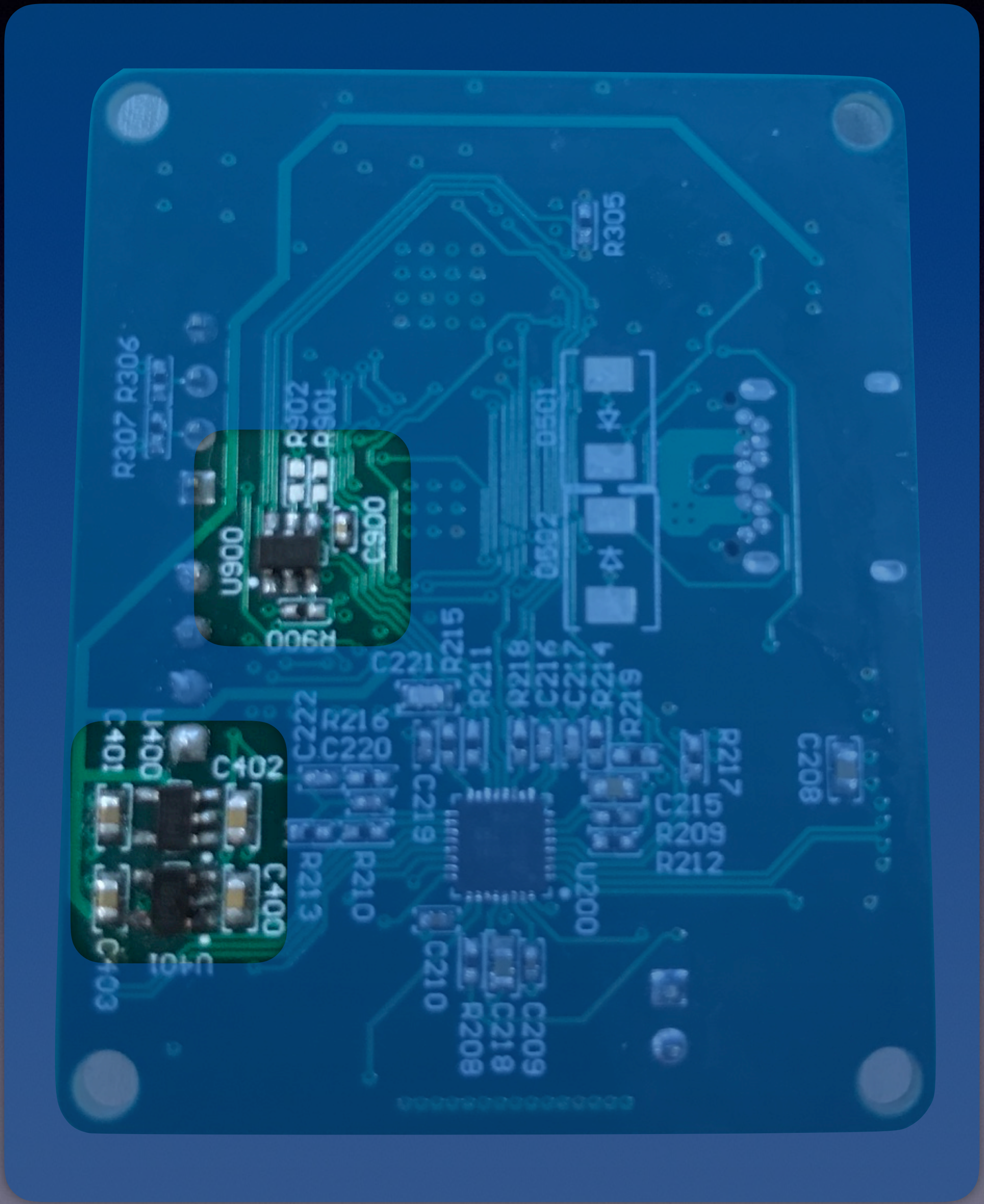
Supporting Circuitry



Supporting Circuitry

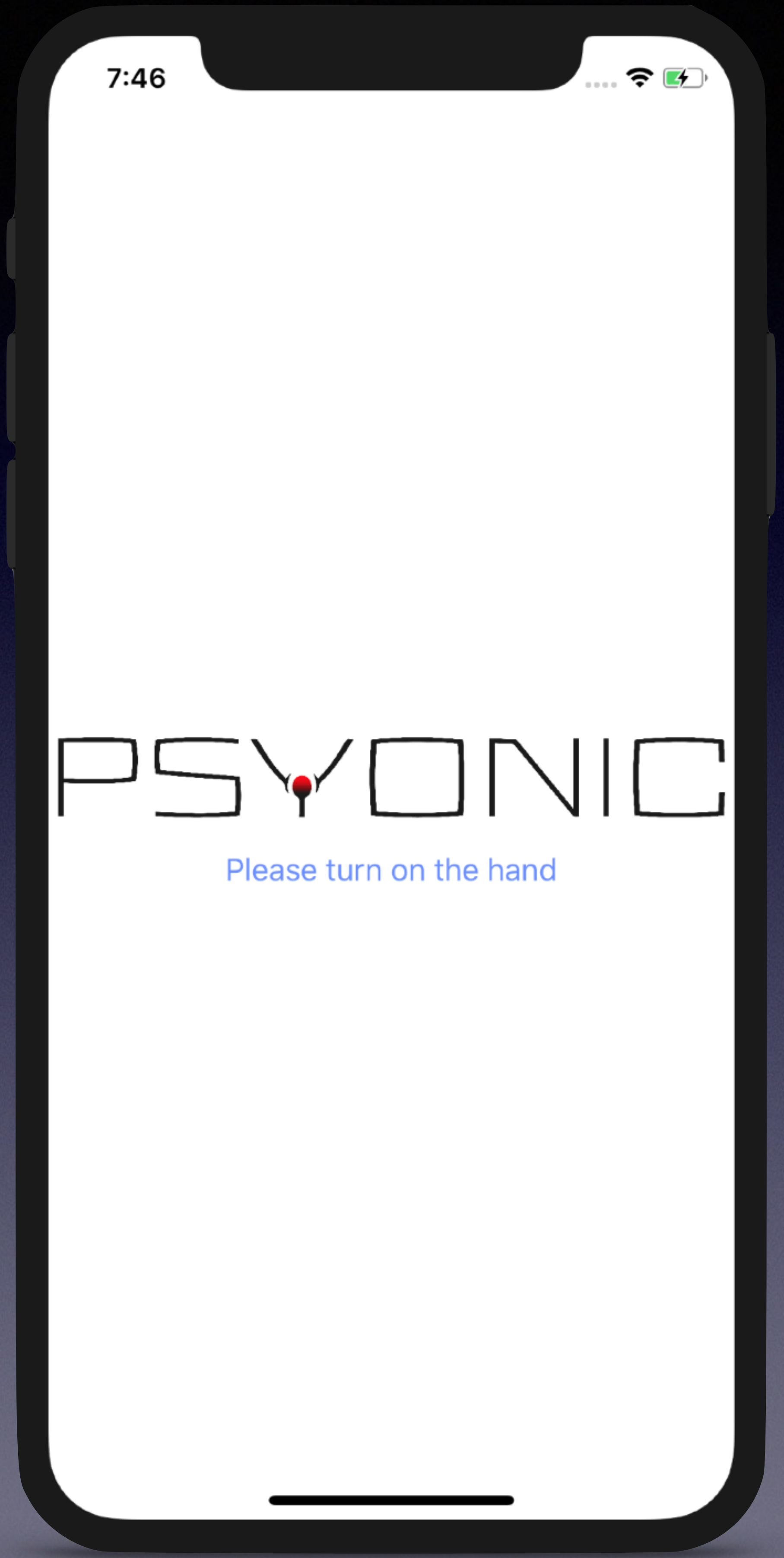
- Linear voltage regulators power onboard electronics

- A temperature sensor monitors the board temperature



iPhone App

Steven Sun



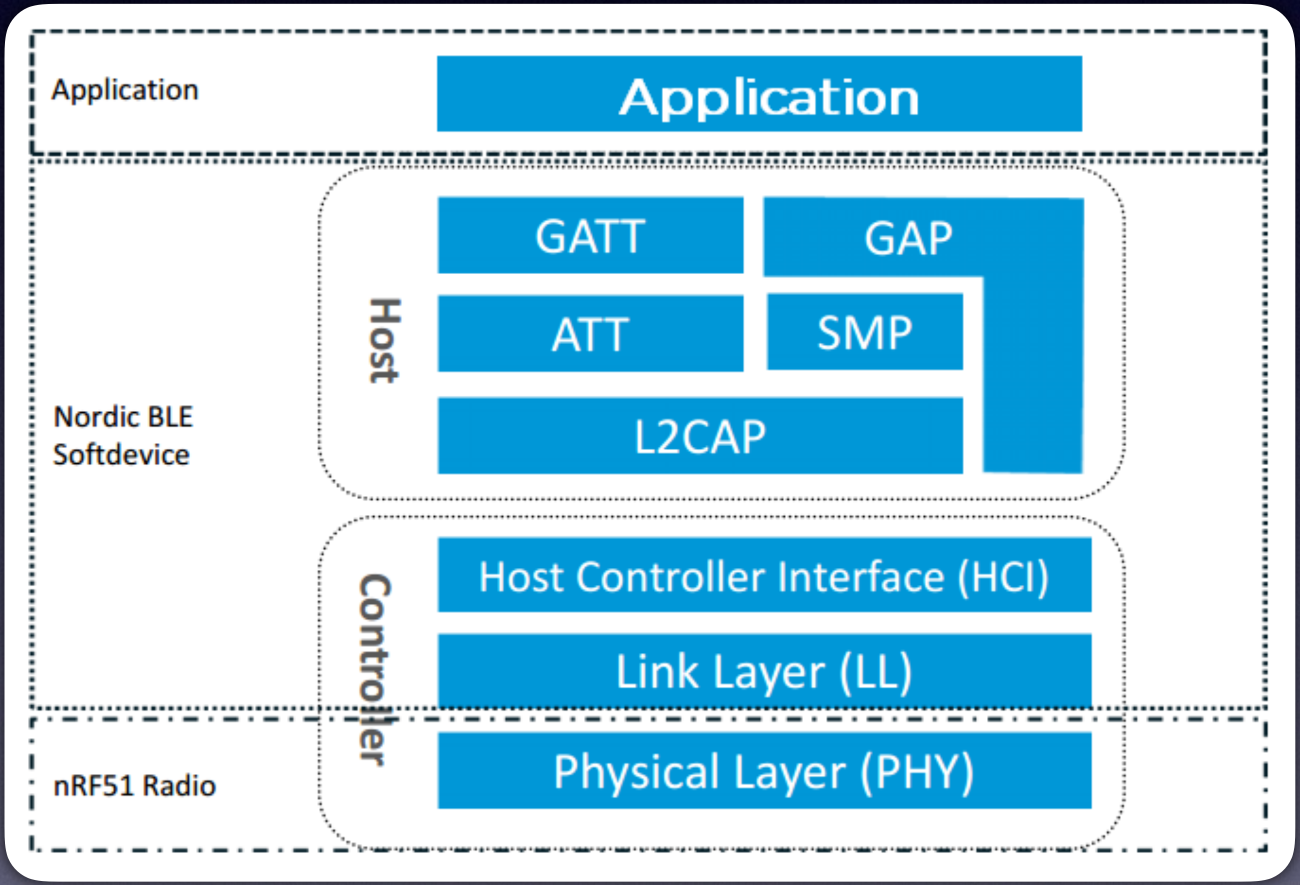
7:46

PSYONIC

Please turn on the hand

App Requirements

- Bluetooth Communications
  - Connects to the I/O Board
  - Sends and receives data from the hand
- User Interface
  - Displays information about the hand's operating status
  - Controls (buttons, sliders, etc.) get user input



App Demonstration

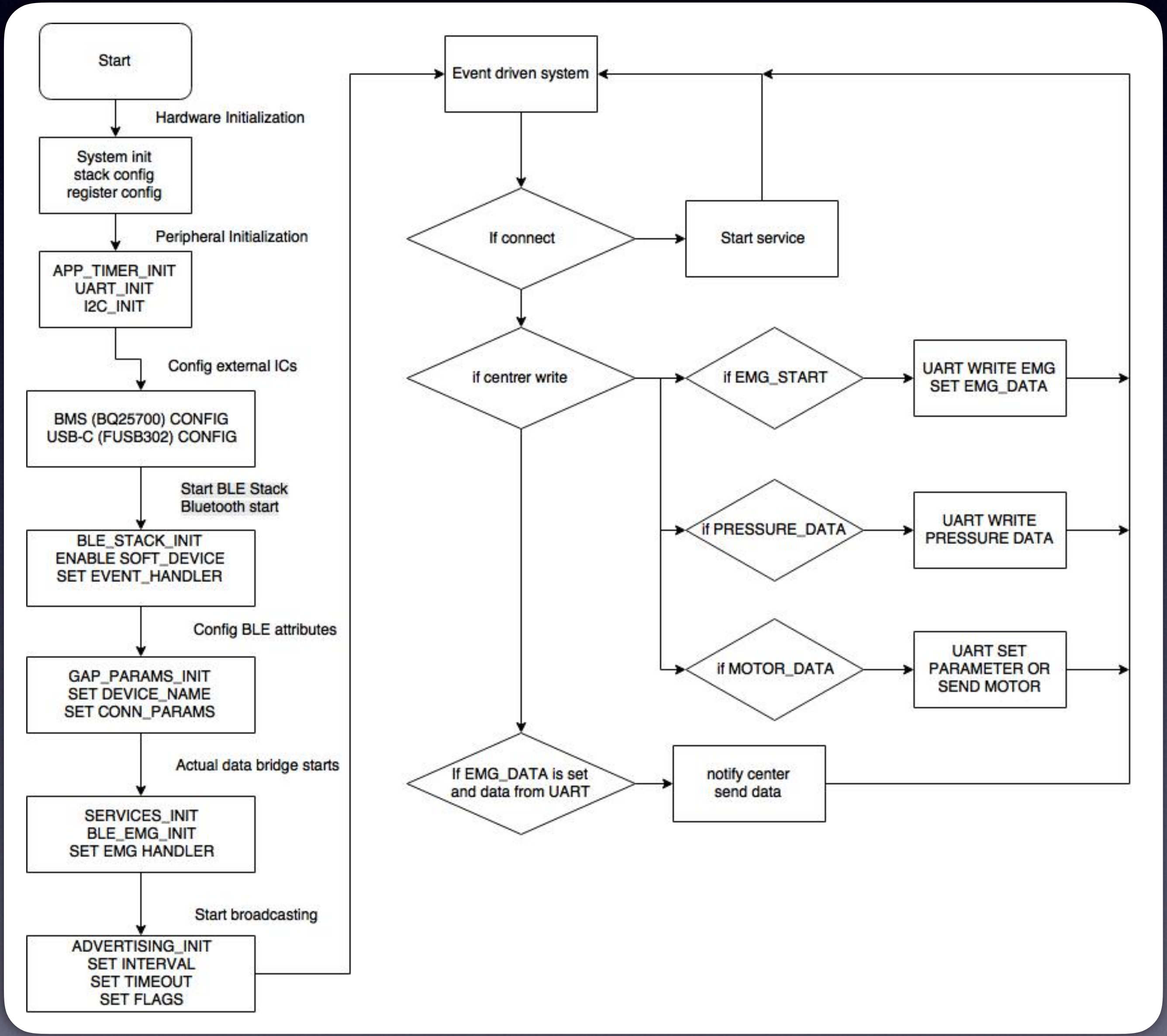
Firmware

Steven Sun

Bluetooth Low Energy

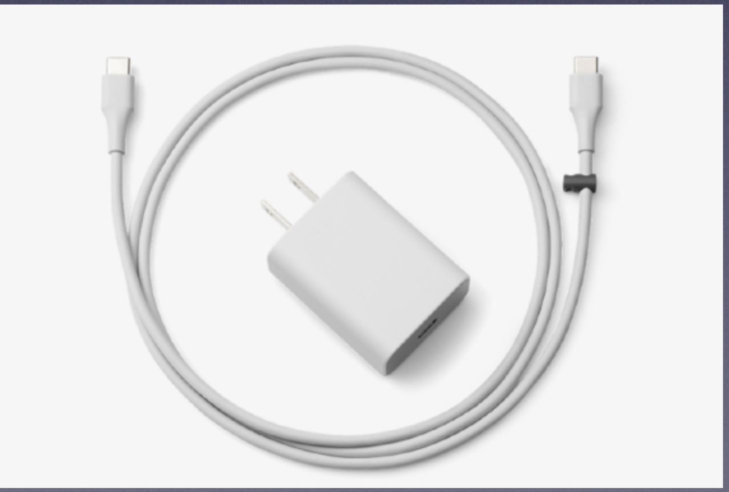
- Firmware needed to implement Bluetooth Low Energy protocol

- Quality firmware needed to ensure connection stability, speed, and security

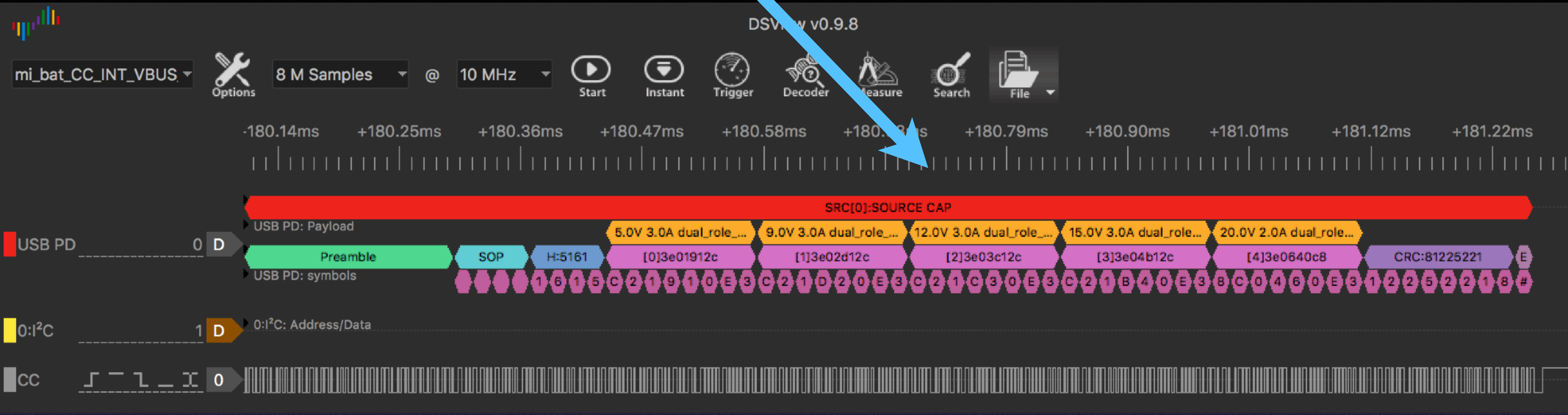


USB Power Delivery

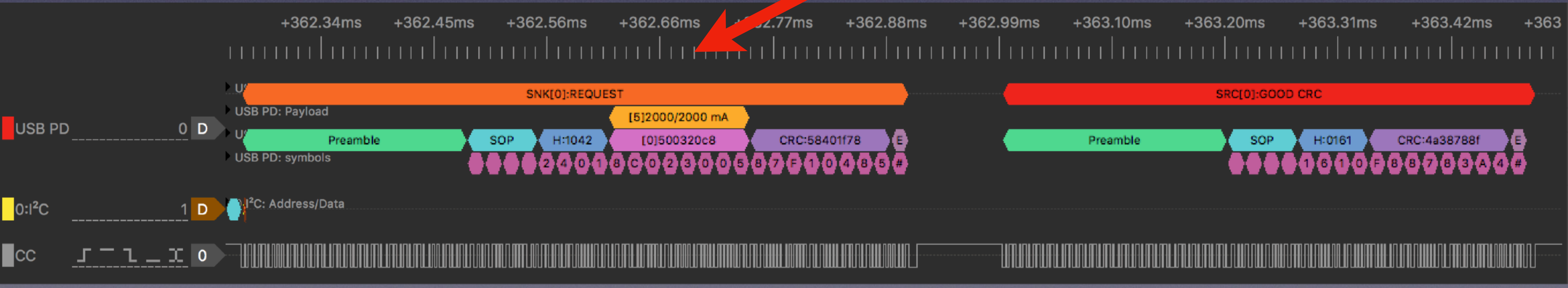
- Communicates with USB wall chargers
- Reduces battery charge times
- Compatible with legacy USB chargers as well



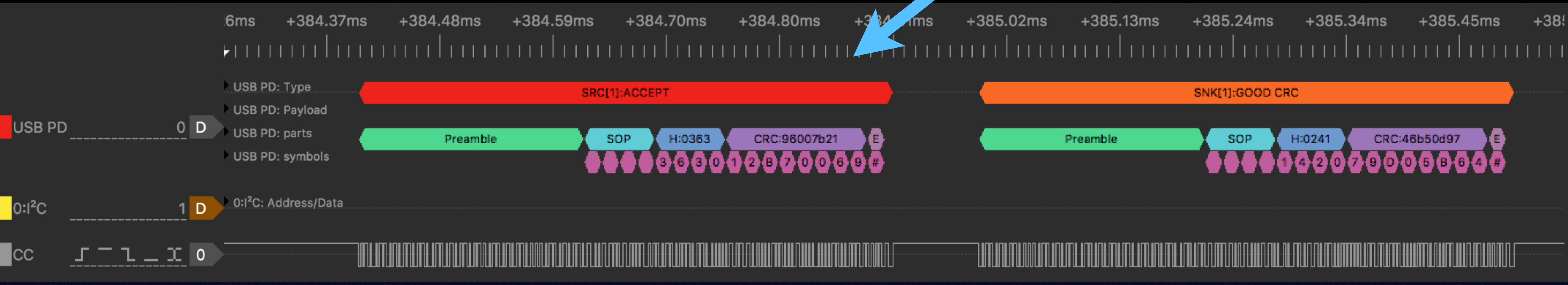
1.Hello, I am Charger, I can provide these power settings



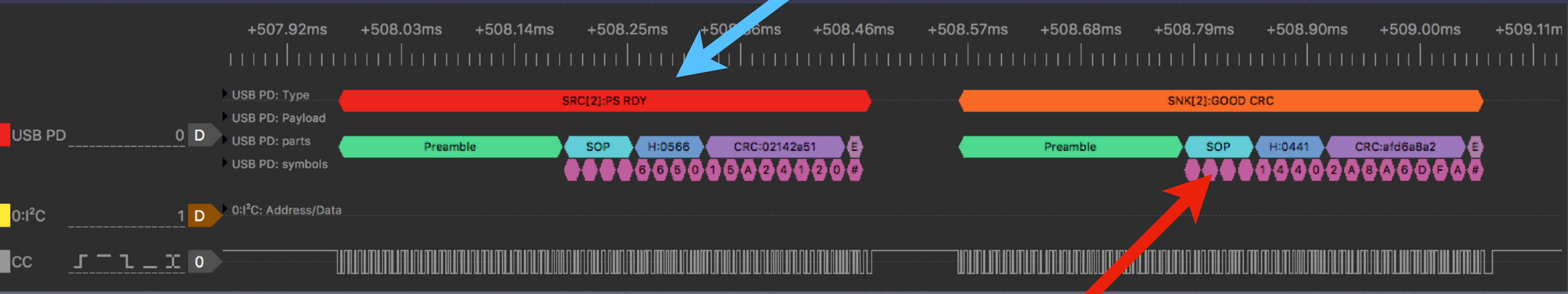
2.Hello, I am the hand, can I get this power setting please



3.Hello, I am Charger, that sounds good, let me get ready.



4.Hello, I am Charger, I AM READY, here you go

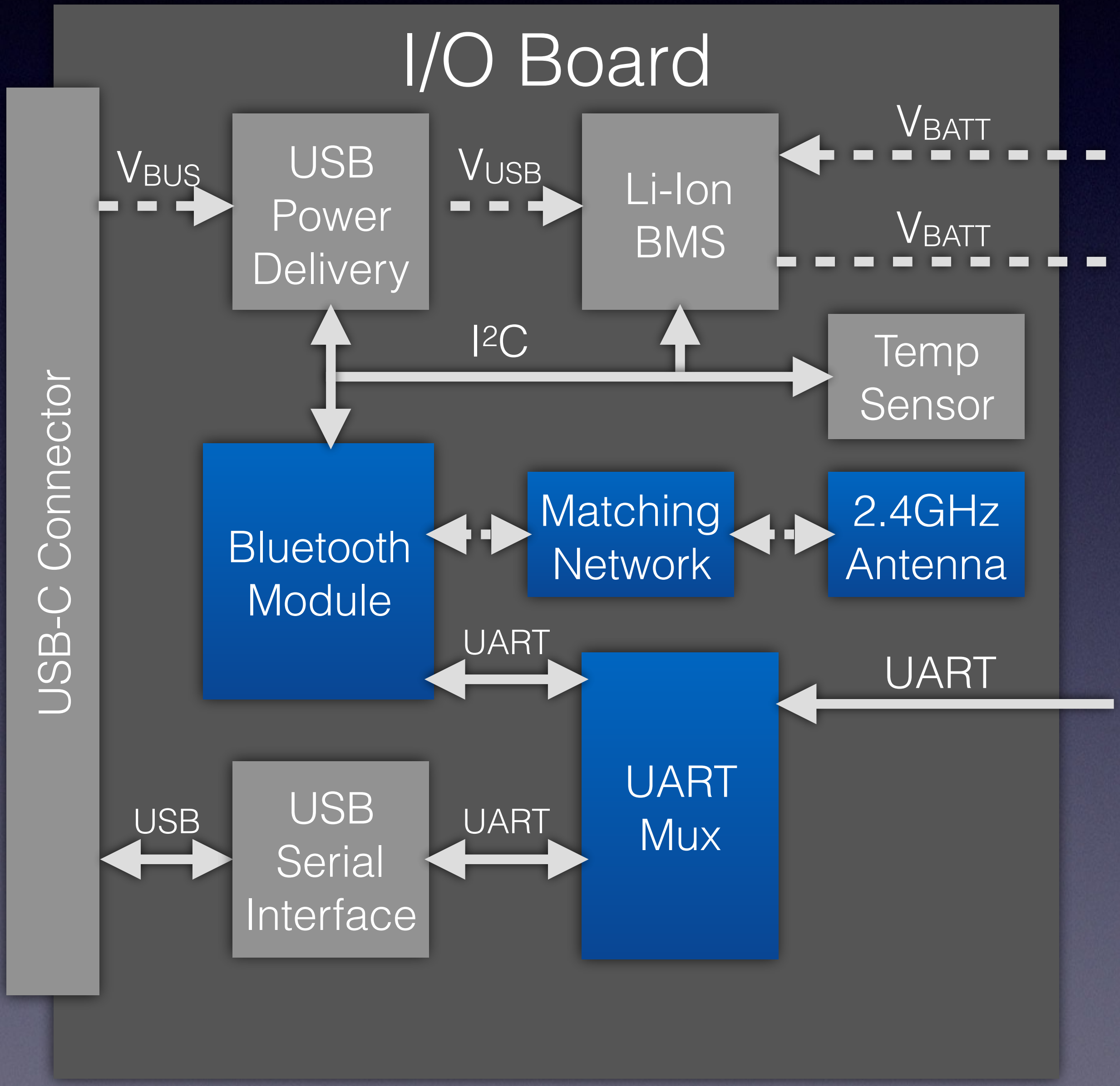


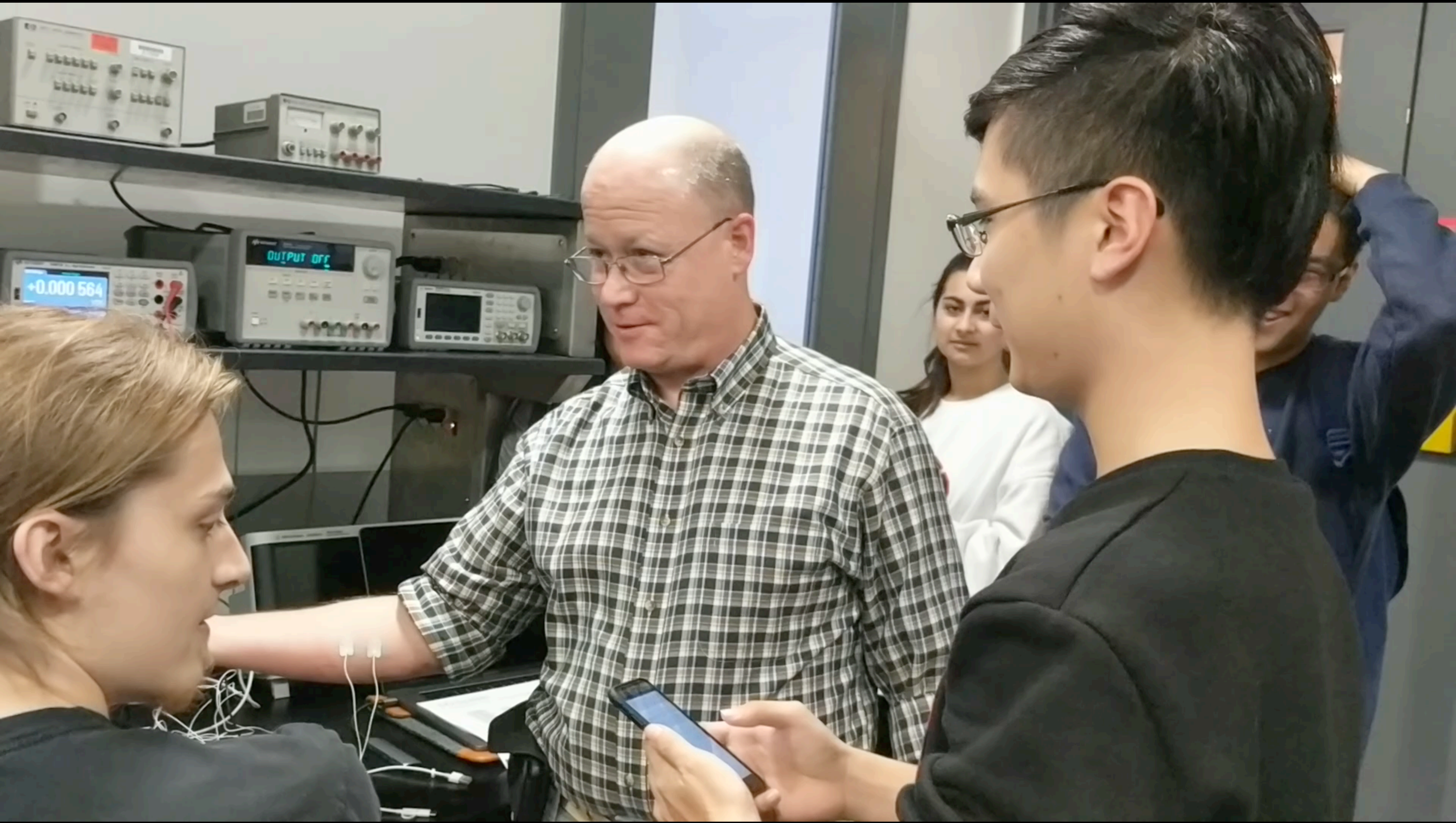
5.Hello, I am hand, awesome, thank you

Results

Bluetooth Low Energy

- Implemented a full Bluetooth Low Energy software stack
- Communicated with multiple smartphones
- Achieved full functionality and met all requirements

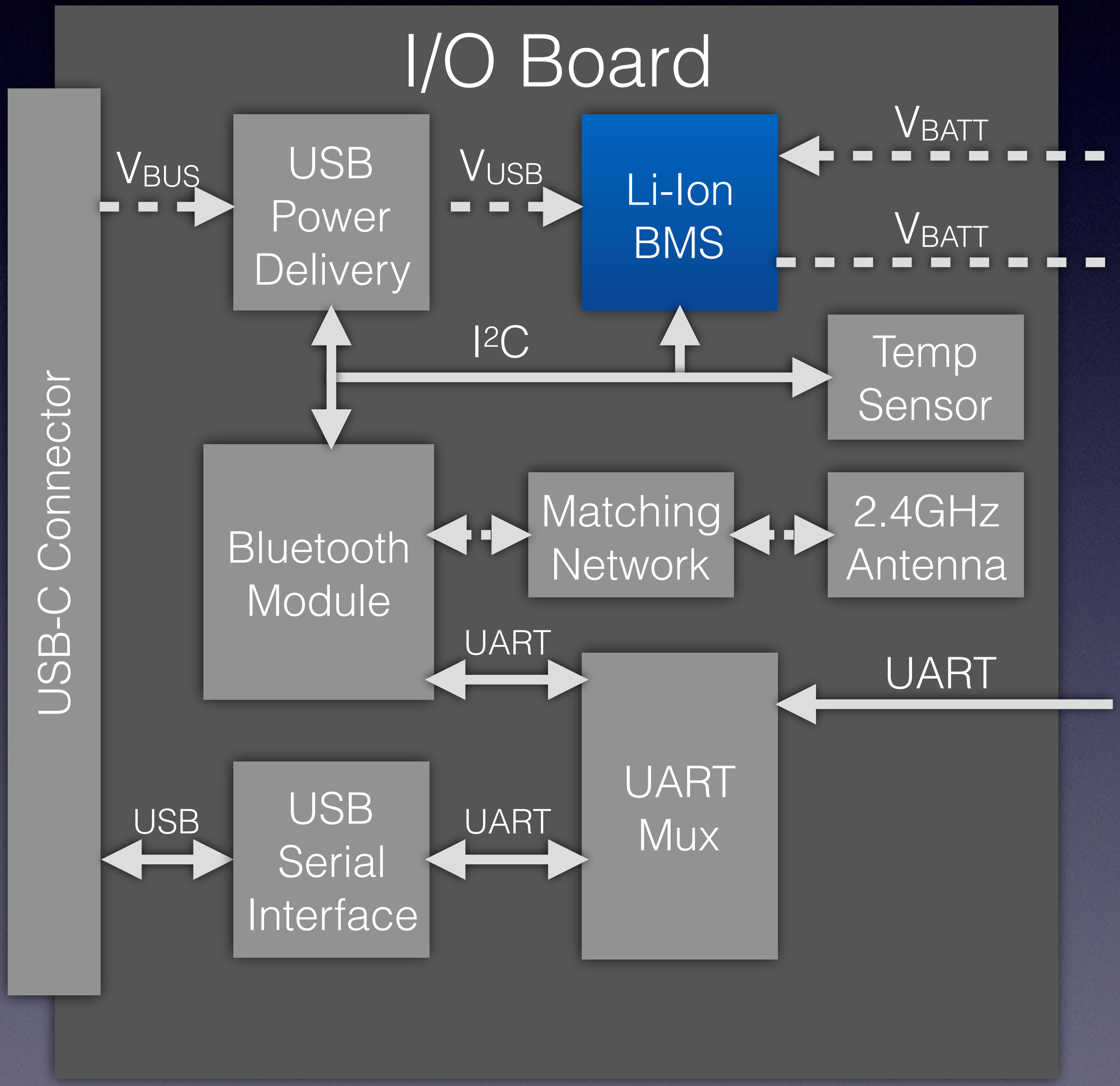




+0.000 564
OUTPUT OFF

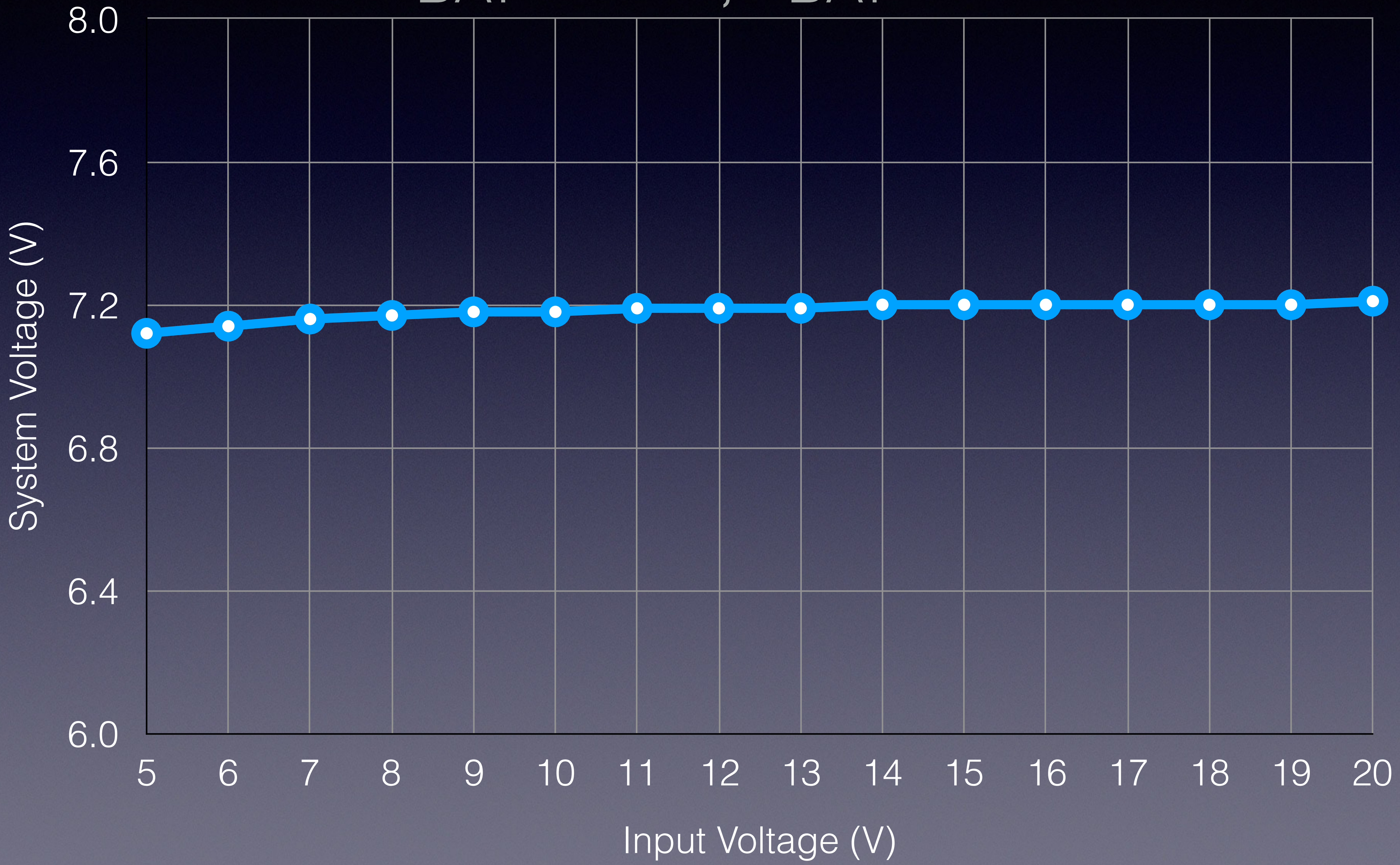
Battery Management System

- Battery can be charged properly across the entire battery voltage range
- Capable of preventing the battery from operating outside of its safe operating area
- Battery voltage and current can be monitored by the Bluetooth Module
- Meets all requirements set in the Design Document



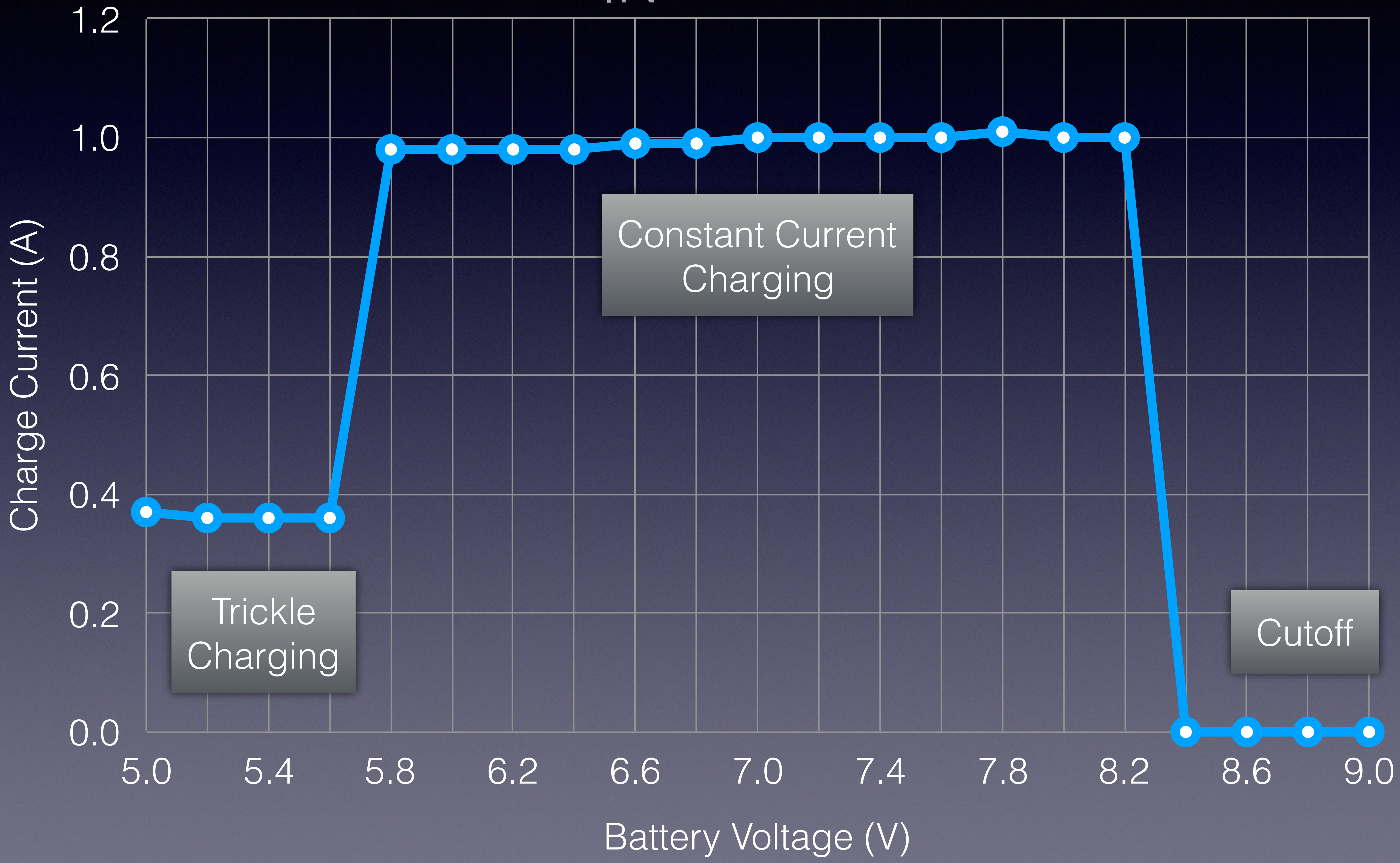
Input Voltage Sweep

V_{BAT} = 7V, I_{BAT} = 1A



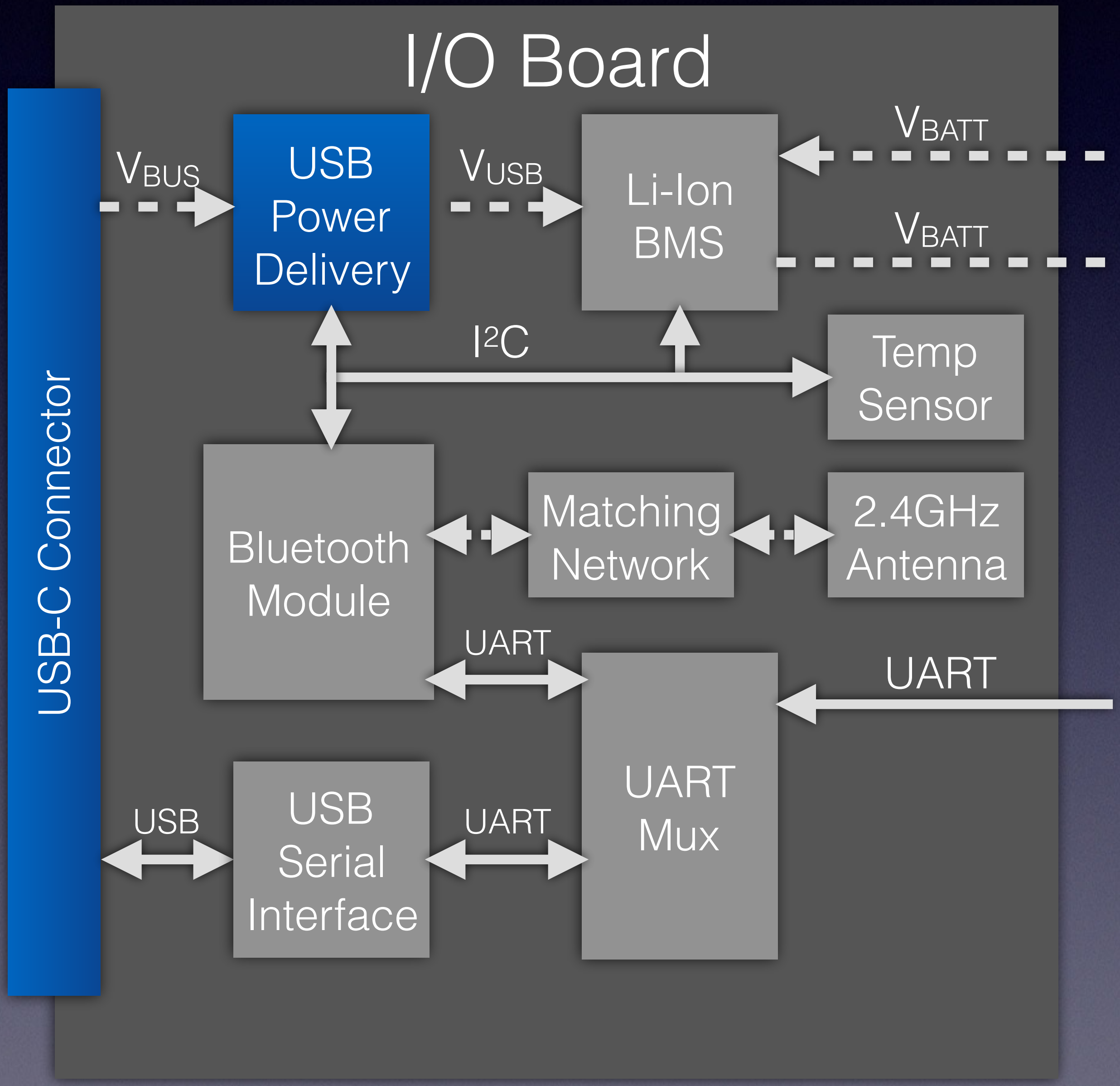
Battery Charge Current

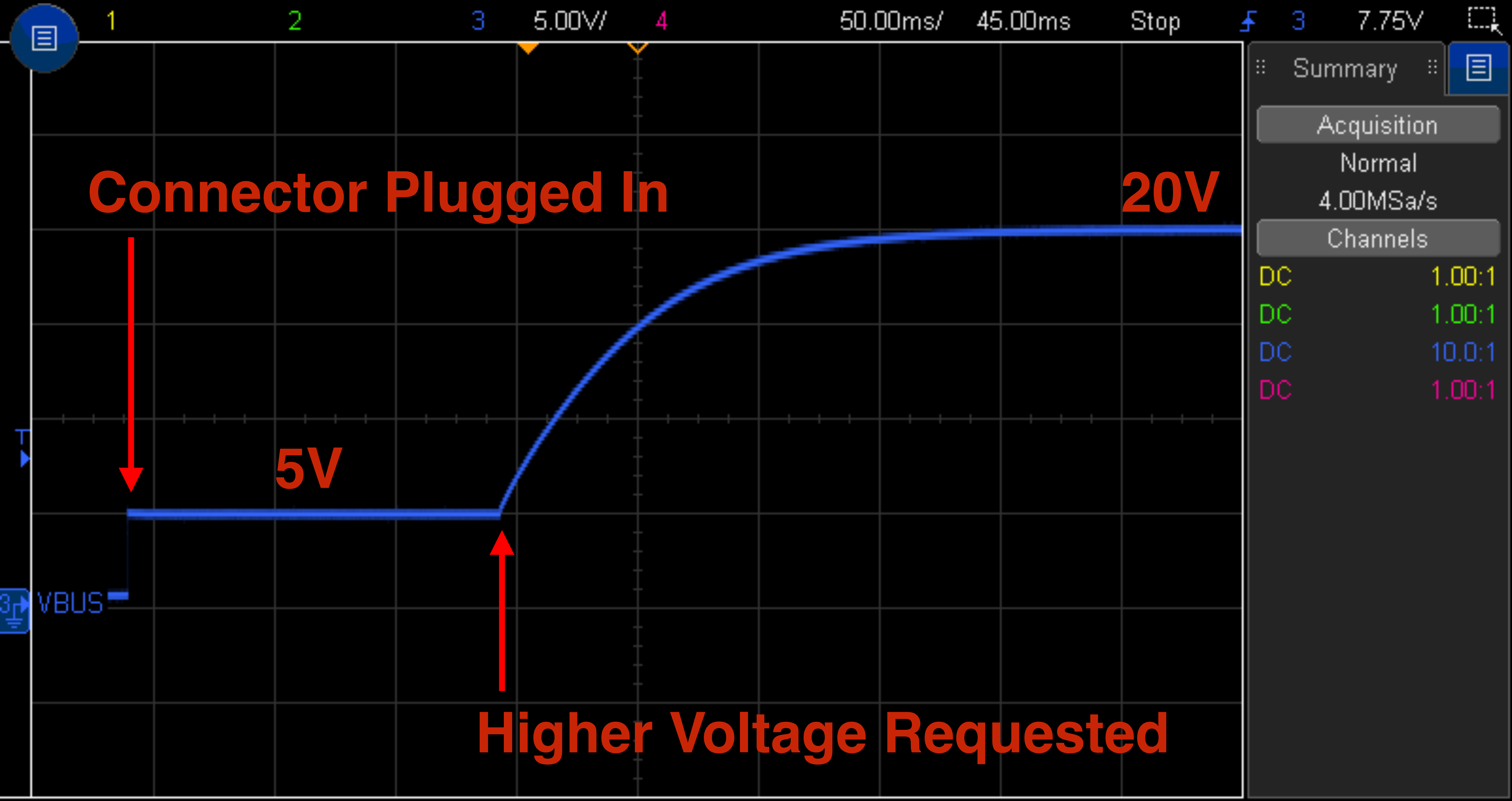
V_{IN} = 20V



USB Power Delivery

- Able to communicate with chargers from Samsung, Google, and a variety of other brands
- Successfully increased the supply voltage upon request
- Met requirements set in the Design Document





Summary

Acquisition
Normal
4.00MSa/s

Channels

DC	1.00:1
DC	1.00:1
DC	10.0:1
DC	1.00:1

Connector Plugged In

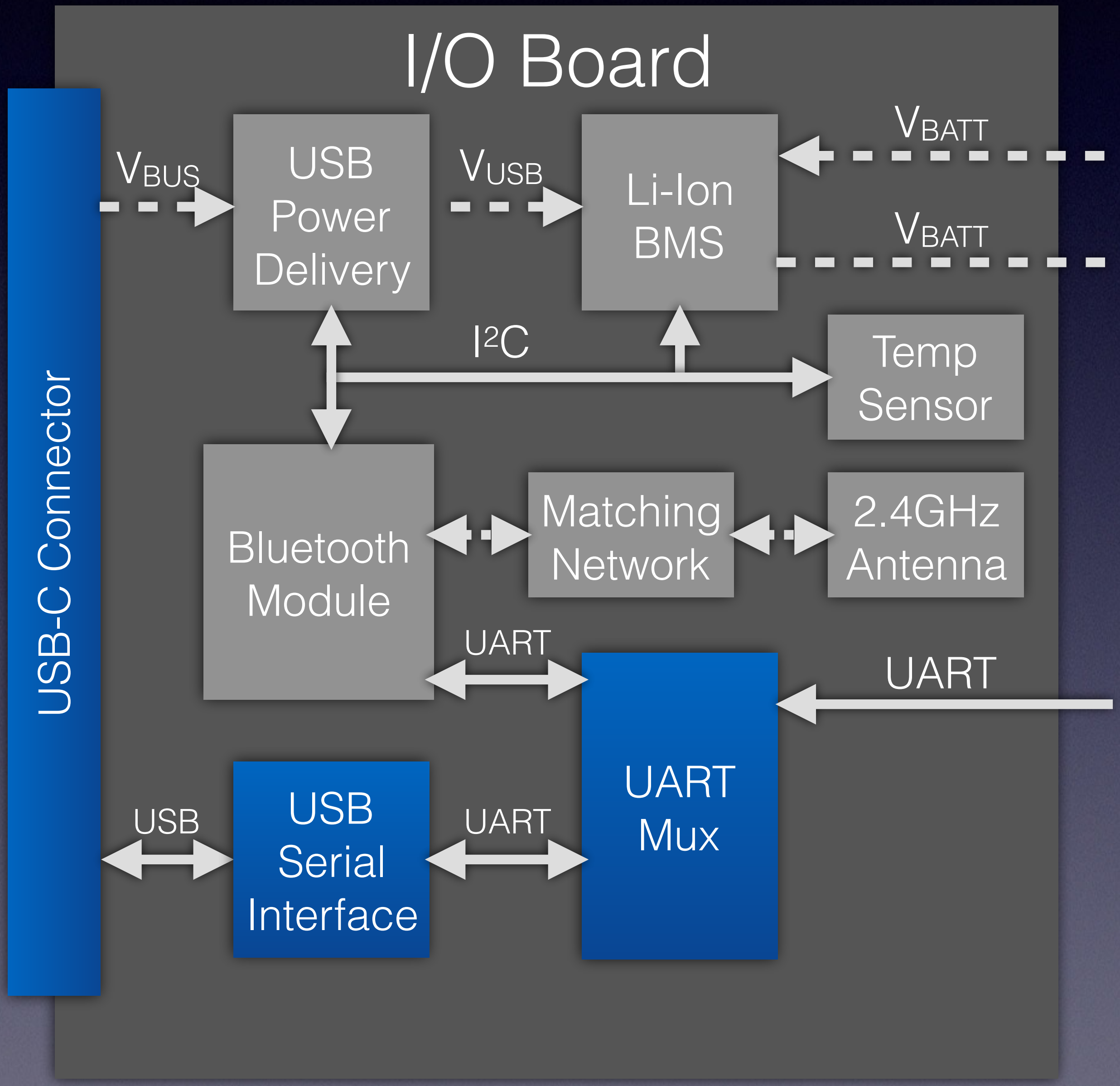
20V

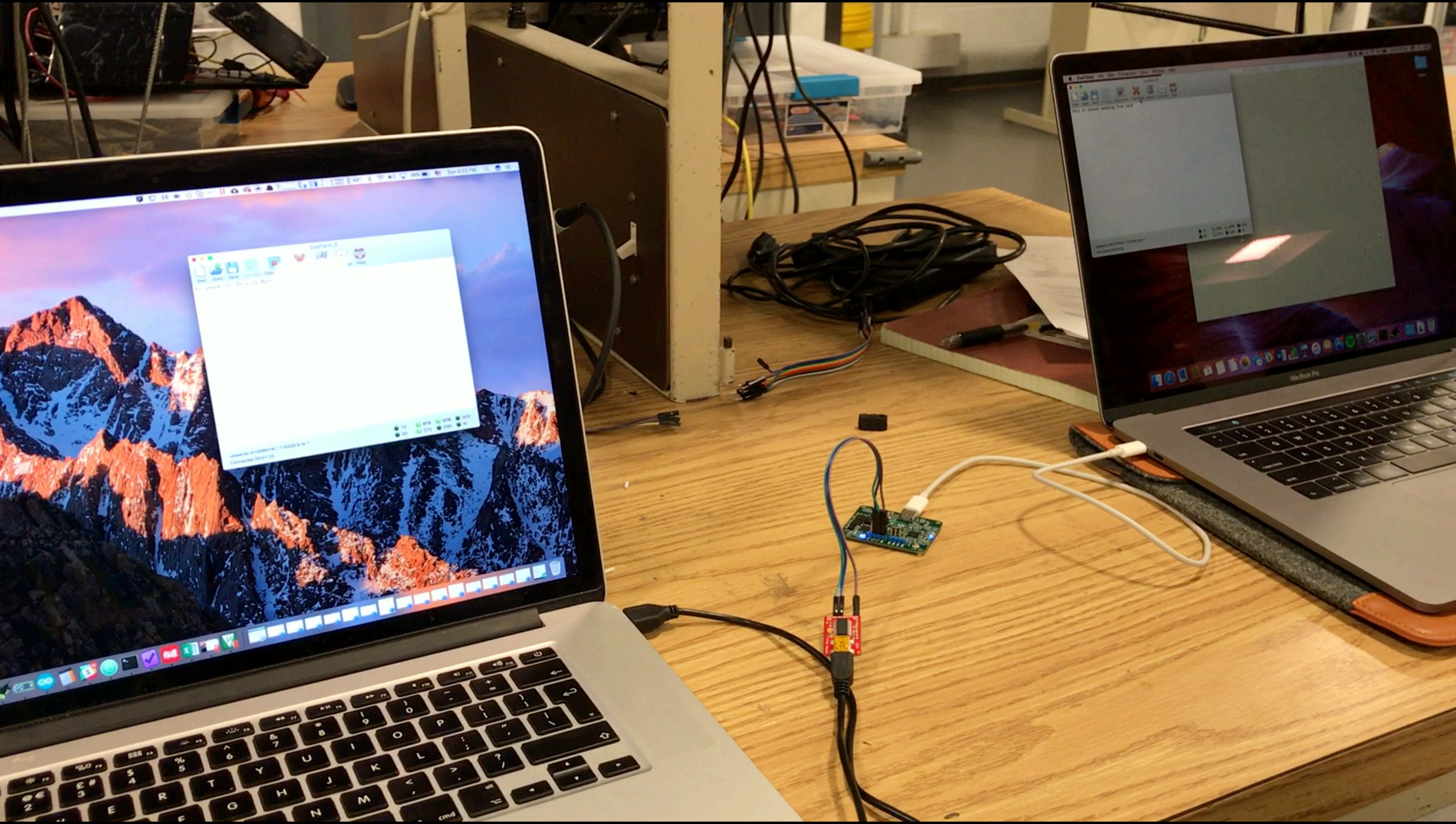
5V

Higher Voltage Requested

USB Data

- Enumerated as a USB serial device to both Windows and MacOS computers
- Supported a baud rate of 115200
- Met requirements set in the Design Document




CoolTerm_0
New
Open
Save
Connect
Disconnect
Help
TX
RX
RTS
CTS
DTR
DSR
DCD
RI
115200 8-N-1
Connected 00:01:25
MacBook Pro

Lessons Learned

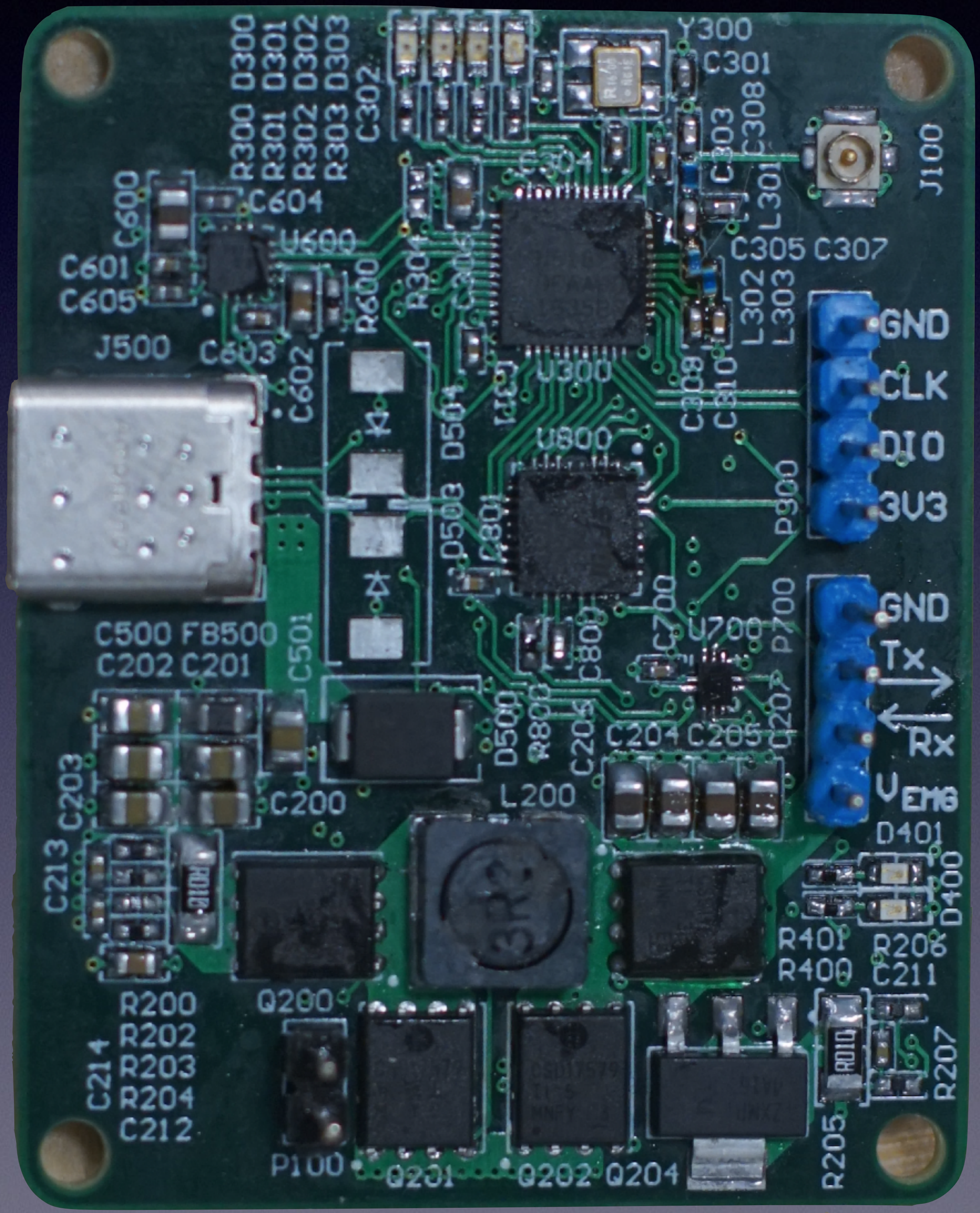
- The Bluetooth Module was not powerful enough to handle both Bluetooth and USB Power Delivery at the same time
- Lack of UART pull-up resistors generates garbage data when no device is attached
- USB protection diodes had too much capacitance, preventing USB communications
- No protection diodes on the Serial Multiplexer created the potential for static electricity damage

Next Steps

- Spin I/O Board incorporating lessons learned

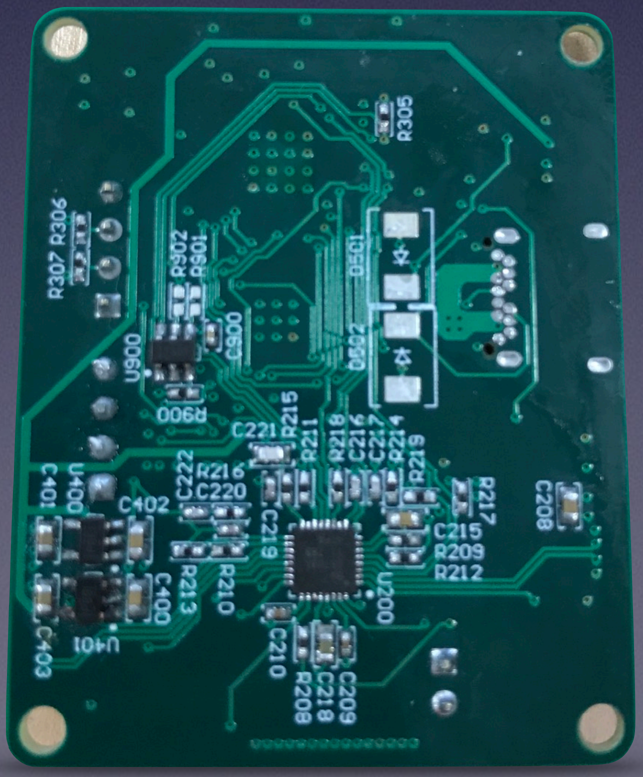
- Mechanically integrate I/O Board into the hand

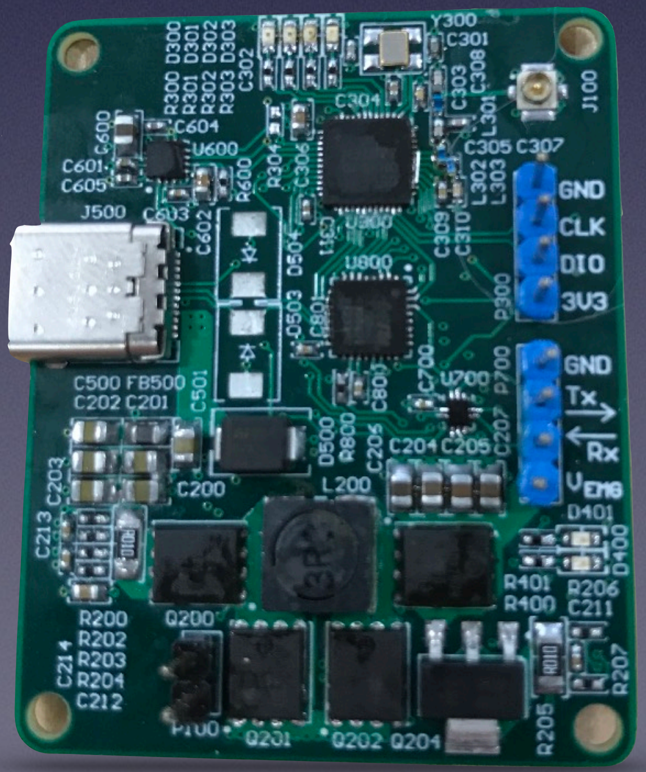
- Evaluate regulatory compliance



Questions?

Thank You

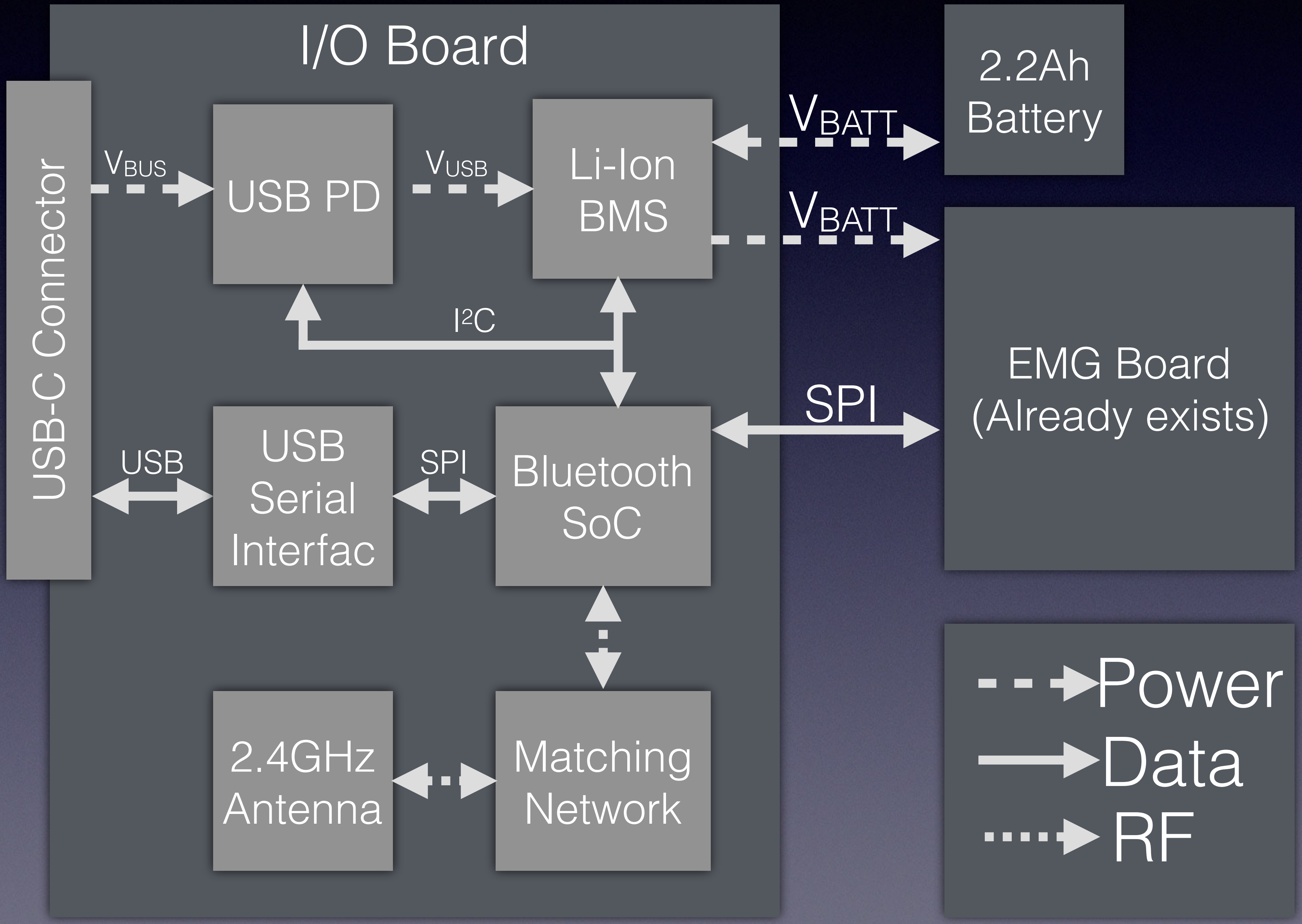




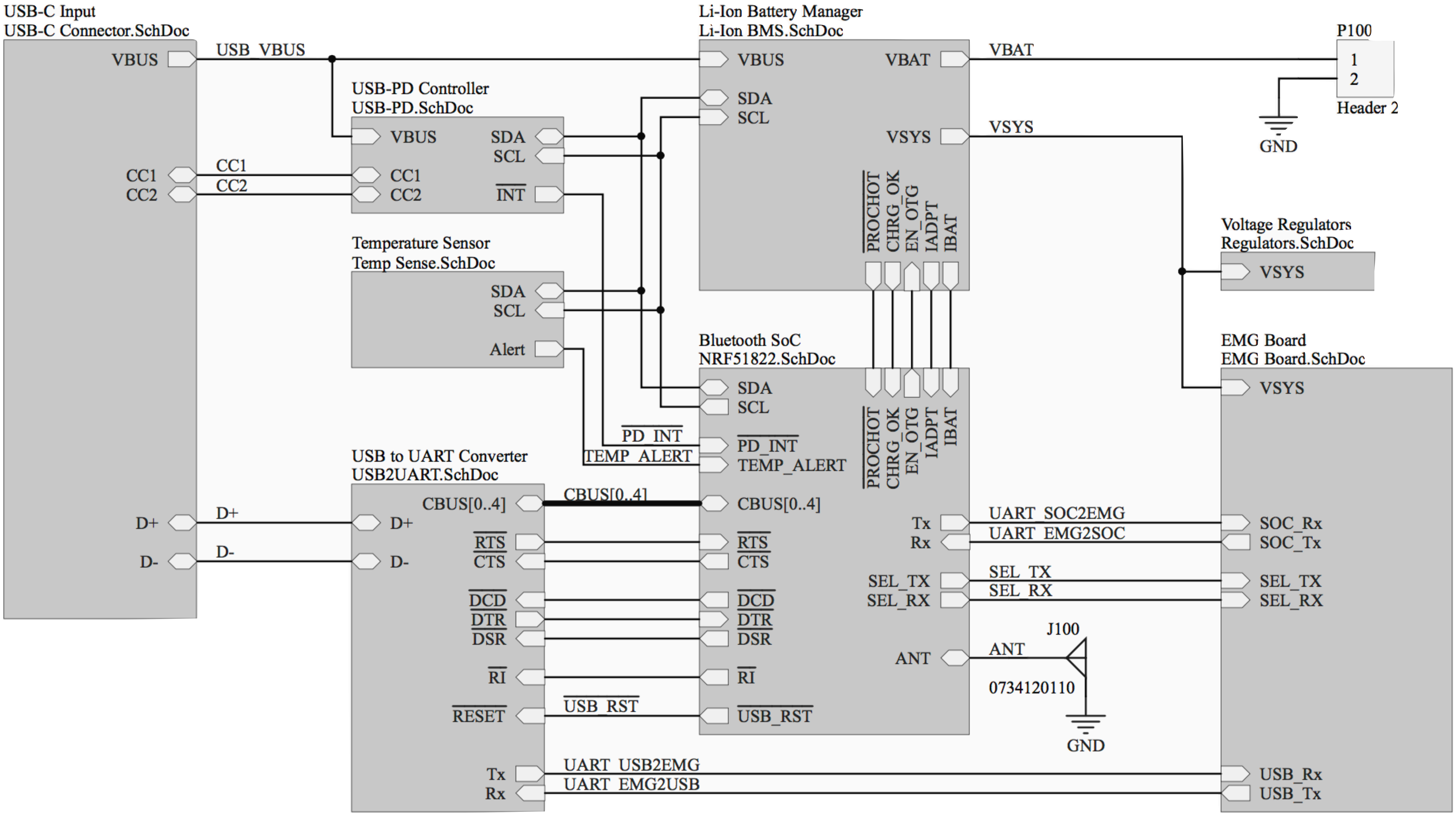
Backup Slides

All following slides are meant to help answer questions
They are not part of the main presentation

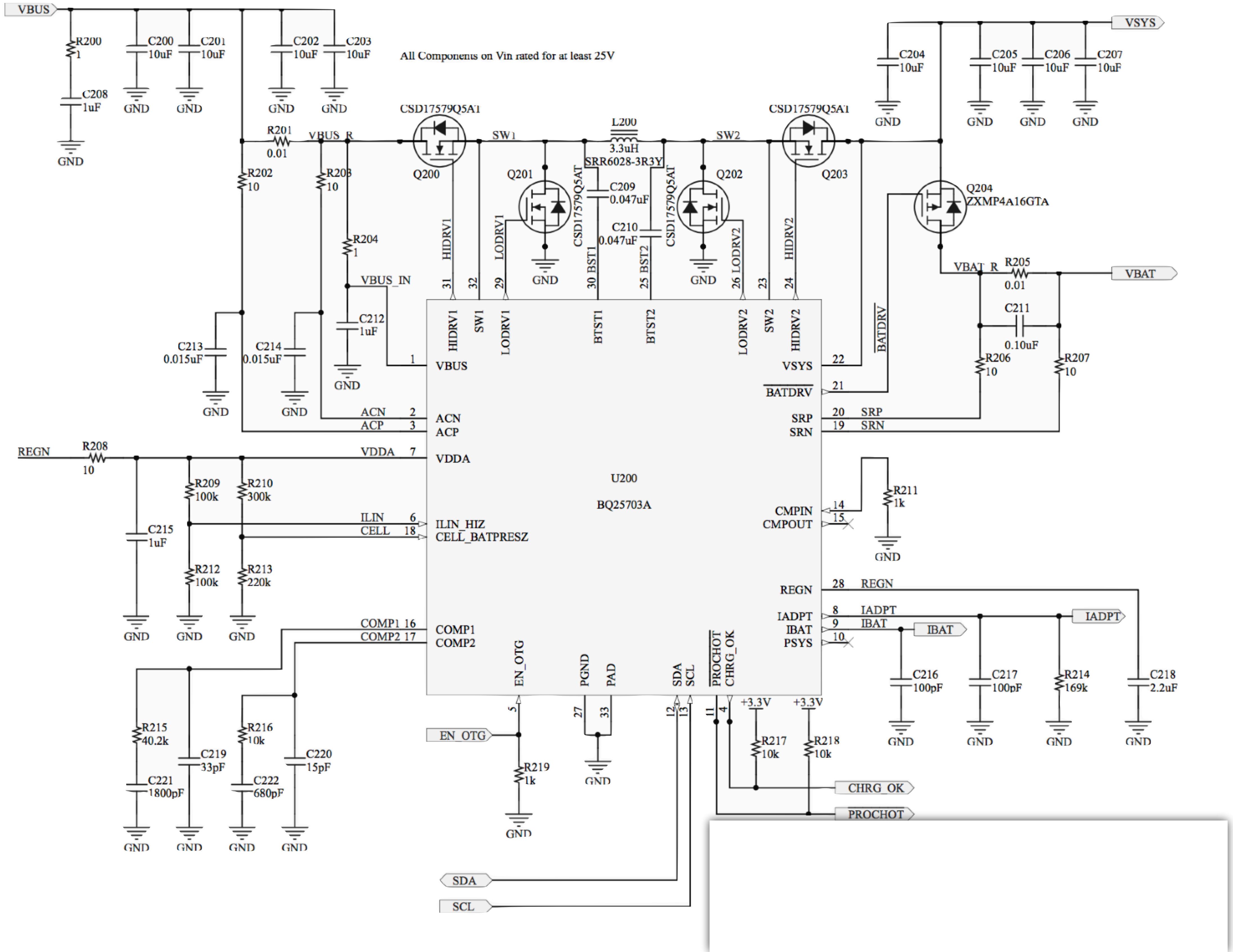
Initial System Architecture



Top-Level Schematic

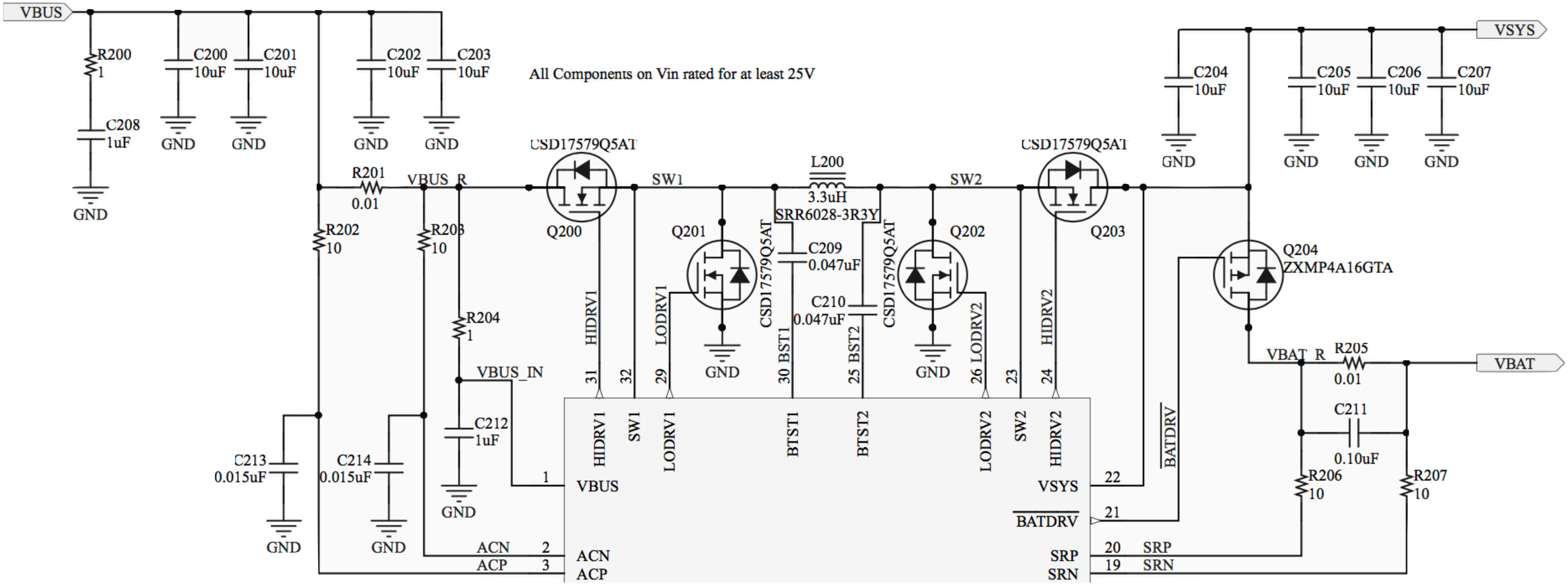


Battery Management System

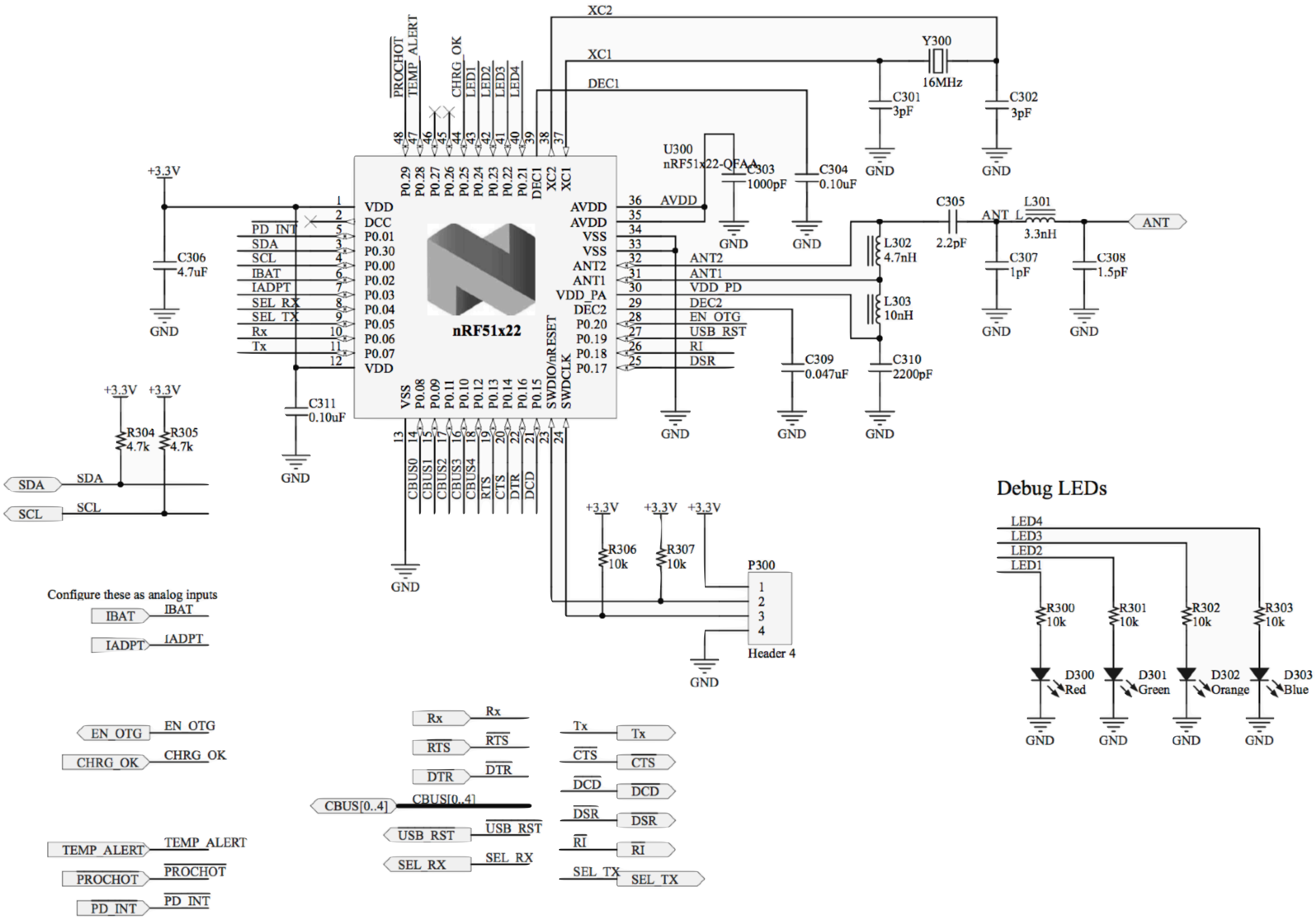


All Components on Vin rated for at least 25V

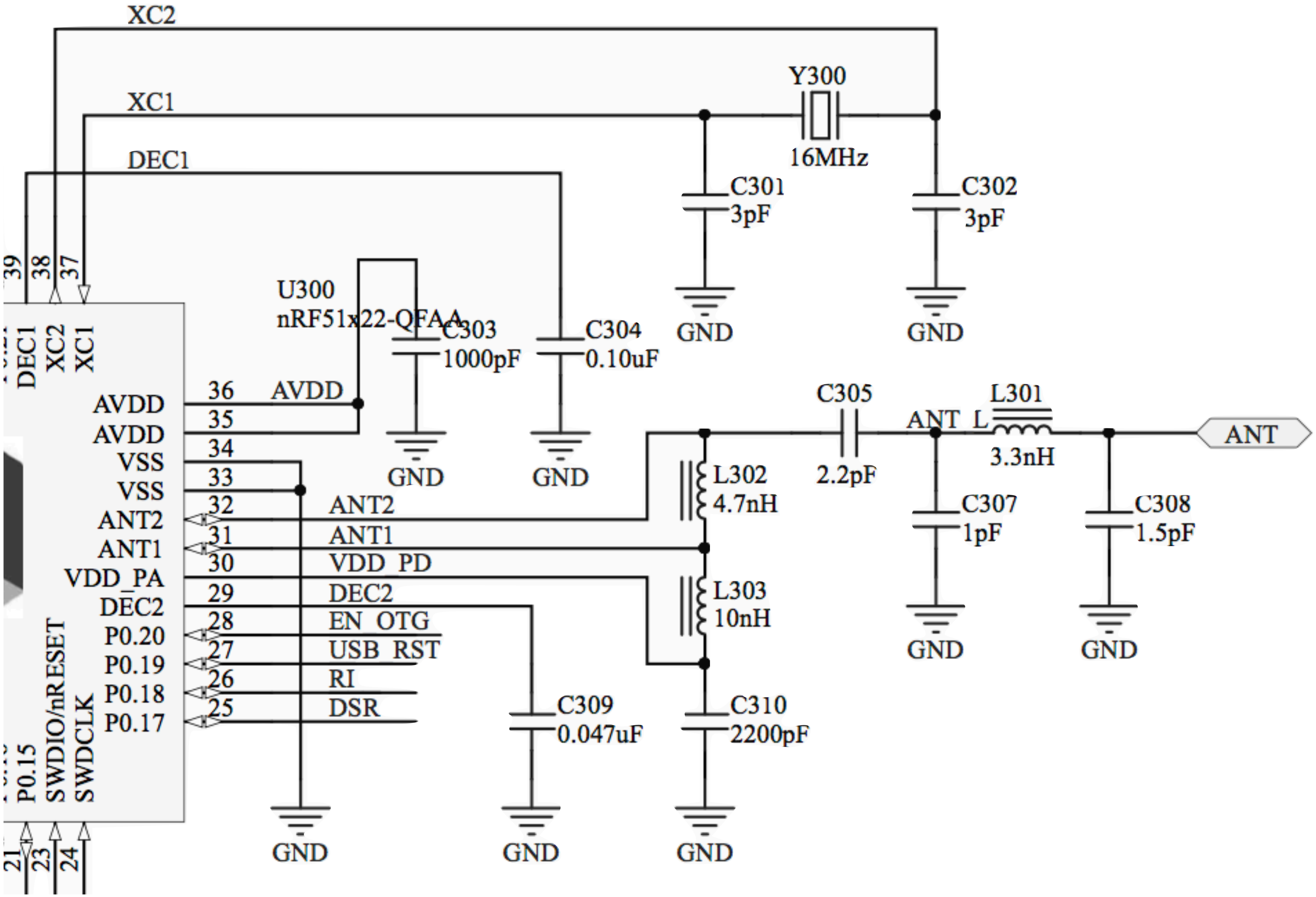
BMS Power Path


All Components on Vin rated for at least 25V

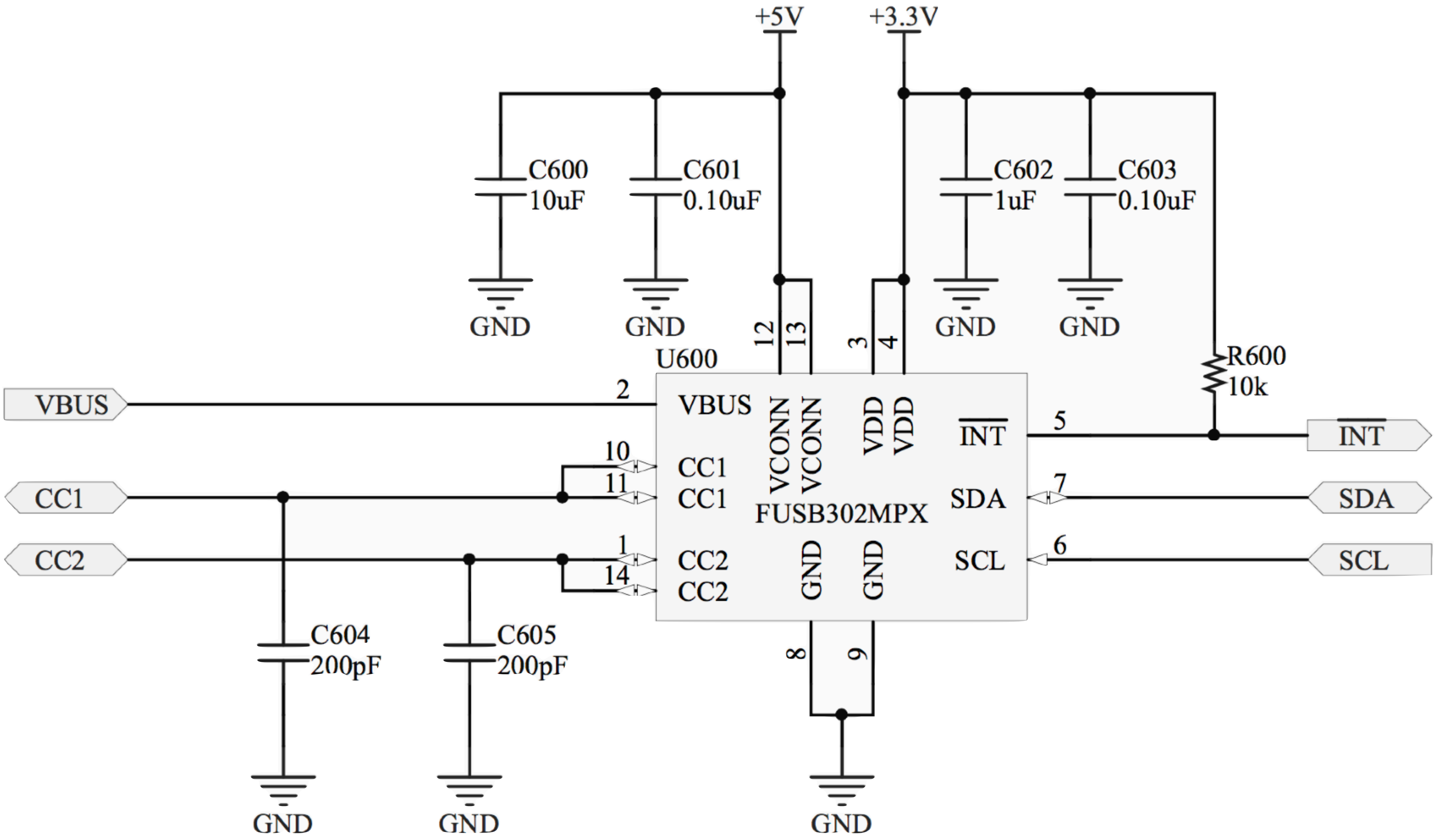
Bluetooth SoC



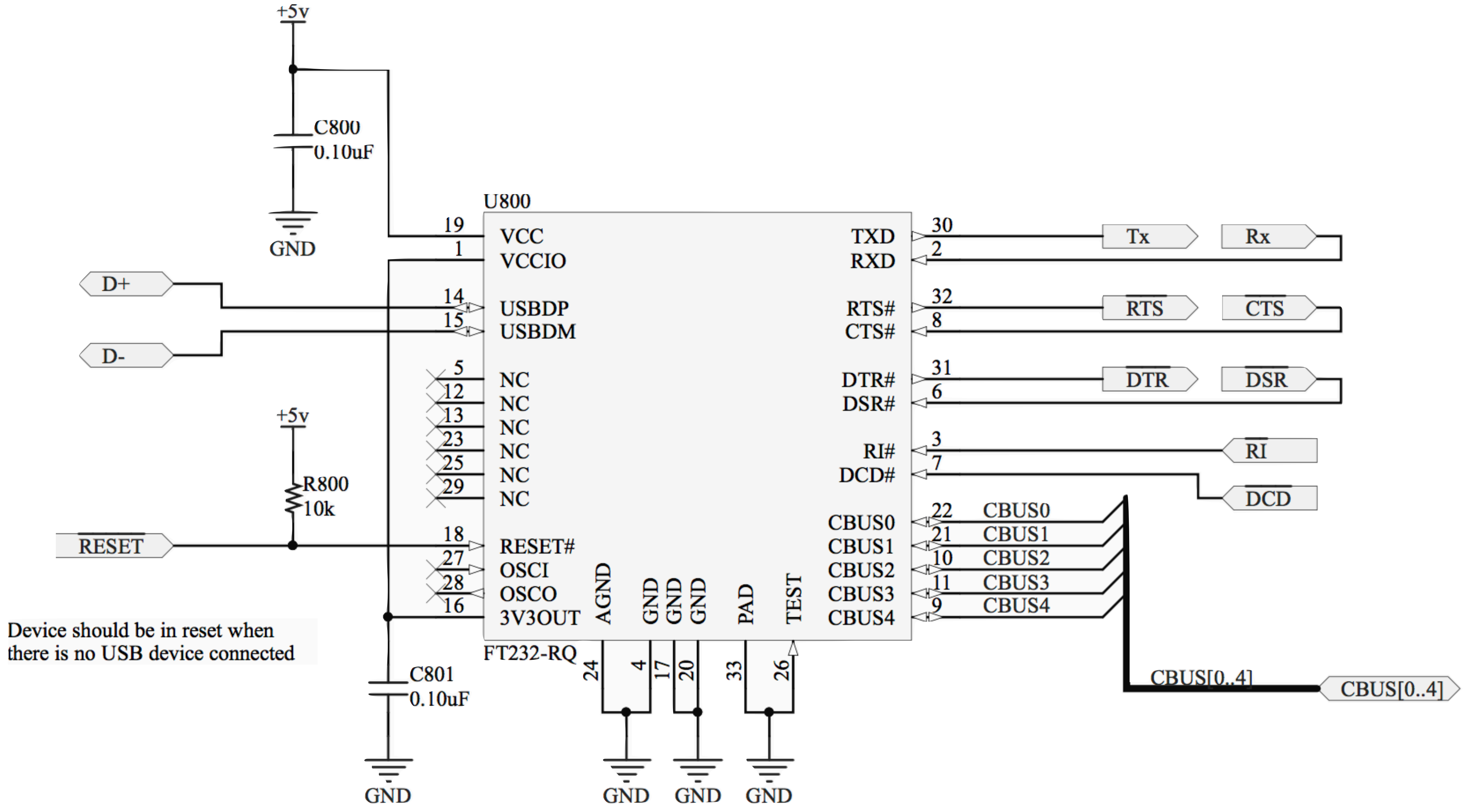
RF Matching Network



USB-PD Negotiator

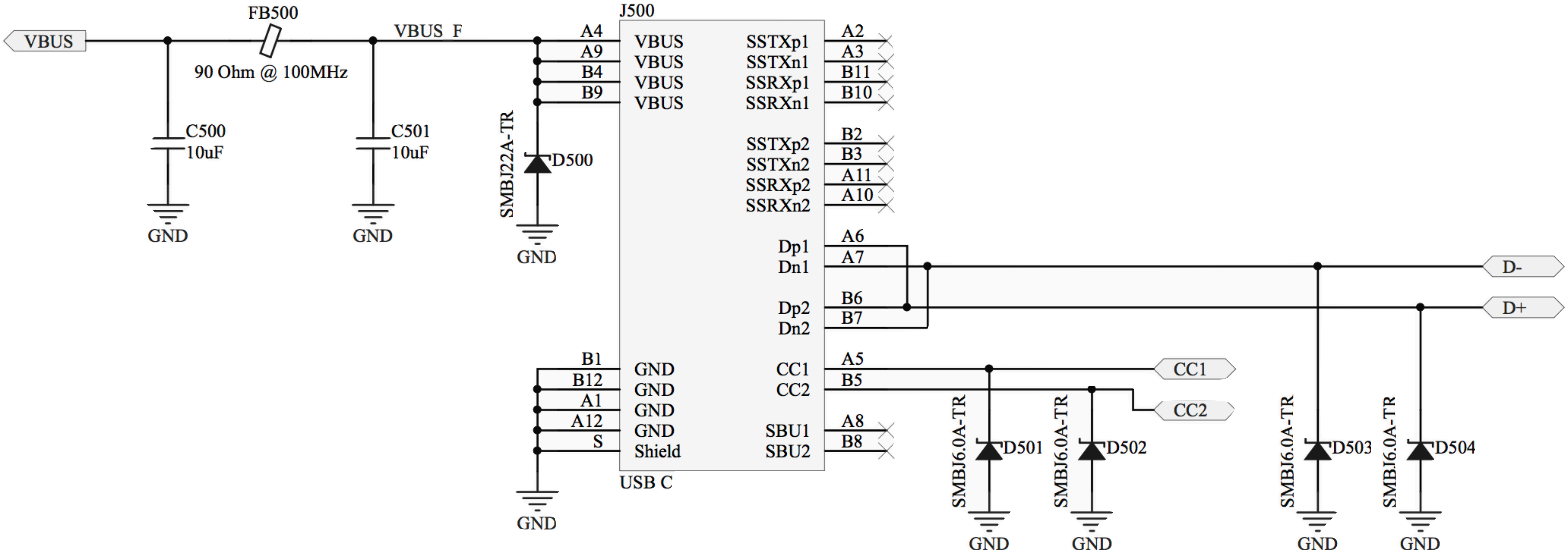


USB Serial Interface

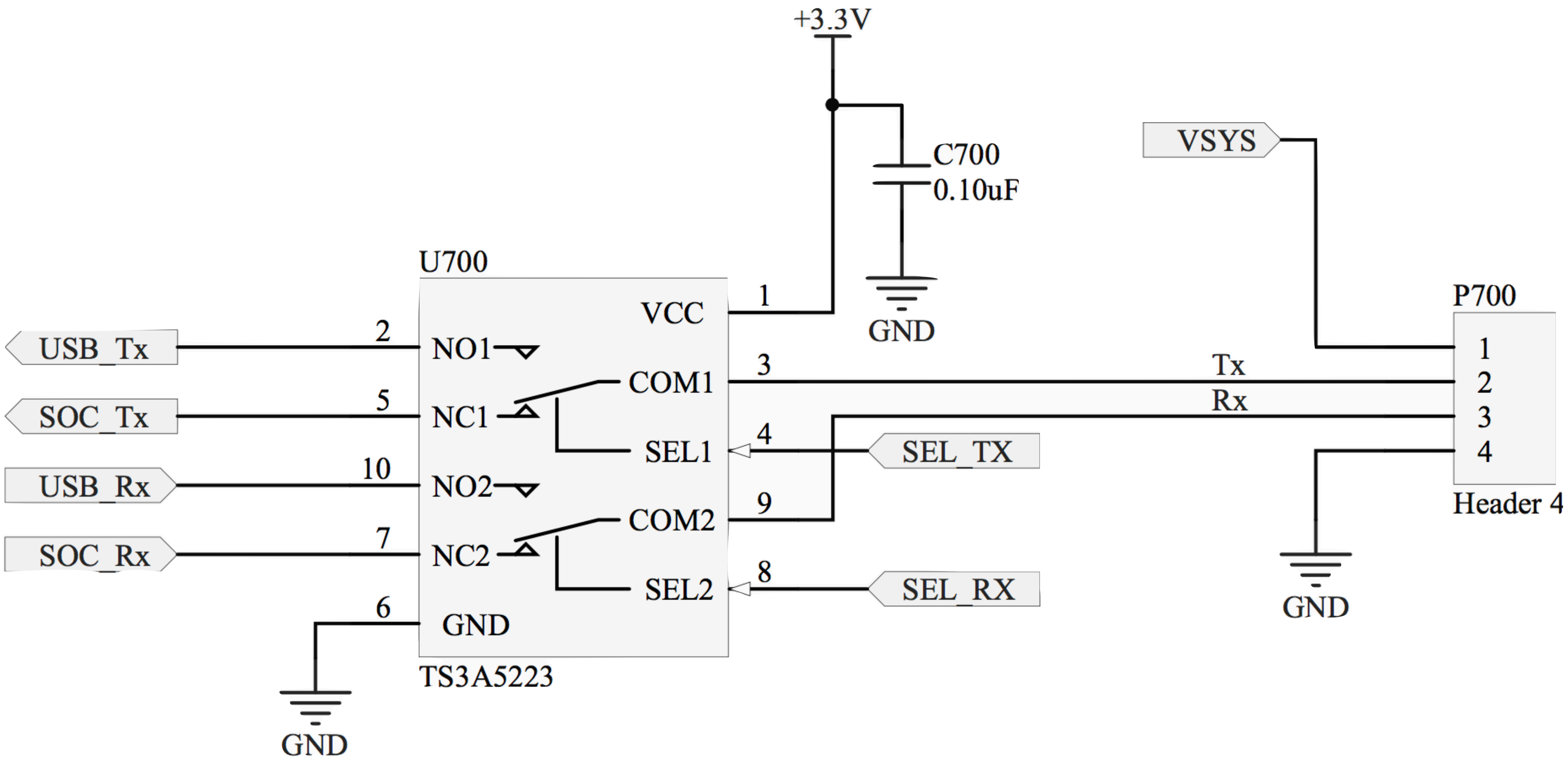


Device should be in reset when there is no USB device connected

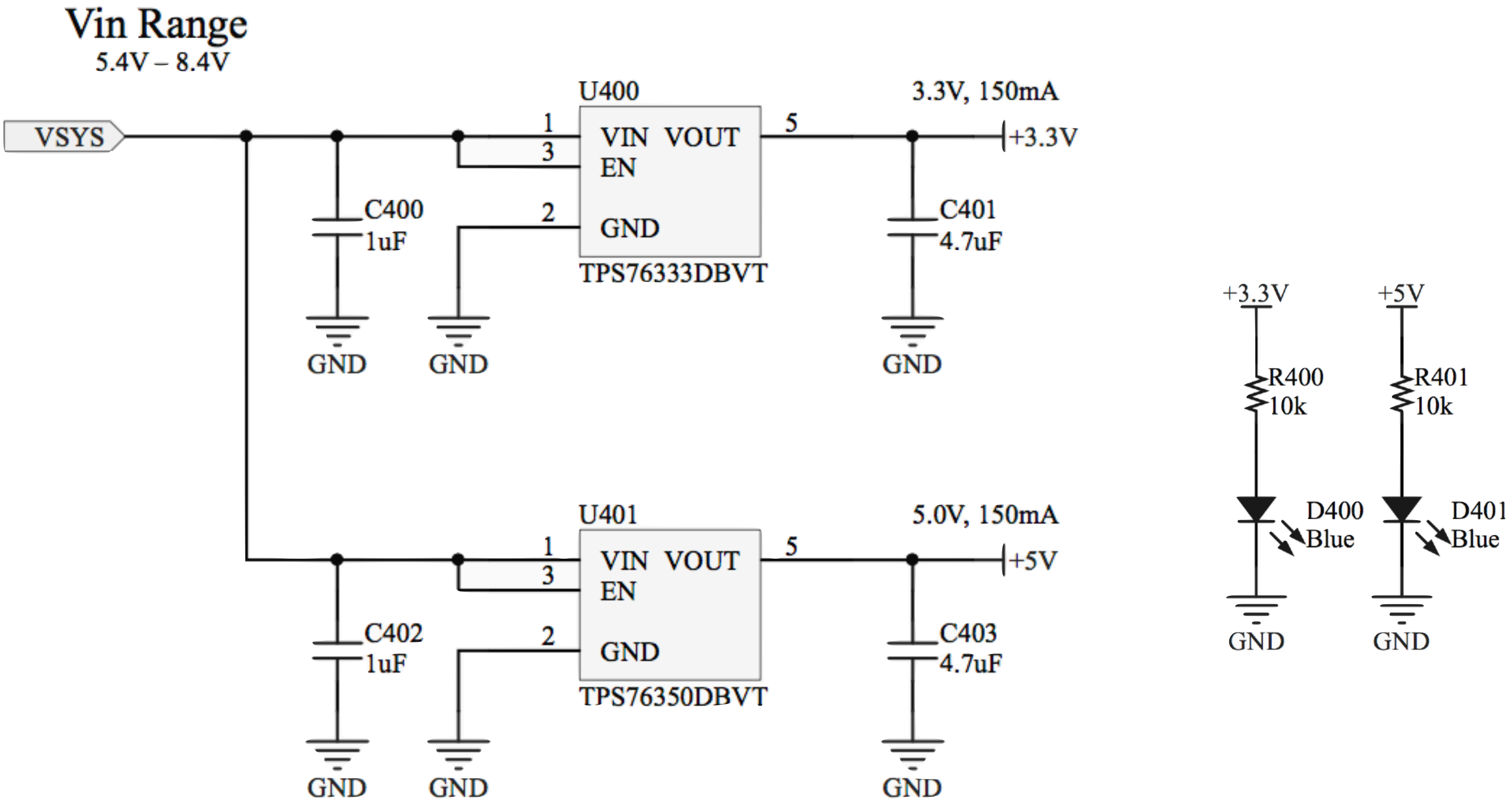
USB Type-C Connector



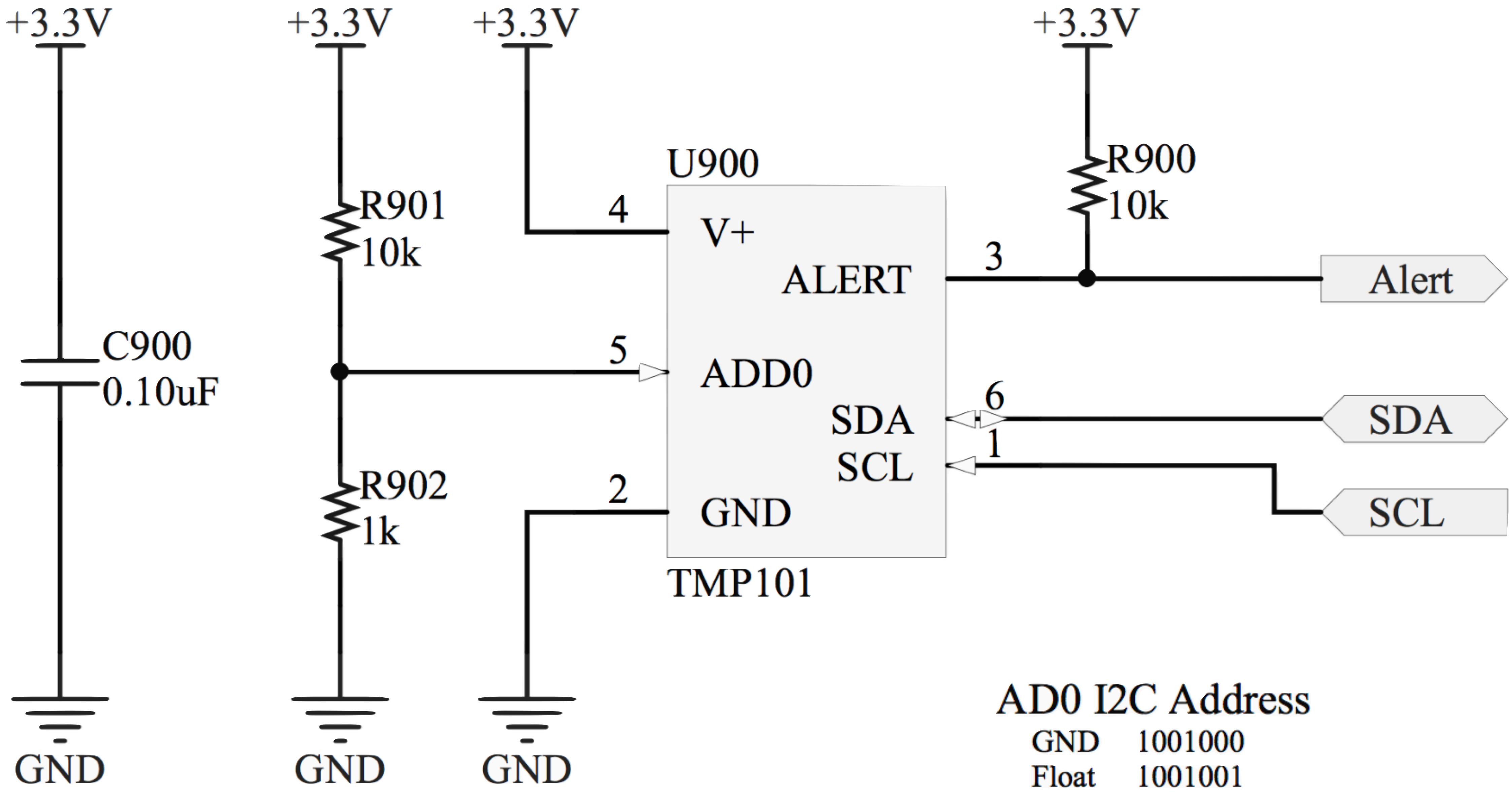
UART Mux


+3.3V
C700
0.10uF
GND
VSYS
U700
P700
VCC
1
USB_Tx
2
NO1
COM1
3
Tx
1
2
SOC_Tx
5
NC1
Rx
3
SEL1
4
SEL_TX
4
USB_Rx
10
NO2
9
Header 4
COM2
SOC_Rx
7
NC2
8
SEL2
SEL_RX
GND
6
GND
TS3A5223
GND
GND

Voltage Regulators



Temperature Sensor

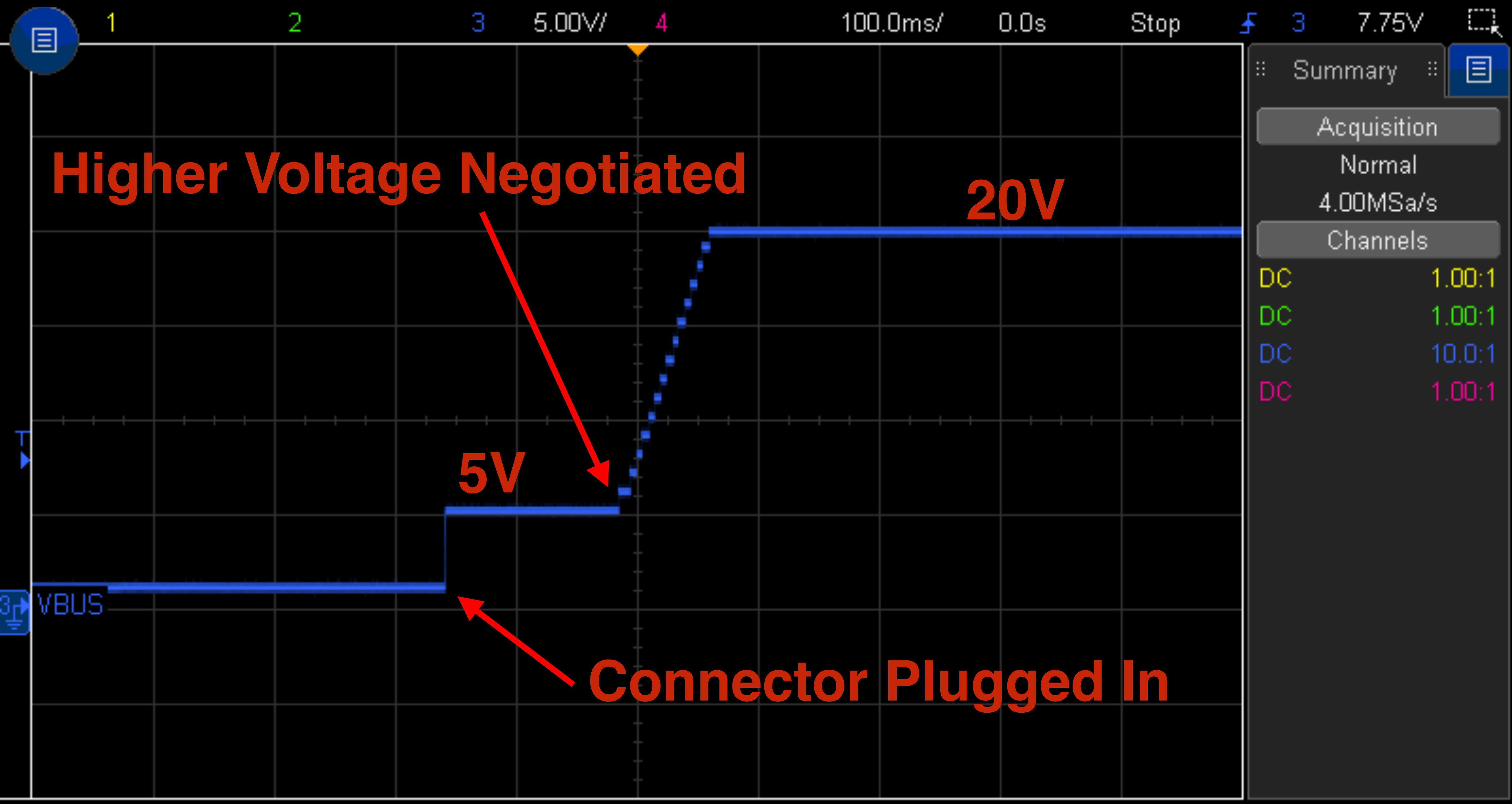


AD0	I2C Address
GND	1001000
Float	1001001
V+	1001010

Requirements

Block	Points
Battery Management System	15
Bluetooth Low Energy	10
USB Power Delivery	10
USB Serial Converter	5
Radiofrequency Front End	5
Lithium-Ion Battery	5

Additional Results



Higher Voltage Negotiated

20V

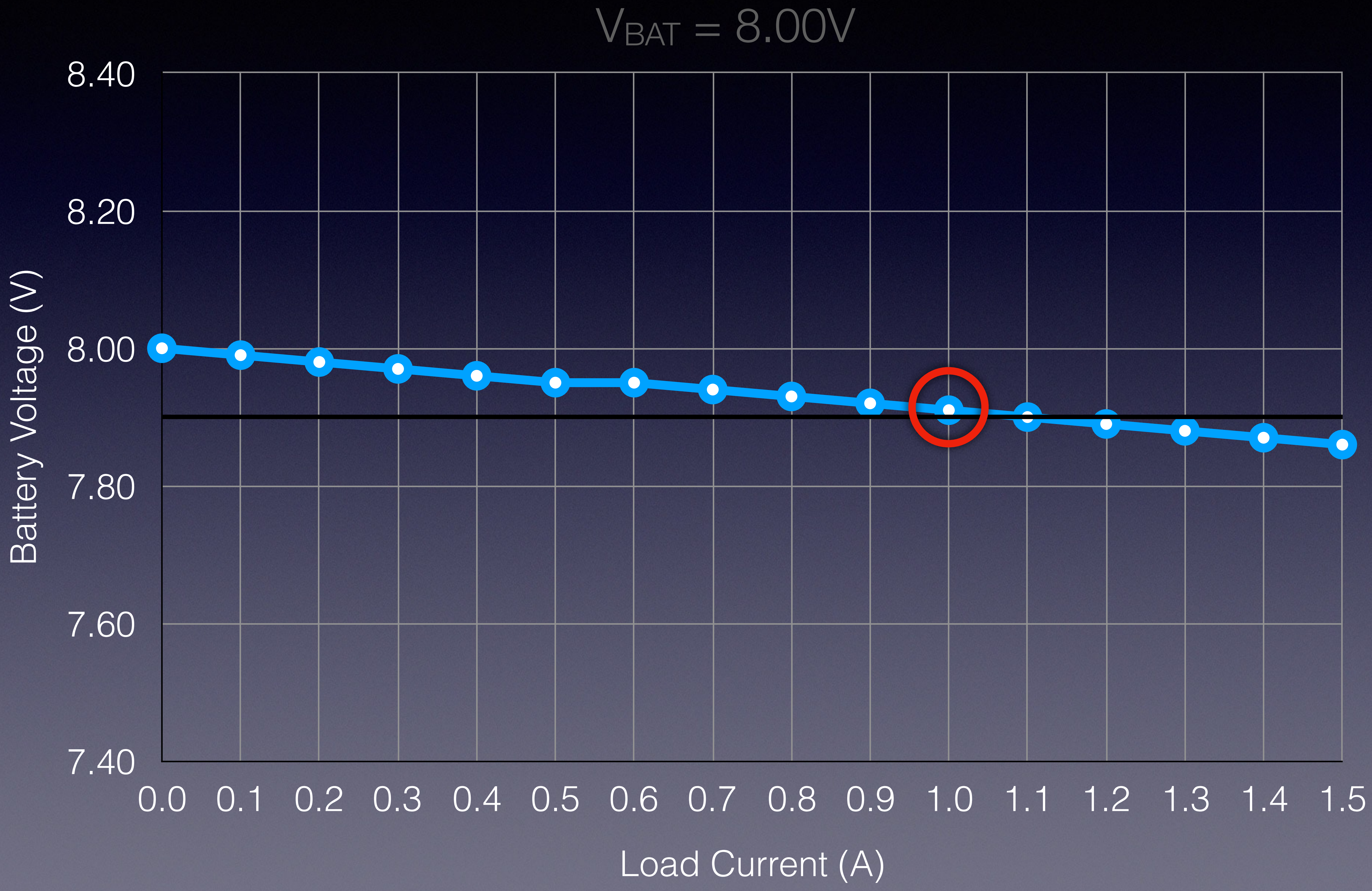
5V

Connector Plugged In

Lithium-Ion Battery

- Battery supported the maximum expected discharge rate without a serious voltage drop
- Met requirements set in the Design Document

Battery Load Sweep


VBAT = 8.00V
Battery Voltage (V)
Load Current (A)