The Phoenix Board

Group 8

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Motivations

- We each wanted different ideas incorporated into a project
  - Solar energy/power management
  - Mobile communications (Wi-Fi or Bluetooth)
  - Computer vision

- We wanted something fun that would keep us all motivated throughout the duration of the project

- We wanted something that could be used regularly and reliably

- Quick travel within a college campus

Goals and Objectives

Core Features:

- A smooth and fast electric motor with easy speed control
- Rechargeable battery via solar and standard outlets
- PCB manages all onboard sensors
- Fast and consistent mobile communications
- Weight-sensitive safety mechanism
- Efficient and reliable

Specifications

Total Board Weight	< 25 lbs
Maximum Board Speed	>= 15 mph
Battery	36V, 10Ah, < = 10A
Battery Charge Time	< 5 hours
Communication	< 0.5s response time between app and PCB
Motor Efficiency	> 70%
Battery Efficiency	> 80%
Cost	< $1000

Existing Projects

Halo Board - 2nd Edition

- 14 lbs
- 286 lb weight limit
- 14 miles of ride time
- Max speed: 26 mph
- Recharge time: 3 hrs
- Cost: $1,497.00 USD

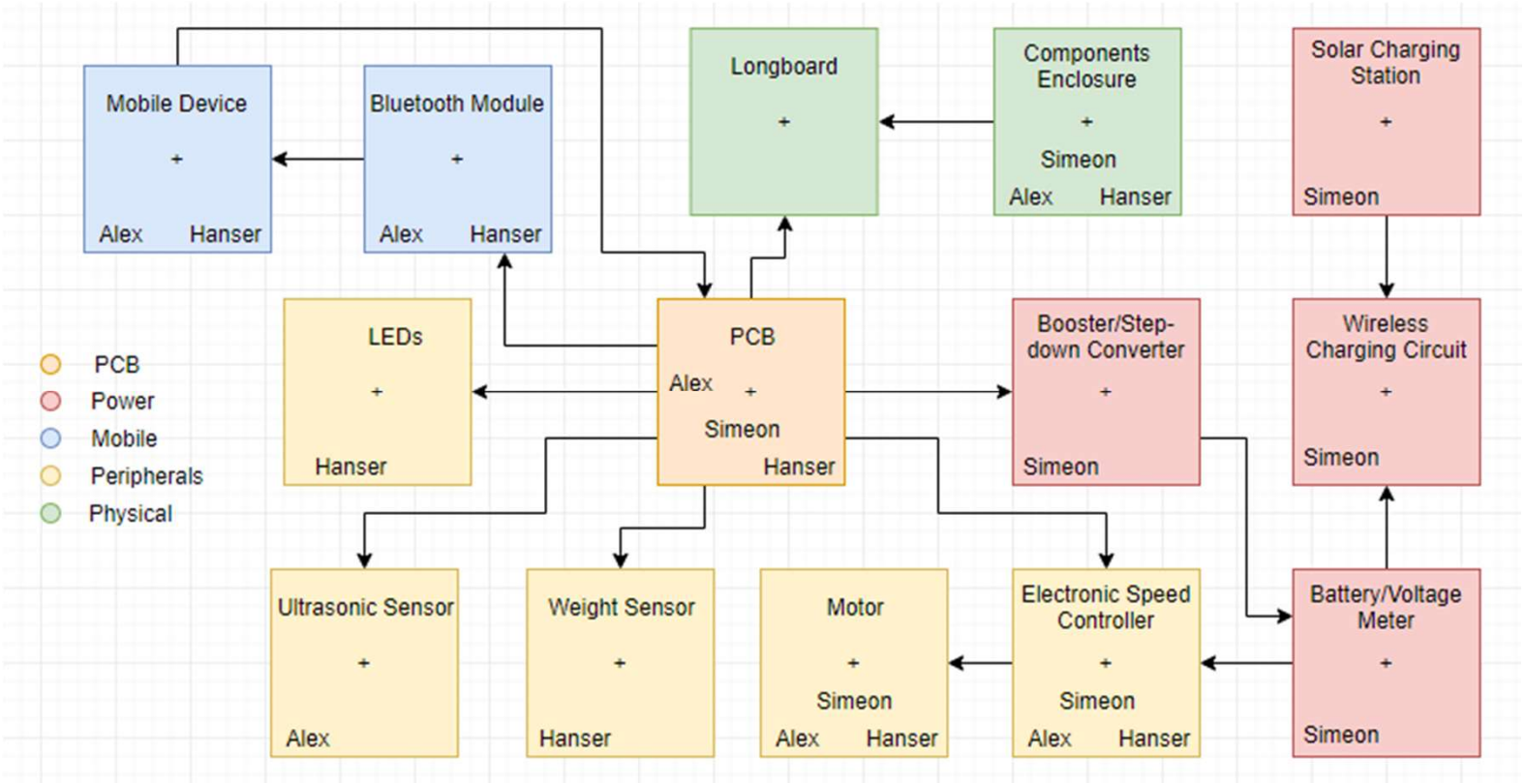
Evolve Boards - Bamboo GTX

- 19.4 lbs
- 220 lb weight limit
- 19 miles of ride time
- Max speed: 26 mph
- Recharge time: 4-5 hrs
- Cost: $1,779.99 USD

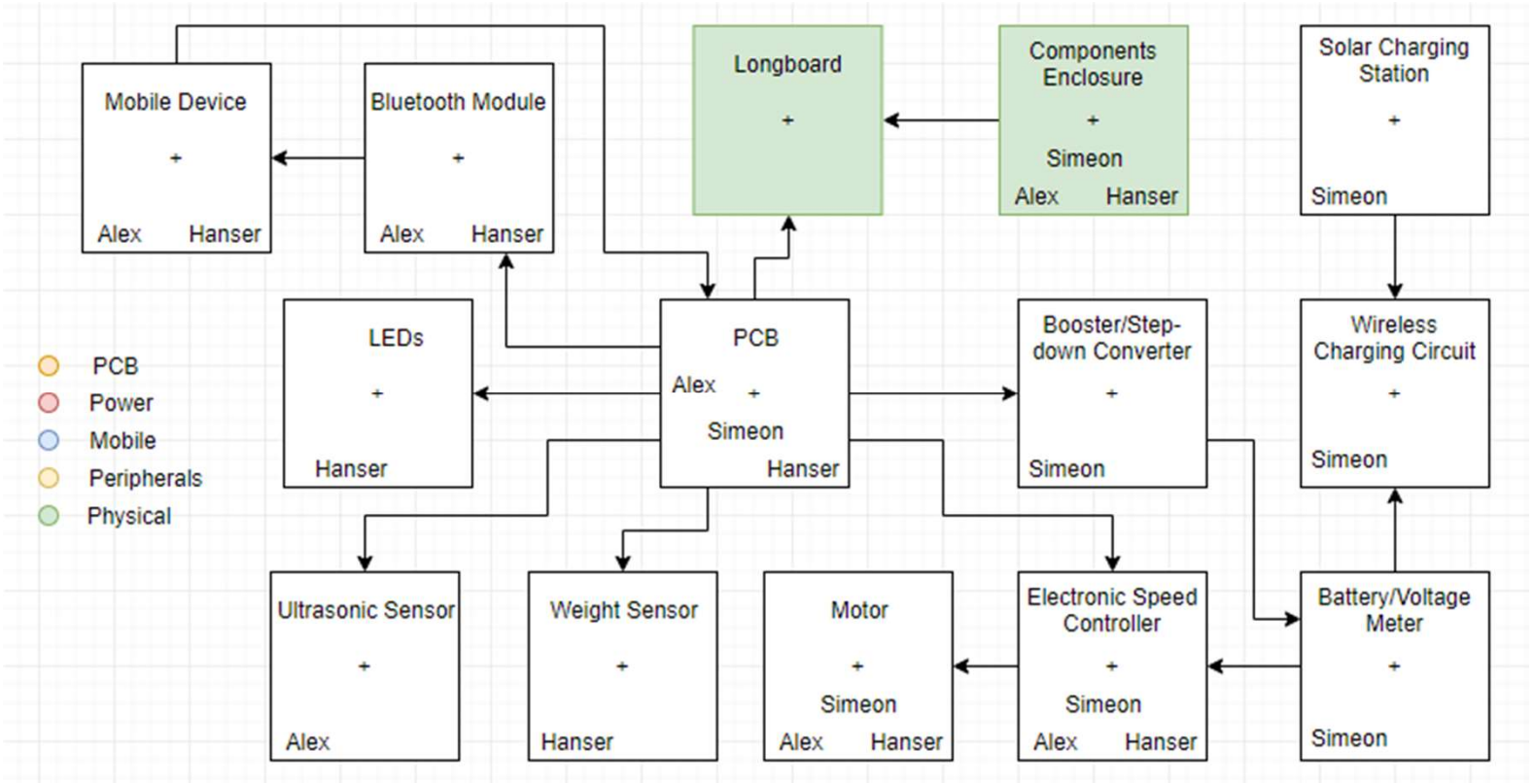
Boosted Boards - Boosted Plus

- 17 lbs
- 250 lb weight limit
- 14 miles of ride time
- Max speed: 22 mph
- Recharge time: 1.75 hrs
- Cost: $1,399.00 USD

Block Diagram



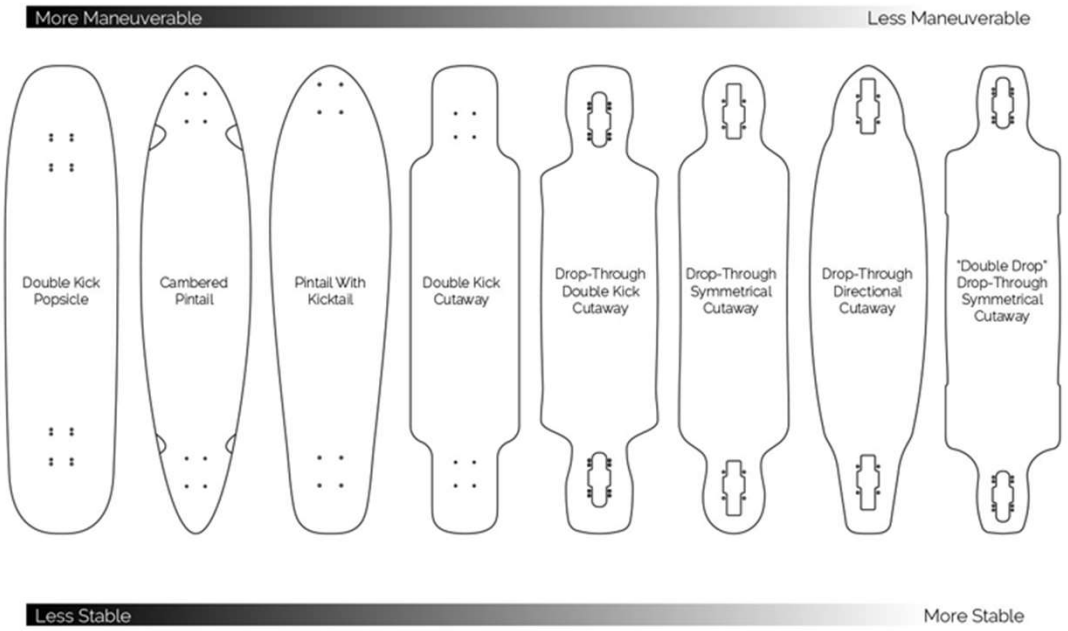
Board and Enclosure



Longboard Selection

Stability/Maneuverability Factors:

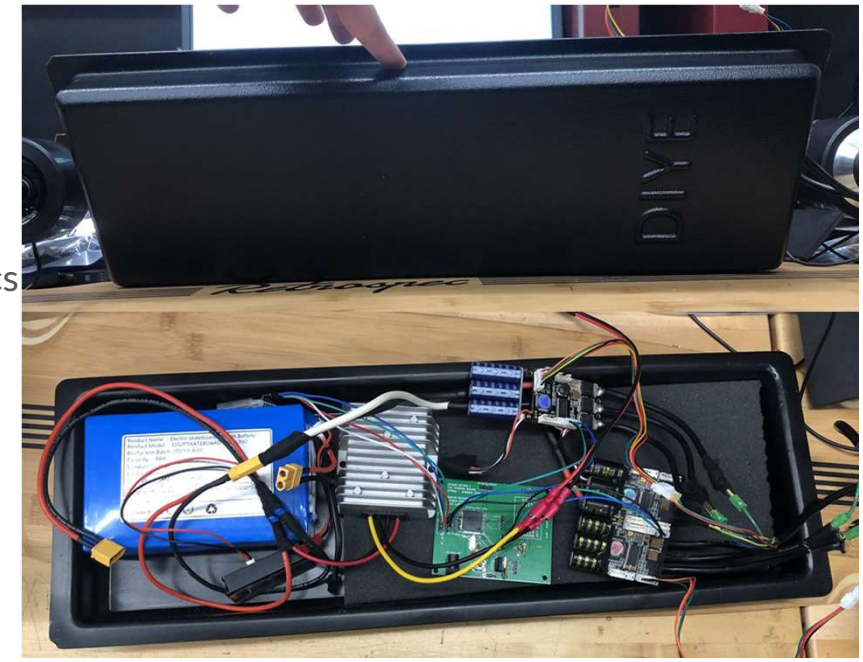
- Length
- Width
- Weight
- Flex
- Style (Truck height)
- Shape



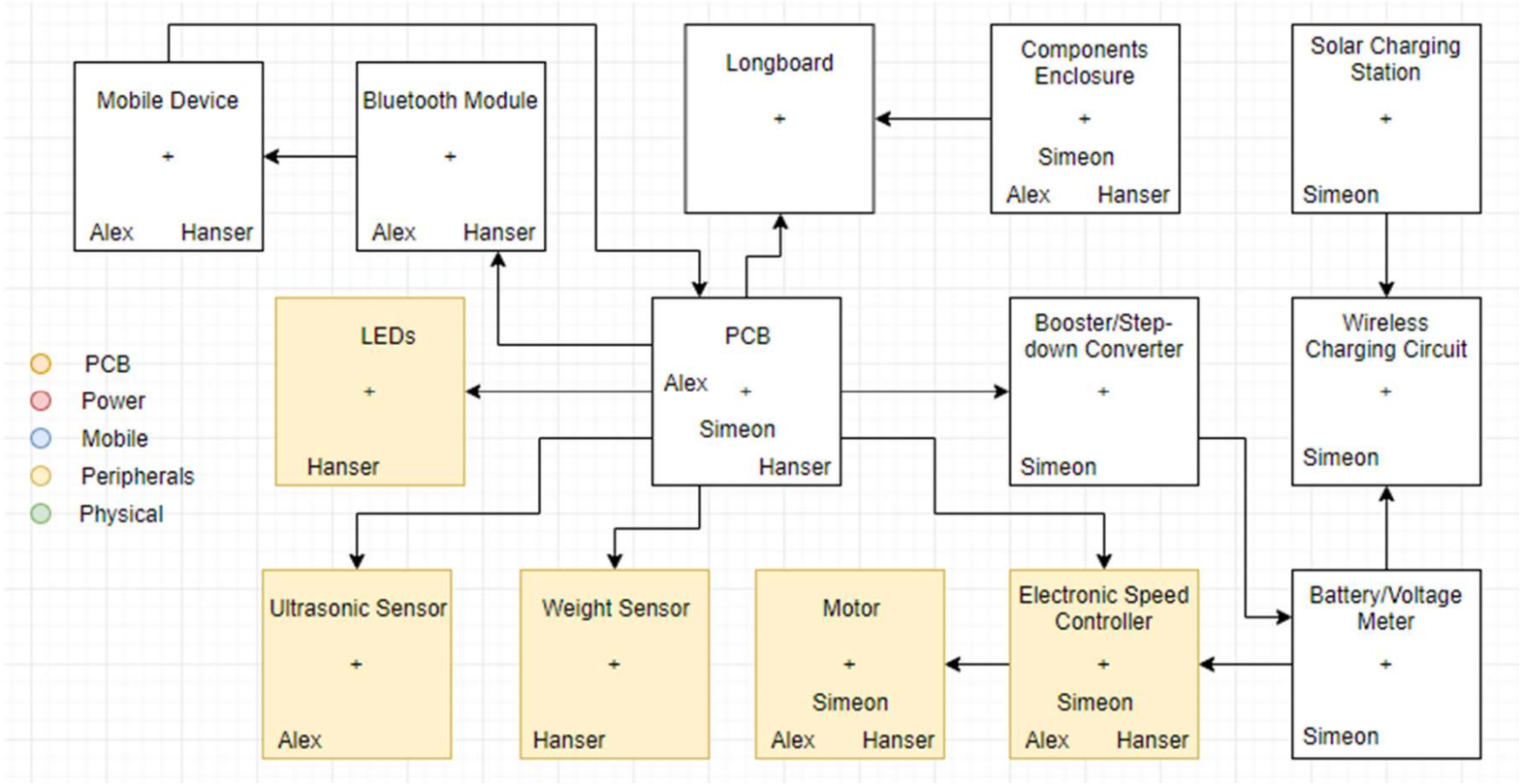
Battery/Component Enclosure

DIYE Electric Skateboard Battery & Electronics Customizable & Scratch-Proof Battery Enclosure

- Outside: 21" x 7 1/40" x 1 3/4"
- Inside: 19 1/9" x 5 3/4" x 1 1/2"
- Heavy-Duty, Durable and Flexible
- Protection for ESC, Battery and Electronics
- Designed for custom built skateboards



Peripherals



Microcontroller

ATMega2560

- Selected over MSP430F5529
  - Multiple UARTs which are needed for Bluetooth and motor control
  - Higher number of GPIO pins, needed for multiple sensors
  - Arduino libraries are widely available and easy to implement

	MSP430F5529	ATMega2560
Architecture	16-Bit	8-Bit
Speed	Up to 25 MHz	Up to 16 MHz
Flash	128 KB	256 KB
RAM	8 KB	8 KB
UART	1	4
I2C	1	1
SPI	1	5
GPIO Pins	64	86

Embedded System IDE

Embedded IDE: Arduino IDE

- Used for developing applications for Arduino based processors
- Supports C/C++
- Wide availability of documentation, tutorials, and ready-to-use libraries for peripherals

Motors: Hub vs. Belt

Hub Motors

- Motor is integrated into wheel reducing the amount of noise made
- Less drag which provides a longer battery life
- Reduced resistance allows users to free roll
- Thinner urethane sleeving around motor as opposed to full-sized wheel reduces shock absorption
- Typically weigh less

Belt Motors

- Involve a belt/pulley system which can create significant amounts of noise
- Provide higher levels of torque
- Present a lot of resistance essentially barring free roll
- Can cause rider to feel a vibration when running
- Can use full-sized wheels for better shock absorption
- Typically weigh more

Motor Selection

Dual 90mm Hub Motor Kit

- Dual 6364 Hub Motors
- Weight: 9.57 lbs
- Motor size: 74.5 mm x 52 mm
- Wheel size: 90 mm
- Top Speed: 25 mph
- Operating voltage: 24V - 42V
- Simple integration
- Replaceable urethane sleeving

Electronic Speed Control

Dual FSESC4.20 100A with Anodized Aluminum Heatsink (VESC Based)

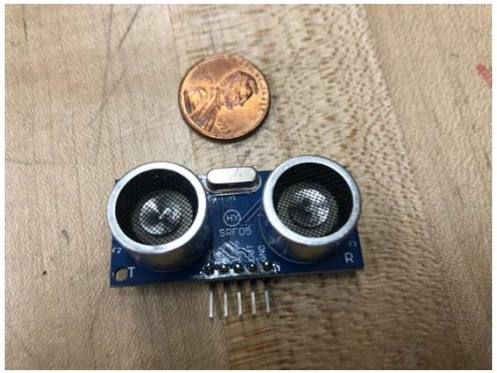
- 50 A Continous/single, 100A contiuous/dual
- 8V - 60V (3-13S LiPo)
- DC, BLDC, FOC modes
- UART capable

FSESC 4.12 50A Based on VESC® 4.12

- 50 A Continous/single
- 8V - 60V (3-13S LiPo)
- DC, BLDC, FOC modes
- UART capable

Ultrasonic Sensor

SMAKN Ultrasonic Module HY-SRF05 Distance Sensor



- Power Supply: +5V DC
- Idle Current: < 2mA
- Ranging Distance: 2 cm - 450 cm
- Resolution: 0.3 cm
- Full measuring angle: 30 degrees
- Effective angle: < 15 degrees
- Pins: VCC, GND, TRIG, ECHO, OUT
- Used for obstacle detection in front of the board and assist with engaging emergency slowdown to prevent/minimize rider injury

Night Mode LEDs

CHINLY 16.4ft WS2812B Individually Addressable LED Strip

- Power Supply: +5V DC
- 5050 RGB LEDs
- 24-bit color (8-bit red, green, and blue data)
- LED strip can be cut to desired length without damaging LEDs.

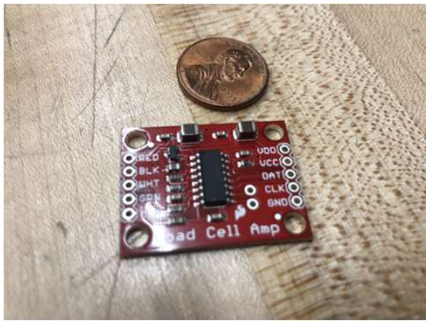
Load Cell and Load Cell Amplifier

Load Cell: TAS606 Load Cell - 200 kg

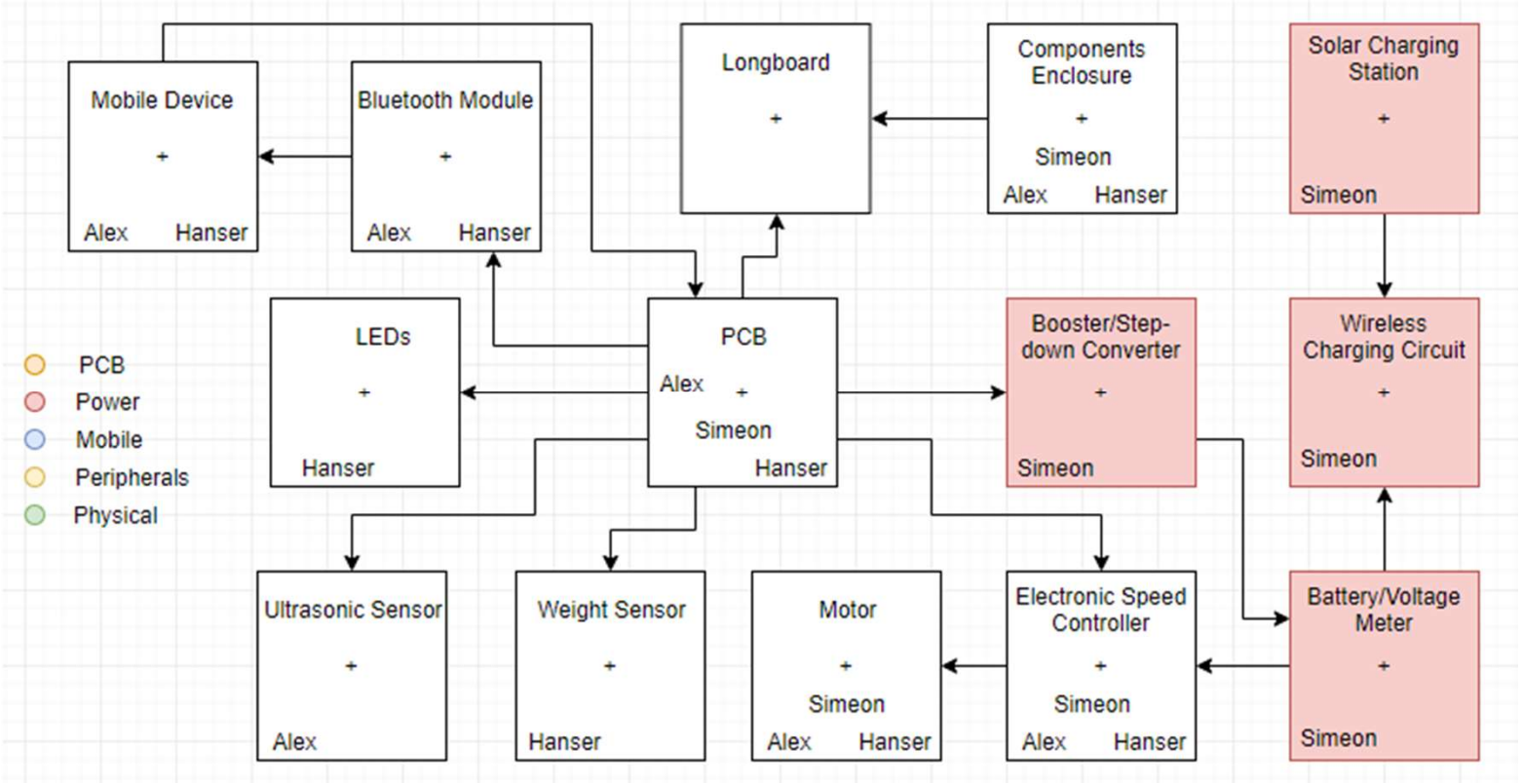
- 200 kg weight capacity
- Consists of 4 Strain gauges hooked up into a wheatstone bridge
- 20 mm x 11 mm, 2000 mm wire
- Operating Voltage: 5 - 15 V

Load Cell Amplifier: SparkFun Load Cell Amplifier - HX711

- ADC to convert analog Load Cell signal into a Digital signal
- Operating Voltage: 2.7 V - 5 V
- Operating Current: < 1.5 mA



Power Management System



Solar Panel

Solar Power

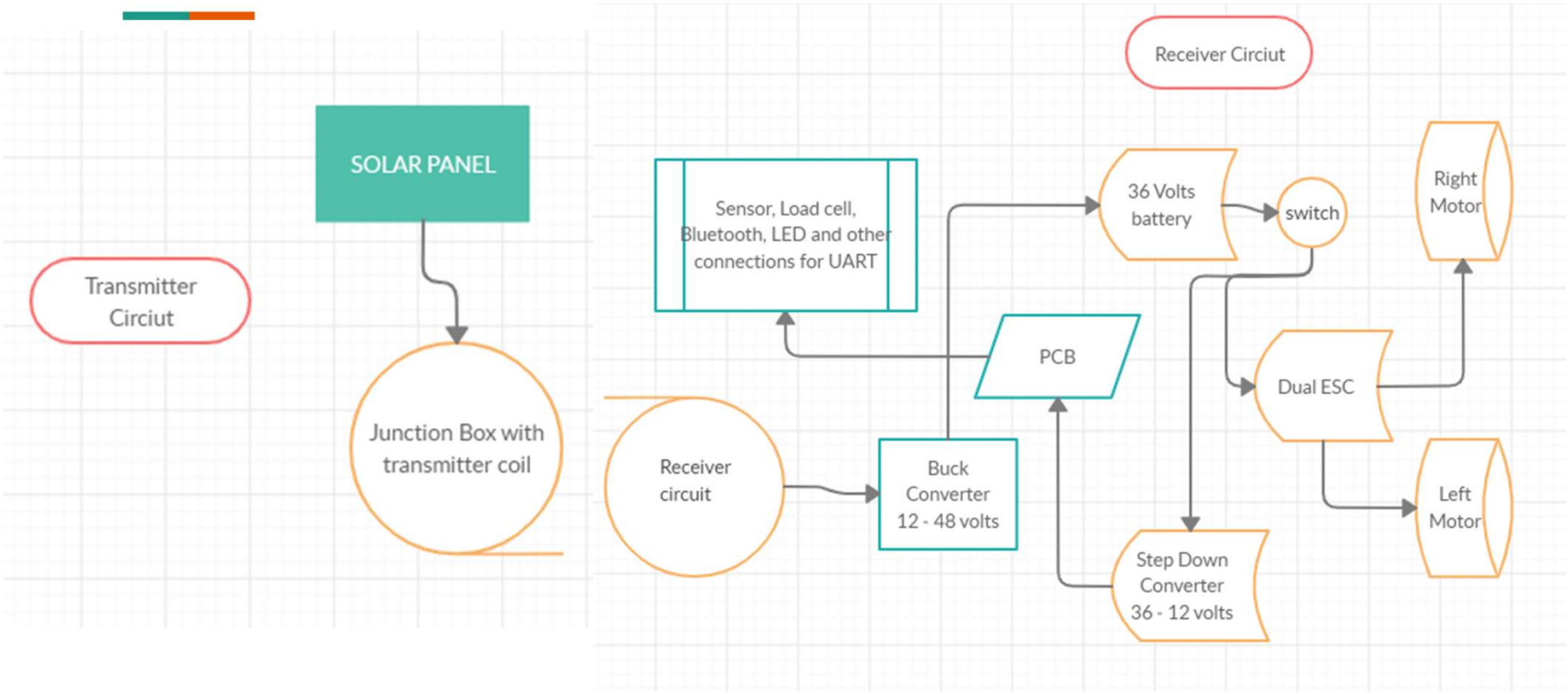
Monocrystalline Panel - Pros

- First choice for highest efficiency
- Highest power output
- Requires least amount of space
- Longevity and long warranty from manufacturers

Monocrystalline Panel - Cons

- More expensive
- Open circuit if covered by shade, dirt or snow (use of micro inverters required)
- More efficient in warmer weather

Power Management Flowchart



Battery

Battery - 36V Lithium-Ion

Pros

- Greatest electrochemical potential
- Largest energy per weight
- High energy density
- Low internal resistance
- Low self discharge rate & low maintenance

Cons

- Fragile
- Requires protection circuit for safe operation (most)
- Expensive to manufacture and requires frequent upgrade

Battery Meter

- Voltage range of 12 - 84 volts
- Battery Meter with real time voltage reading
- Liquid Crystal Display for battery state
- Waterproof design
- No external switch needed
- Lead-acid and Lithium-ion compatible

Wireless Charging

Magnetic Induction (Inductive)

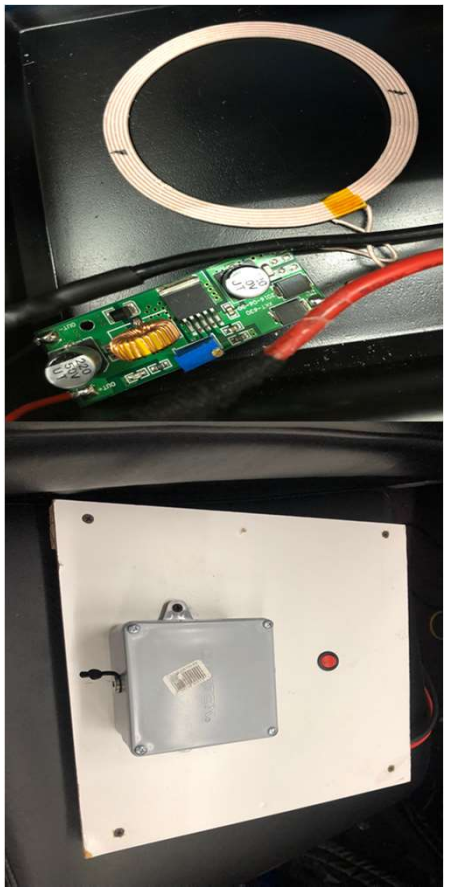
High resonant frequency wirelessly transfers energy using inductive coupling.

Pros

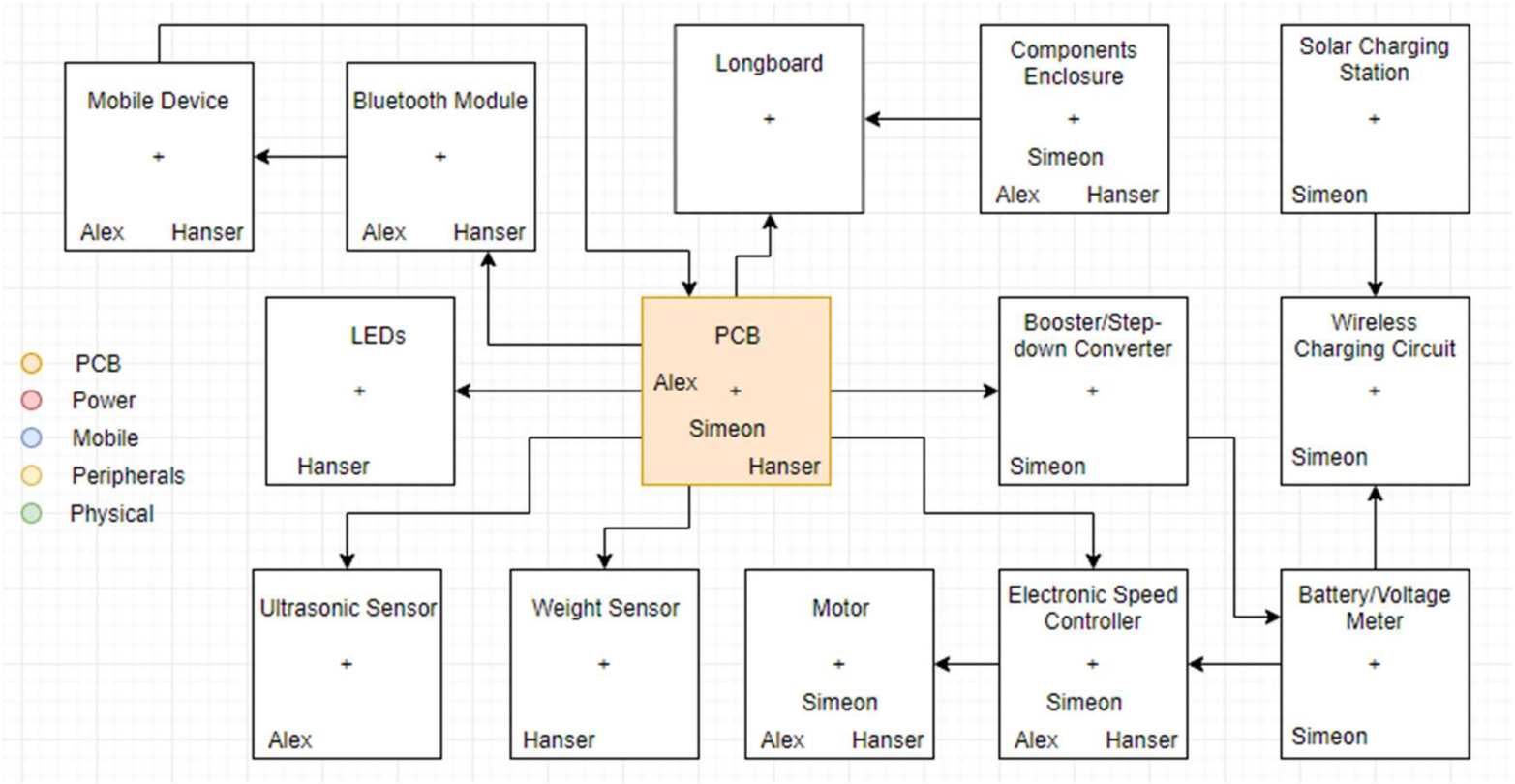
- Simple and efficient
- Safe
- Scalable
- Mature
- Good coupling

Cons

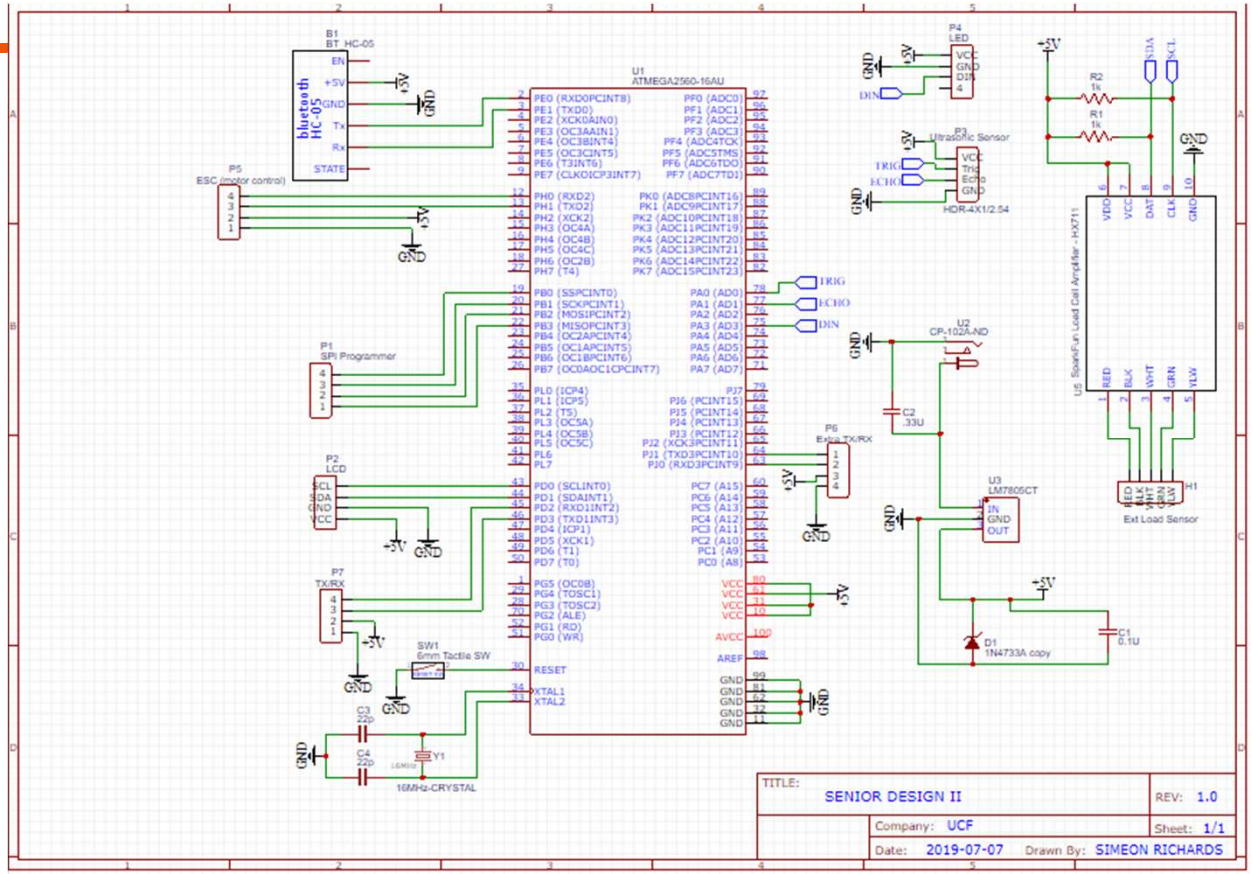
Has to be in close proximity



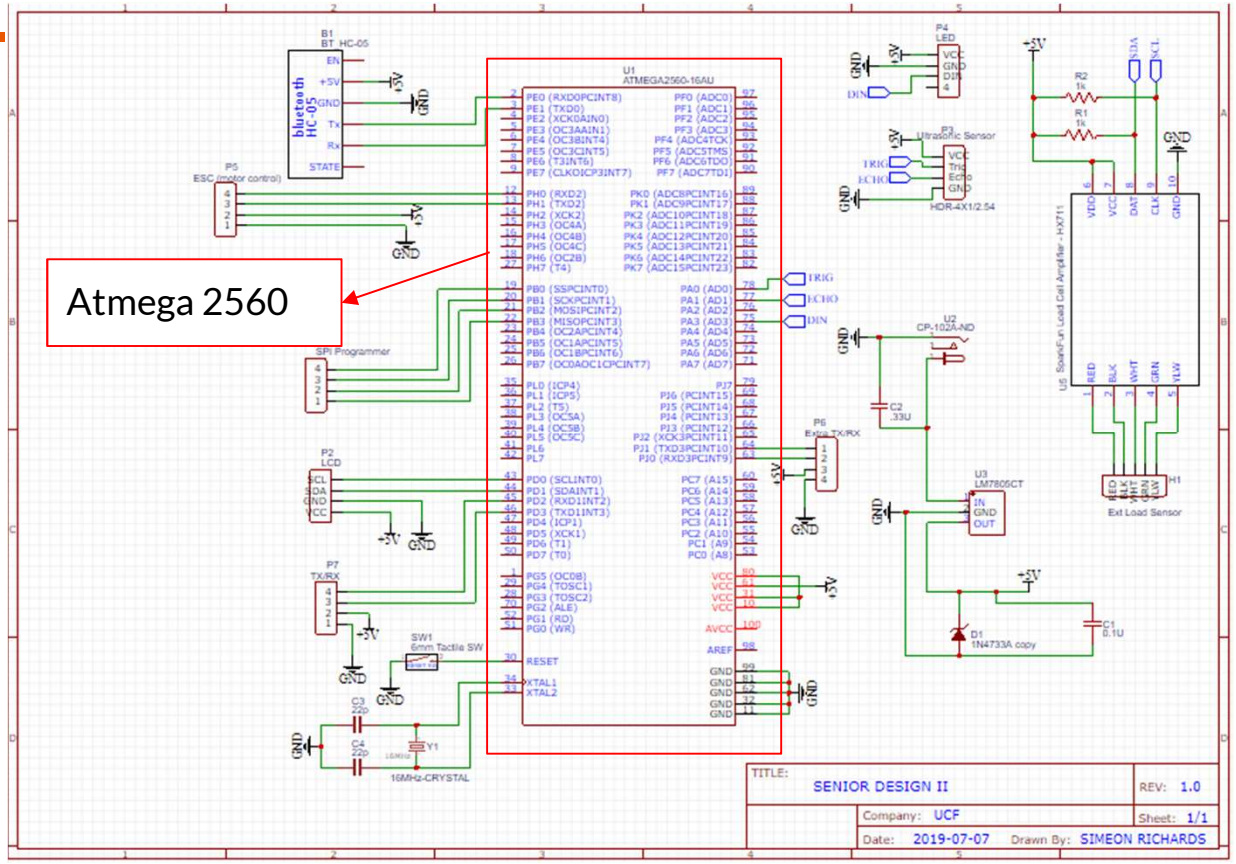
PCB


Mobile Device
+
Alex Hanser
Bluetooth Module
+
Alex Hanser
Longboard
+
Components Enclosure
+
Simeon
Alex Hanser
Solar Charging Station
+
Simeon
LEDs
+
Hanser
PCB
Alex +
Simeon
Hanser
Booster/Step-down Converter
+
Simeon
Wireless Charging Circuit
+
Simeon
PCB
Power
Mobile
Peripherals
Physical
Ultrasonic Sensor
+
Alex
Weight Sensor
+
Hanser
Motor
+
Simeon
Alex Hanser
Electronic Speed Controller
+
Simeon
Alex Hanser
Battery/Voltage Meter
+
Simeon

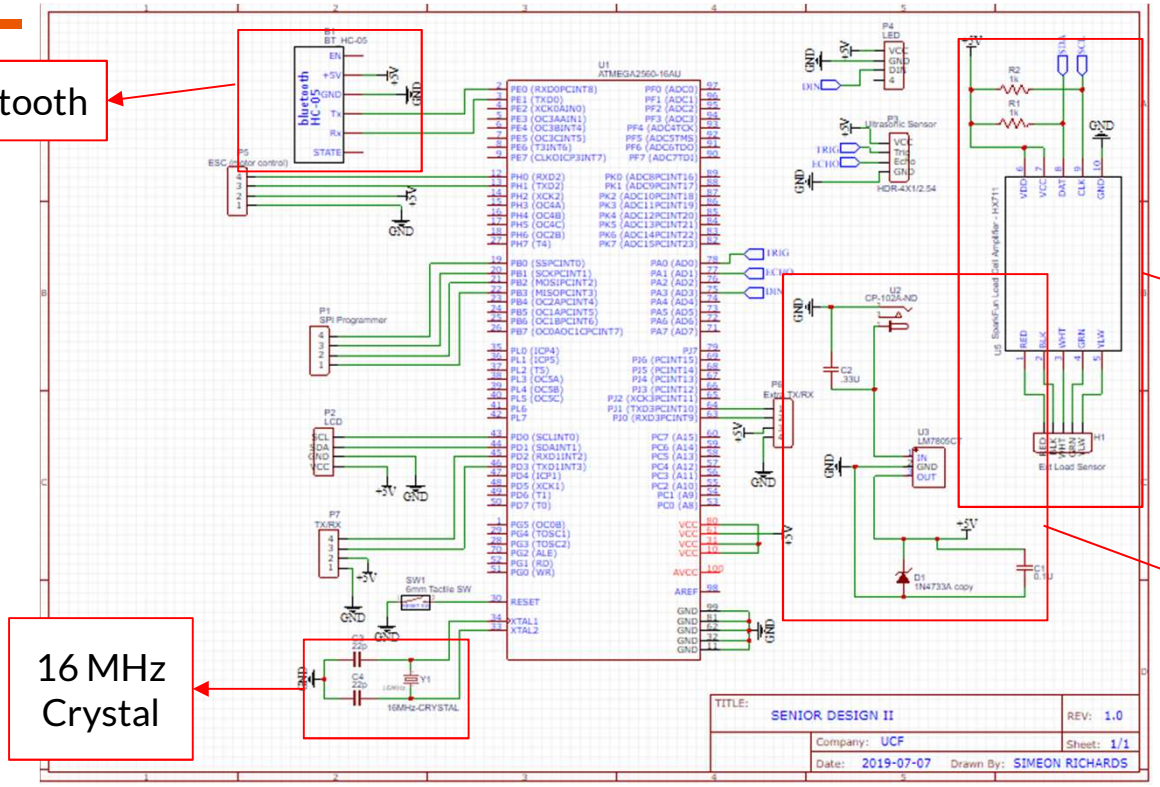
PCB Schematic Design



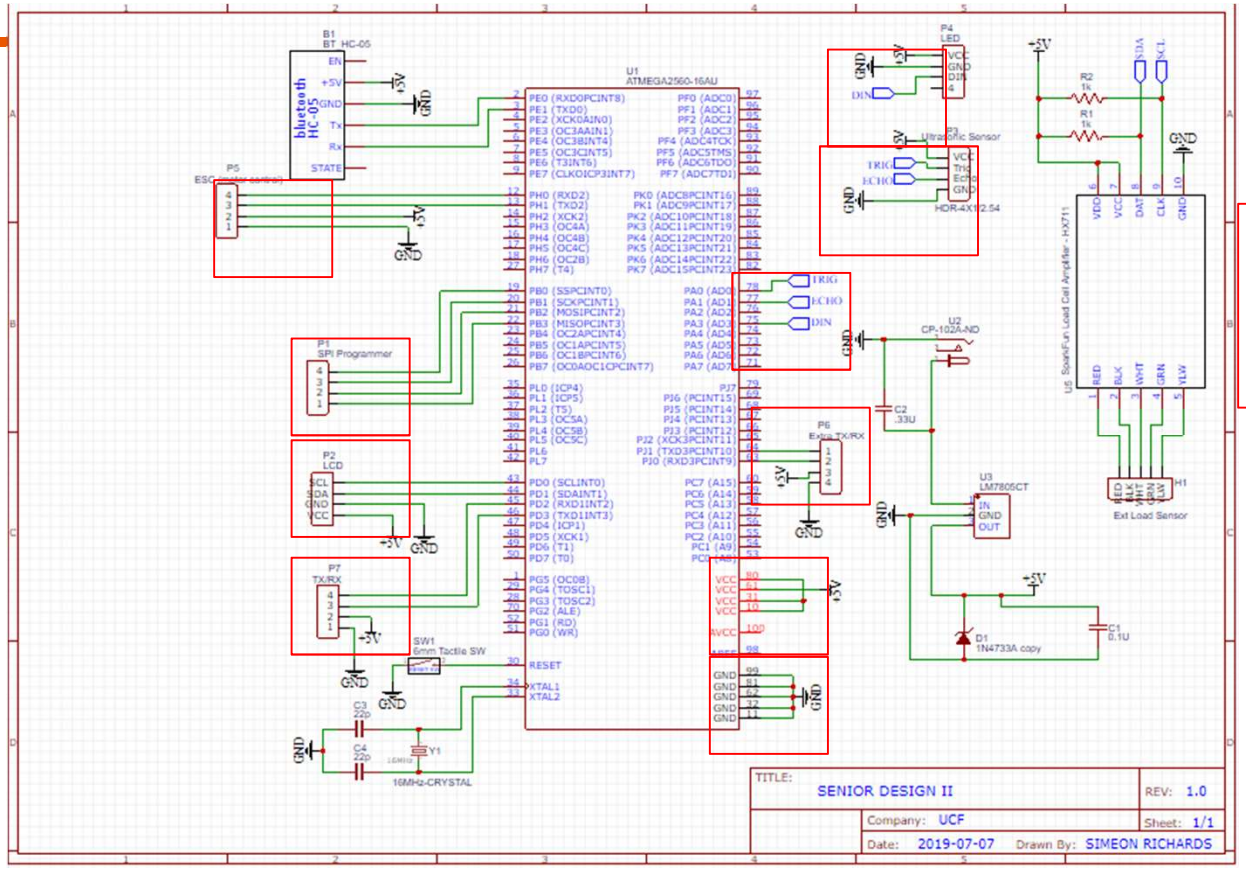
PCB Schematic Design



PCB Schematic Design

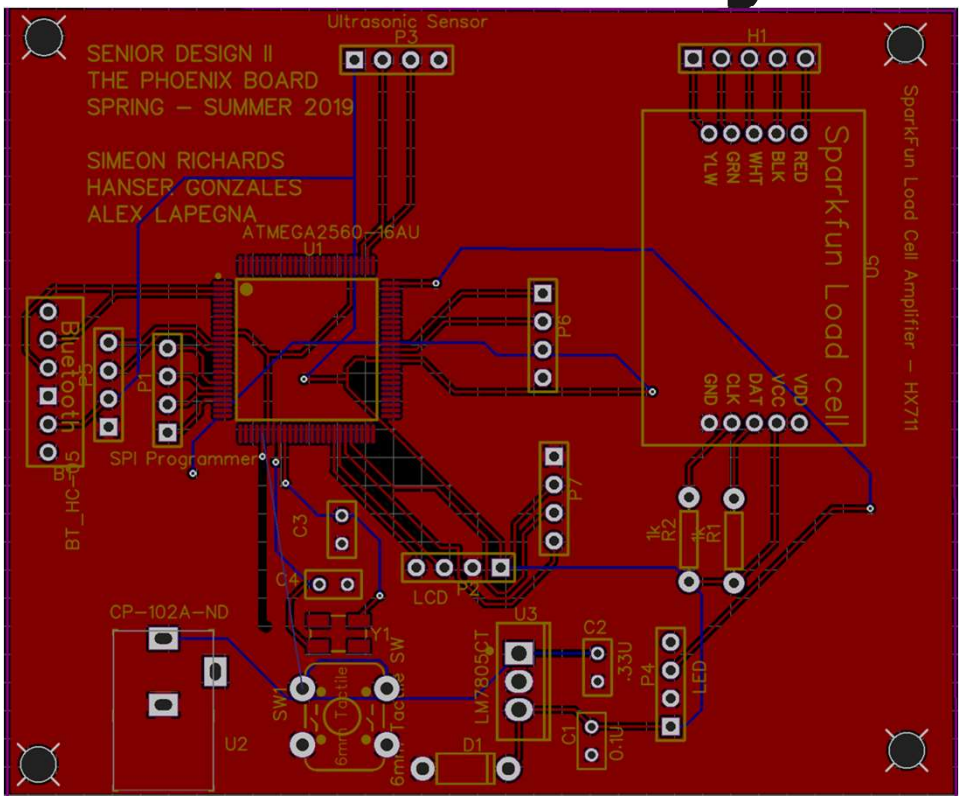


PCB Schematic Design

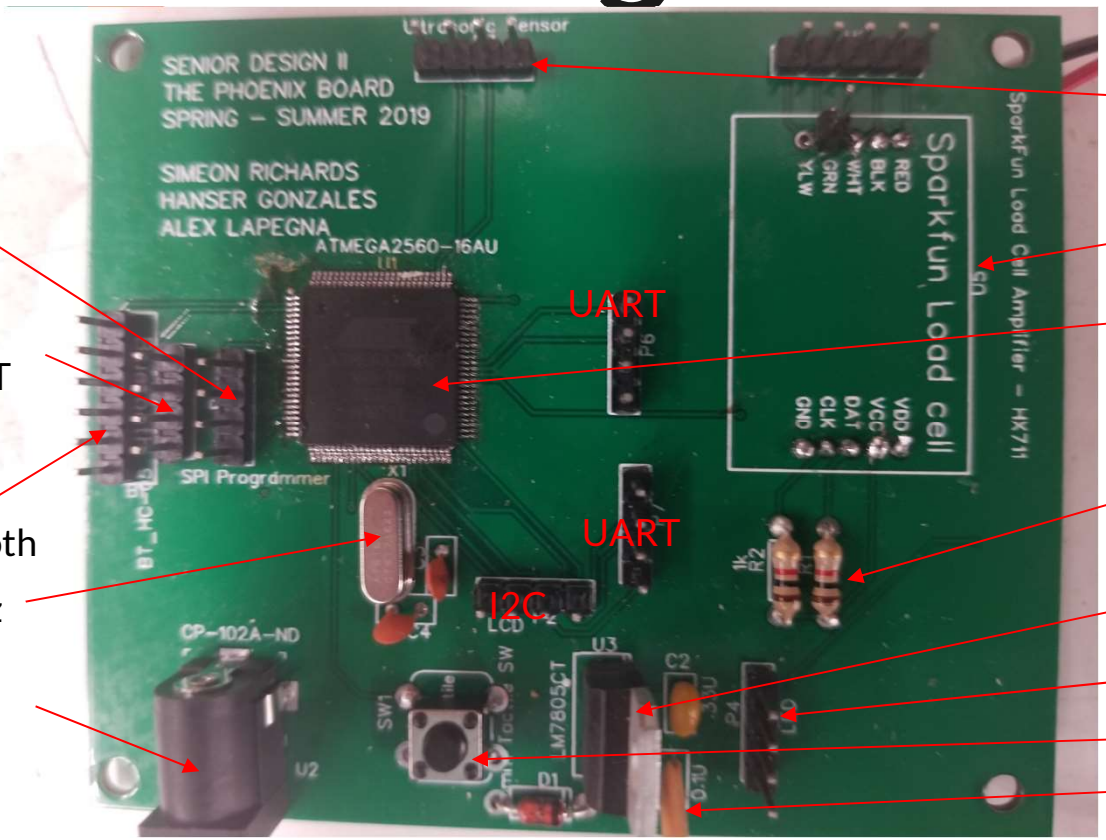


Pins and connectors for external devices

PCB Board Layout



PCB Design



SPI

UART

Bluetooth

16 MHz Crystal

12 V DC

Sensor pins

Load cell

Atmega 2560

Resistors (1K)

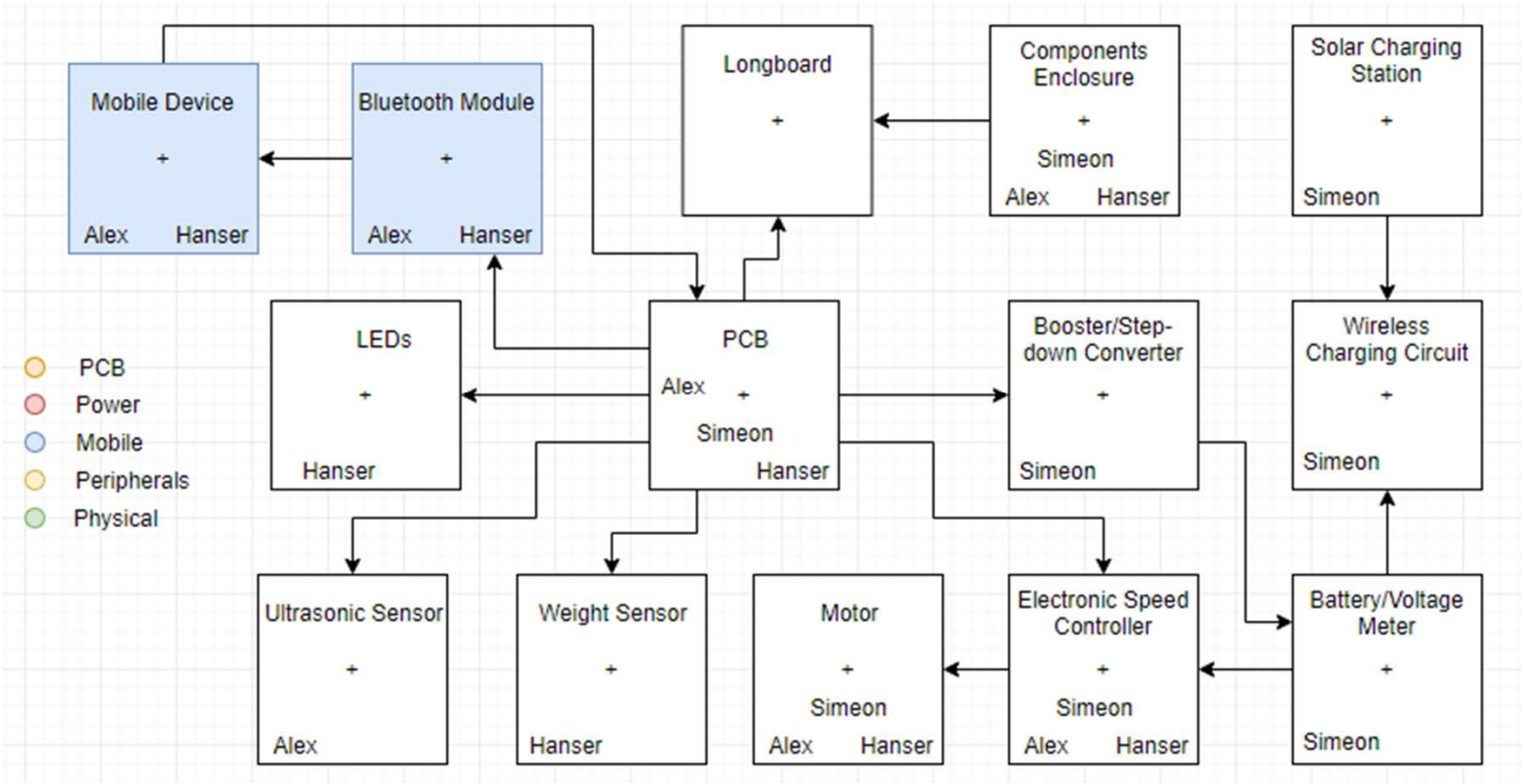
Voltage Regulator

LED pins

Reset pin

Capacitors

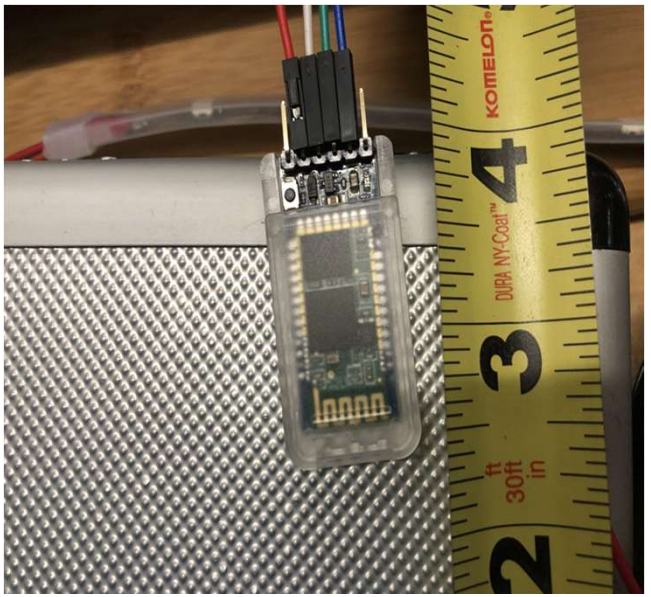
Mobile App / Wireless Communication



Bluetooth Module

DSD Tech HC-05 Bluetooth Serial Pass-Through module

- Bluetooth Classic 2.0 module
- +5 V
- Default baud rate of 9600
- Connected to PCB UART
- Used to received data from the mobile app

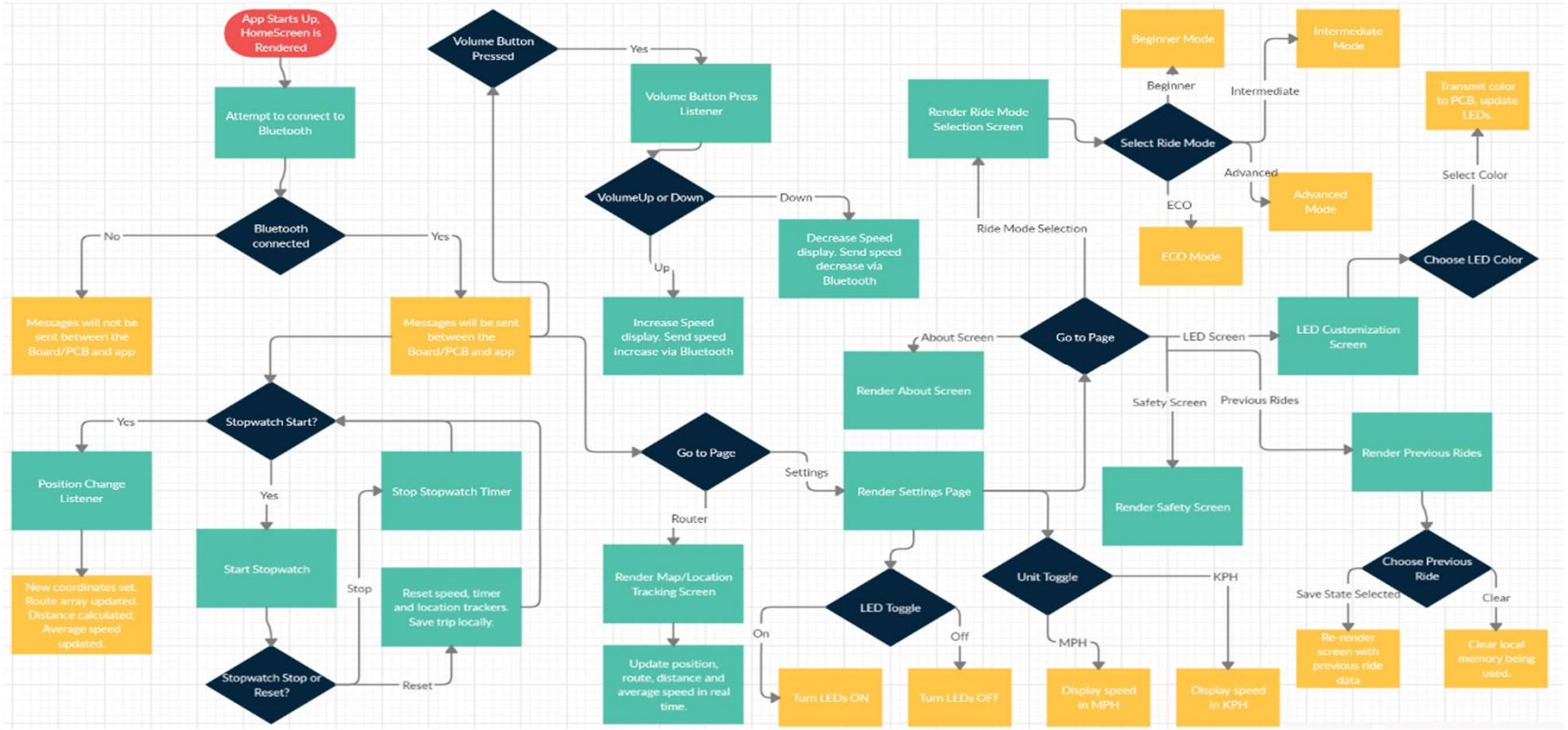


Mobile Application IDE

Mobile IDE: React Native

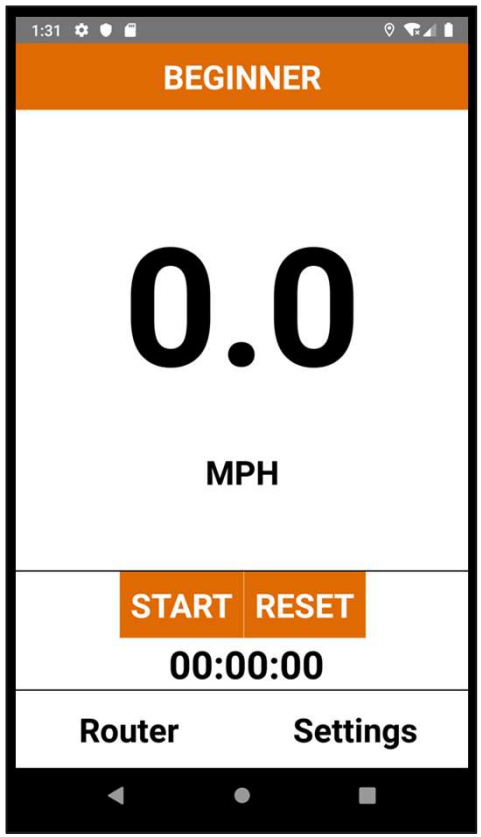
- React Native selected for ability to natively develop for both Android and iOS
- Utilizes Node.js, Python2, and Java SE Development Kit 8
- Development done in Android Studio
- Current goal is developing Android version only, future goal can expand to iOS version
- Testing done on Samsung Galaxy S5 and Android Virtual Device

Flowchart


App Starts Up. HomeScreen is Rendered
Attempt to connect to Bluetooth
Bluetooth connected
No
Yes
Messages will not be sent between the Board/PCB and app
Messages will be sent between the Board/PCB and app
Volume Button Pressed
Yes
Volume Button Press Listener
VolumeUp or Down
Down
Decrease Speed display. Send speed decrease via Bluetooth
Up
Increase Speed display. Send speed increase via Bluetooth
Stopwatch Start?
Yes
Position Change Listener
New coordinates set. Route array updated. Distance calculated. Average speed updated.
Yes
Start Stopwatch
Stop
Stop Stopwatch Timer
Reset speed, timer and location trackers. Save trip locally.
Stopwatch Stop or Reset?
Reset
Go to Page
Settings
Router
Render Map/Location Tracking Screen
Update position, route, distance and average speed in real time.
Render Settings Page
LED Toggle
On
Off
Turn LEDs ON
Turn LEDs OFF
Render Ride Mode Selection Screen
Ride Mode Selection
Select Ride Mode
Beginner
Intermediate
Advanced
ECO
Beginner Mode
Intermediate Mode
Advanced Mode
ECO Mode
Go to Page
About Screen
LED Screen
Render About Screen
LED Customization Screen
Choose LED Color
Transmit color to PCB, update LEDs.
Select Color
Safety Screen
Previous Rides
Render Safety Screen
Render Previous Rides
Unit Toggle
KPH
MPH
Display speed in MPH
Display speed in KPH
Choose Previous Ride
Save State Selected
Clear
Re-render screen with previous ride data
Clear local memory being used.

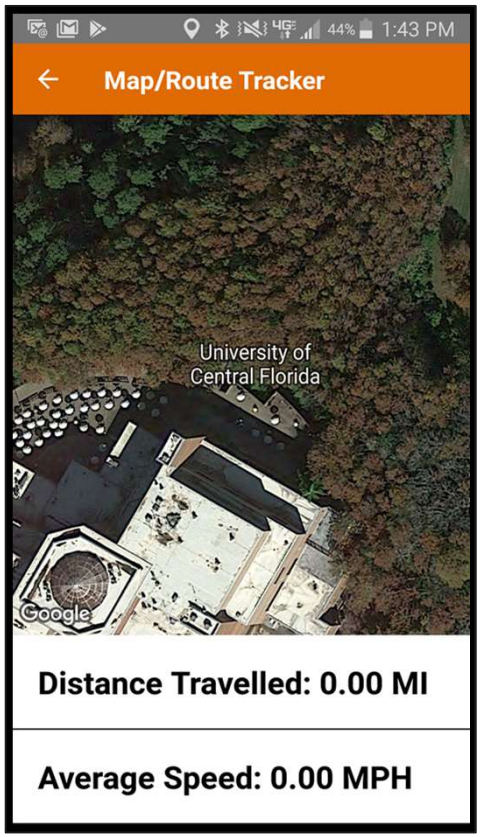
Mobile App Design

- Bold header with current Ride Mode
- Speed, in MPH or KPH displayed prominently in center of screen
- Stopwatch used in tracking trip duration as well as average speed
- Reset button
  - Resets the stopwatch
  - Resets the board's speed
  - Logs trip into local memory
- Buttons to traverse to map screen and setting screen



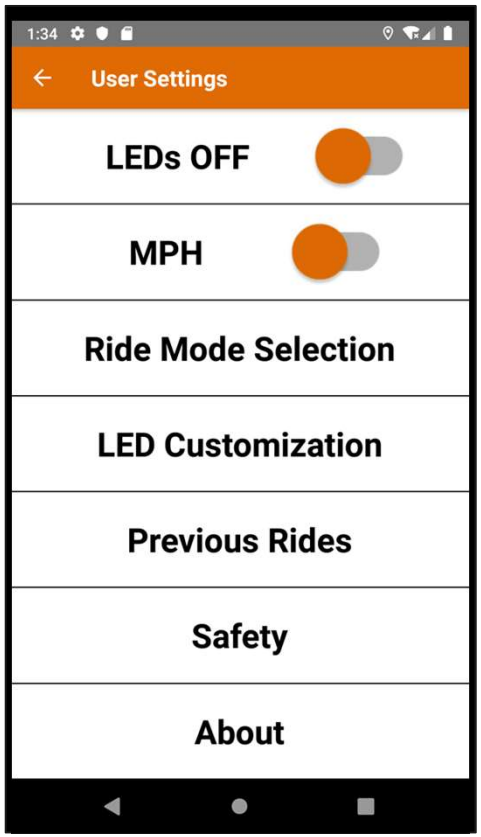
Mobile App Design

- Integrated map
  - Using the phone's internal GPS in order to get this information
  - Tracks location in real time
- Tracking Ride Data
  - Can be used in various ways in order to maximize ride efficiency
  - Metrics can be used to compare different routes



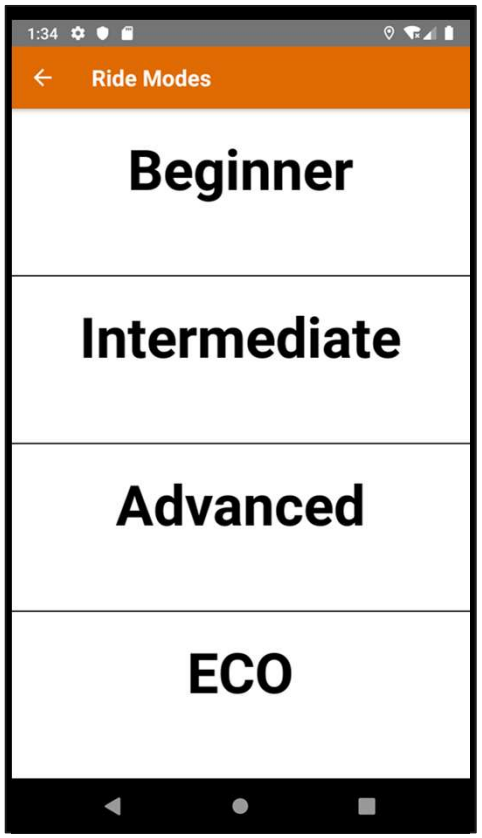
Mobile App Design

- Toggle switches, for the LEDs and for unit of measurement for speed/distance
- Access to multiple screens
  - Ride Mode Selection
  - LED Customization
  - Previous Rides
  - Safety
  - About



Mobile App Design

- Ride Modes
  - Beginner
    - Includes ultrasonic sensor safety feature
  - Intermediate
  - Advanced
  - ECO
    - Disables safety features to extend battery life



Embedded Design

- Board_Main Setup
  - Initializes 3 UARTS: Bluetooth adapter and 2 VESC motor controls
  - Clears LED strip in case of any residual PWM signal on signal line
  - Initialize load cell for weight sensing
  - Initialize ultrasonic sensor for obstacle detection

Embedded Design

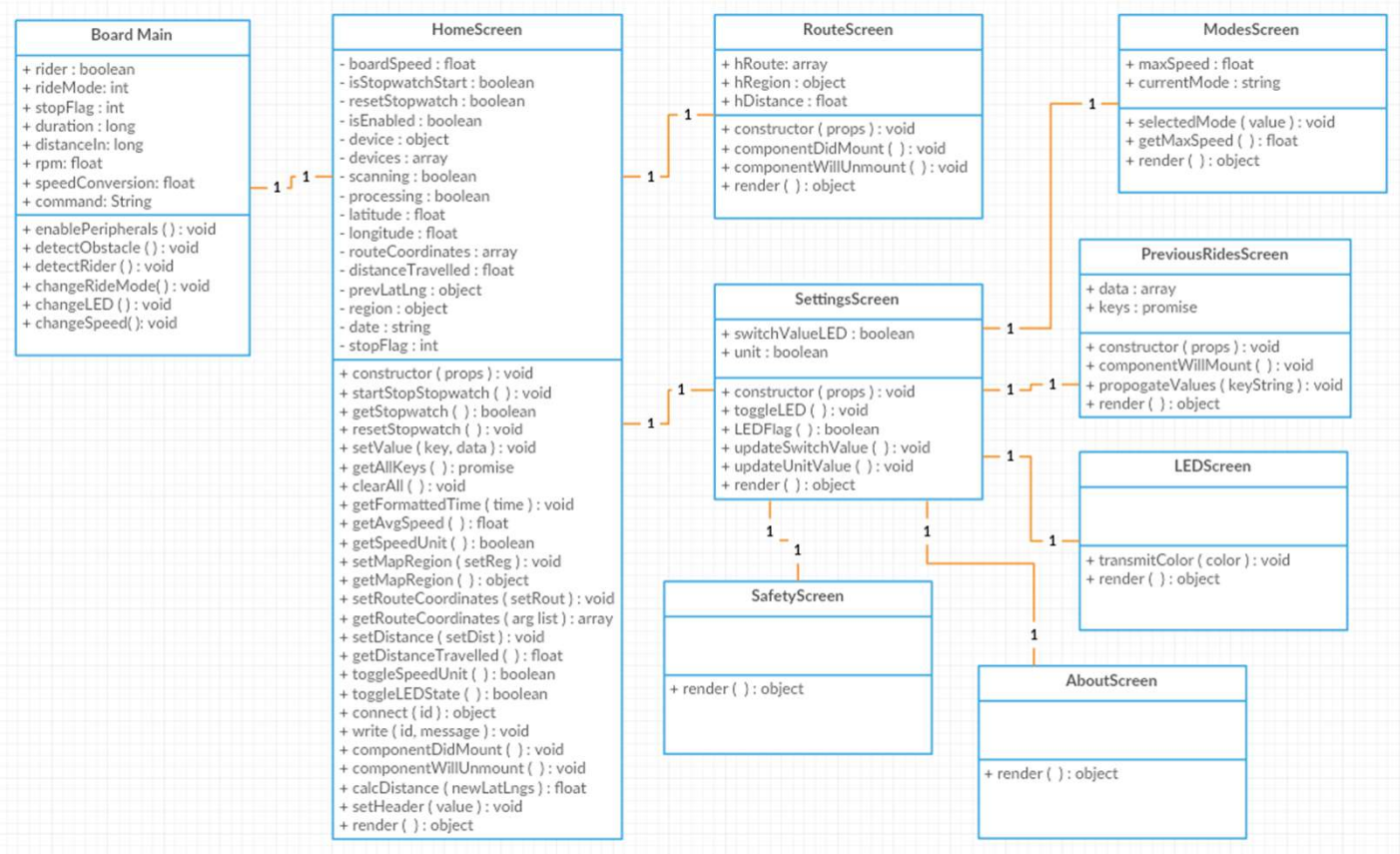
- Board_Main Loop
  - Check for load cell for rider, if non-zero input detected over threshold, transmit flag to app, signals app is safe to transmit data
  - Check for obstacles, if obstacle detected under threshold distance, begin emergency stop procedure, transmit flag to app

Embedded Design

- Board_Main Loop Cont'd
  - Check for incoming serial commands
    - LED Change
    - Speed Change
    - Ride Mode Change

Complete Internals & Externals

Class Diagram



Constraints

- Economic
  - Exceeded project budget
- Size and weight
- User experience
  - Accessible for any level of rider
  - Customizable and easy-to-use app
- Ensuring safety of user without compromising experience

Issues

- Having to switch from MSP430F5529 to ATmega2560 in last month of development
- Initial time lost designing MSP430 software and PCB
- Accidentally damaging part of our ESC
- Physically fitting all components into enclosure
- Communications between different mobile app components
- Finding best placement of wireless charging coils to maximize charging voltage
- Battery shorted the day before the presentation and damaged multiple components

Distribution of Responsibilities

Name	Mobile App	PCB	Sensor Suite	Battery / Power Management	Motor / ESC	Components Enclosure
Alex	S	S	P		P	S
Hanser	P	S	S		S	P
Simeon		P		P	S	S

P = Primary

S = Secondary

Initial Budget

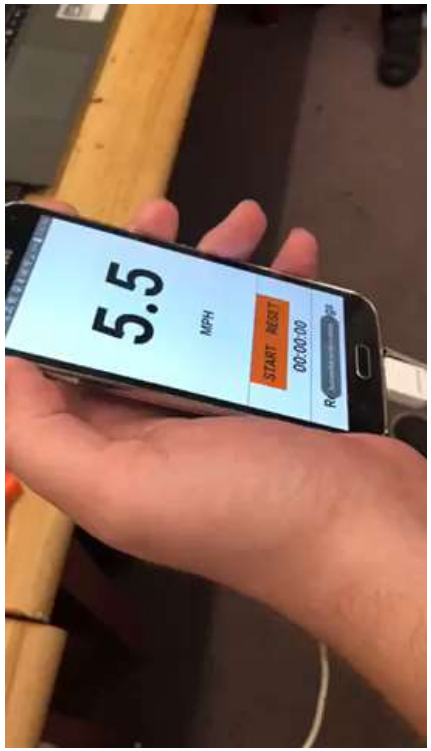
Part	Price (USD)	Part	Price (USD)
Longboard	$60	Ultrasonic Sensor	$6
Load Cell	$60	PCB Fabrication	$50
Load Cell Amp	$10	Voltage Regulator	$7
Battery	$146	RGB LED Strip	$20
Battery Fuel Gauge	$4	Launchpad	$13
Hub Motor	$220	MPPT Charge Cont.	$47
Solar Panel	$87	Boost Converter	$34
Bluetooth Module	$30		
Camera	$40	Total	$834.00

Actual Expenses

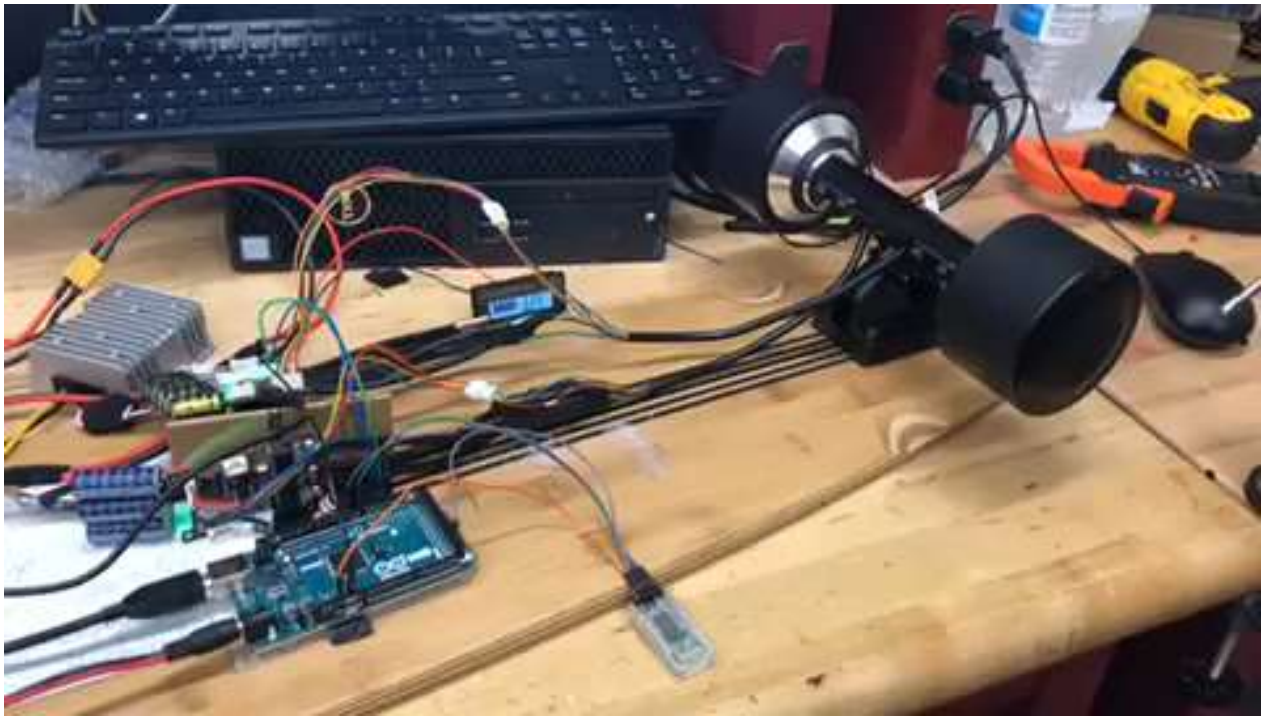
Part	Price (USD)	Part	Price (USD)
Longboard	$60	Ultrasonic Sensor	$6
Load Cell	$60	PCB Fabrication	$150
Load Cell Amp	$10	Voltage Regulator	$7
Battery	$146	RGB LED Strip	$20
Battery meter	$10	Arduino MEGA	$30
Hub Motor	$220	Boost Converter	$60
Solar Panel	$87	VESC	$120
Bluetooth Module	$30		
Miscellaneous	$100	Total	$1180.00

Any Questions?

Demo: Dual Motors



Demo: Dual Motors, Max Speed



Demo: LEDs (App and PCB)

Demo: App, Motors, and PCB

Demo: Wireless Charging (fast, DC power supply)

Demo: Wireless Charging via Solar Panel