Model for Wireless Charging for E-Bikes

Team 30
Ronald Roy, Maneesh Madala, Jason Gong
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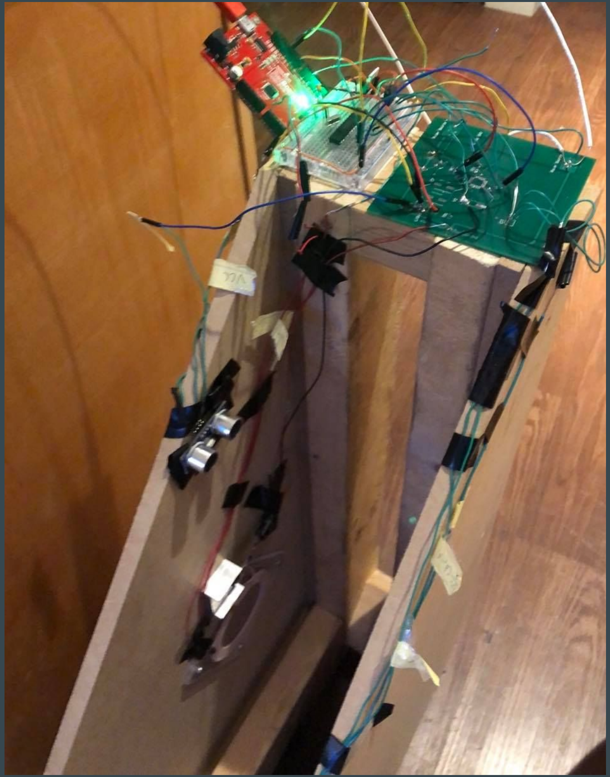
Introduction

- Our model allows easy charging using inductive charging on E-bikes for users while saving money for companies such as Lime and Veoride
- The model is broken up into 2 seperate parts. The bike and the bike rack.

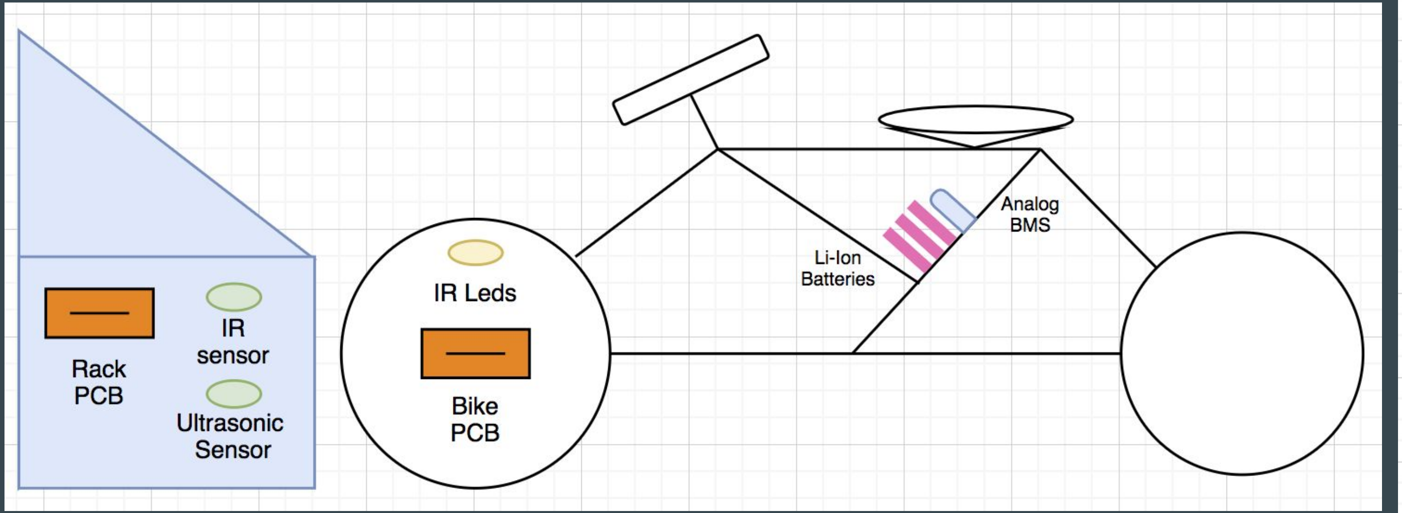
Introduction

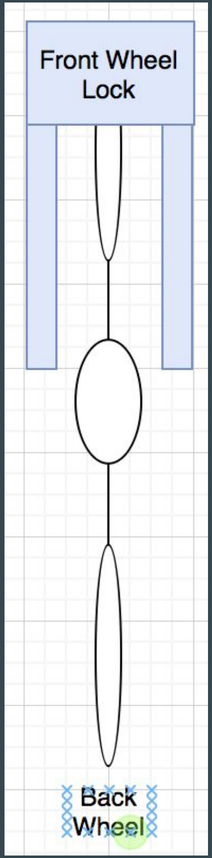
- The bike rack system is connected a power source to power a transmitter Qi Coil
- The bike monitors a Li-Ion battery pack, using a Qi Coil receiver to charge the battery
- During normal charging the front wheel of the bike is inserted into the bike rack where the Qi Coil line up to allow for inductive charging.

Product



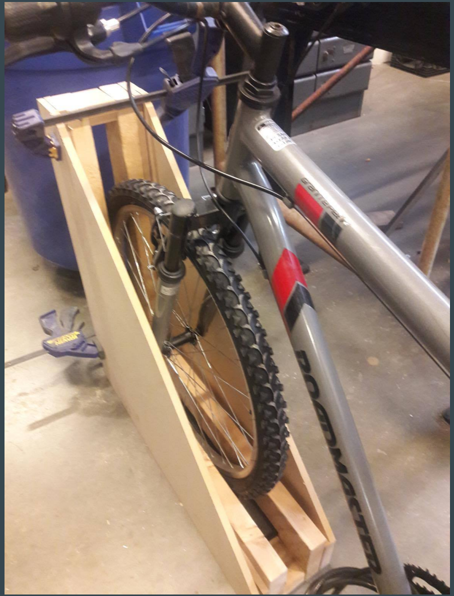
Ideal Layout





Physical Design

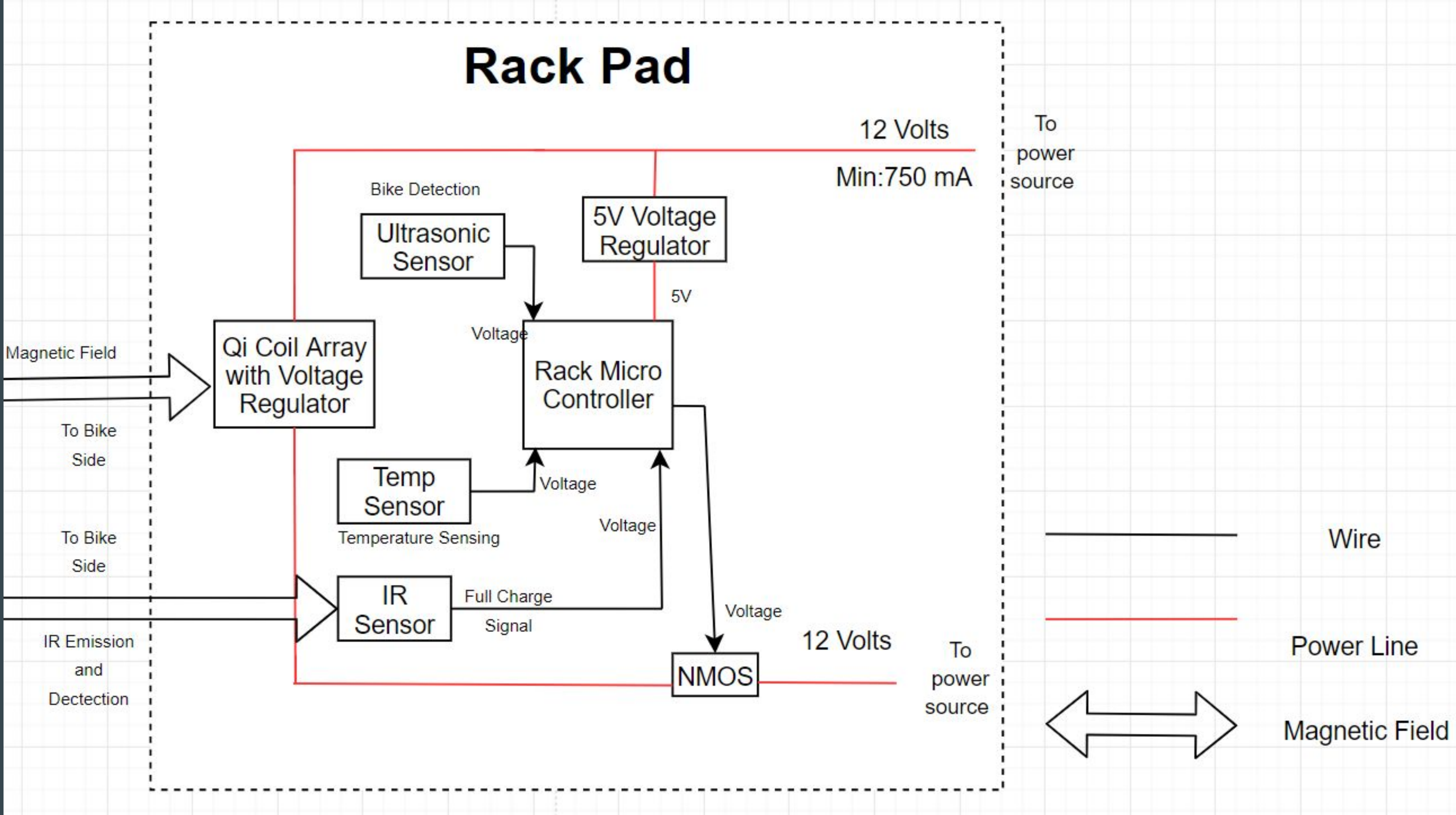
The bike rack has rails to help stabilize the bike once it has been inserted. The front tire insert is an inch wider than the width of the tire. The bike-side pad is mounted near the center axis of the front tire.



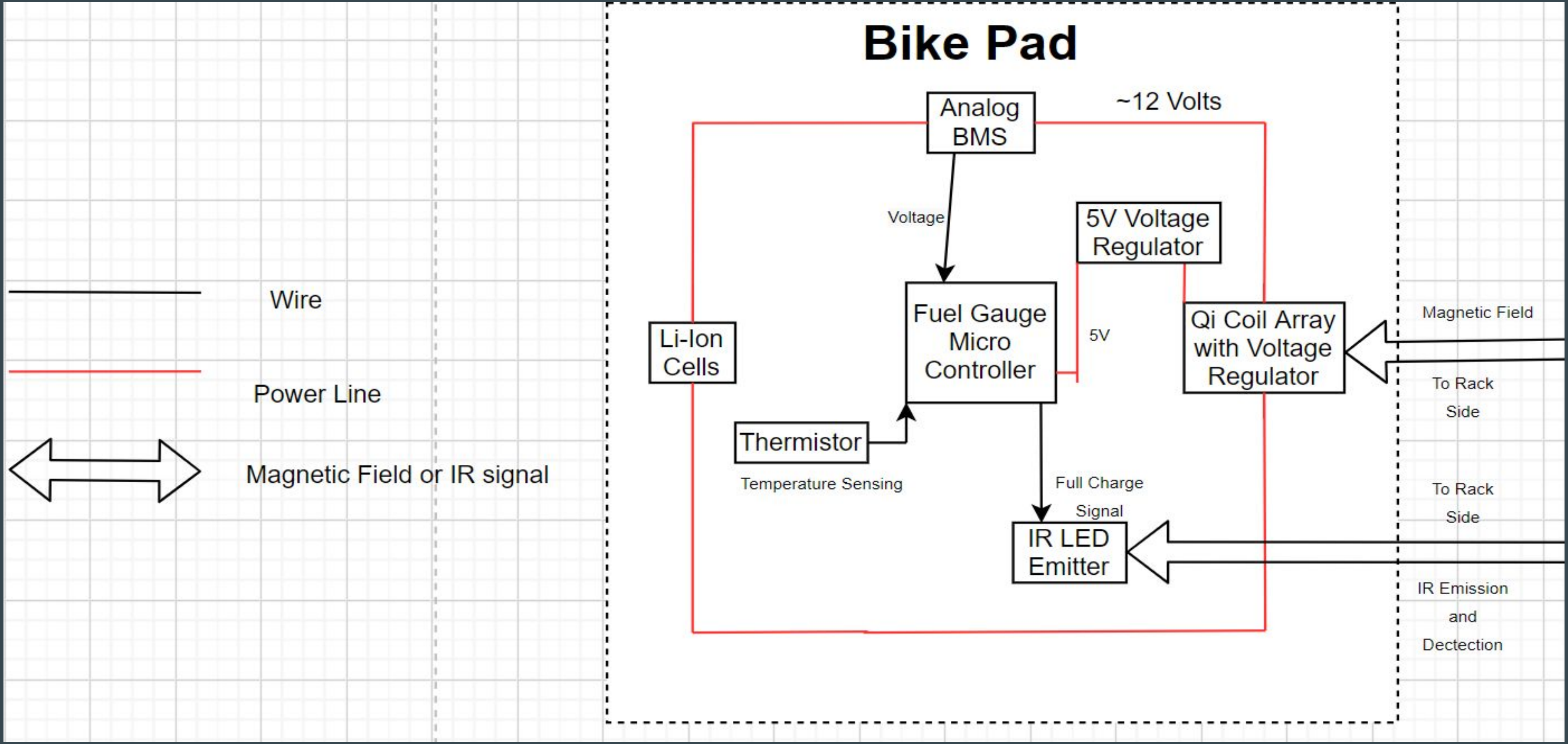
Features

- Expandable and easily scalable design
- Up to 70% efficient compared to wired charging
- Simple user interface
- Only requires a 2 terminal 12V power source to power the bike rack
- Full Capacity Charge Time: ~9 hours to 7 hours

Rack Side Block Diagram



Bike Side Block Diagram



System Overview

- Mechanical
  - Front tire clasp to hold tire in place where TX and RX Qi Coils line up
  - Bike should be able stand upright while on the rack.
- Hardware
  - Power- Qi Coils, N-channel MOSFET, Analog BMS, Li-Ion battery pack
  - Control- Ultrasonic Sensors, IR Sensors, IR LEDs, Temperature Sensors, ATMEGA328P-PU
- Software
  - Bike rack code for charging
    - Allow charging during normal operation
  - Bike code for signalling whether battery is charged
    - Detect any safety conditions and signal the rack side

Hardware Overview

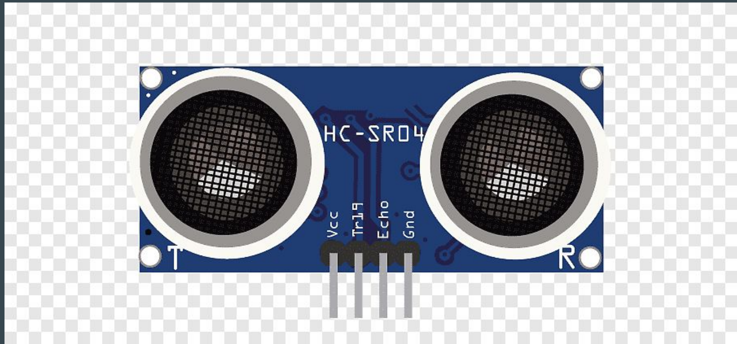
- Power
  - Qi Coil transmitter should take a 12V input to generate a changing magnetic field. The Qi Coil receiver will be placed inside this magnetic field and generates a current on the bike side.
  - N-channel MOSFET should be placed on the power path between TX Coil - and ground to turn the coils off/on
  - Analog BMS controls the battery pack and prevents overvoltage, prevents undervoltage, prevents overcurrent and does cell balancing.
  - Li-Ion battery pack is 4S2P. Nominal voltage is 13.8 V and nominal capacity is 6000mAh.

Hardware Overview

- Control
  - The ATMEGA328P-PU will be the microcontroller we will be using. It will run on external crystal of 16Mhz
  - Ultrasonic sensor on the rack side measures the distance of the walls of the rack.
  - IR Sensor on the rack side detects any IR emission.
  - IR LEDs are on the bike side and should be an output driven by the ATMEGA.
  - The temperature sensors will be placed near the battery on the bike side and near the TX coil on the rack side and measure temperature.

Ultrasonic Sensor

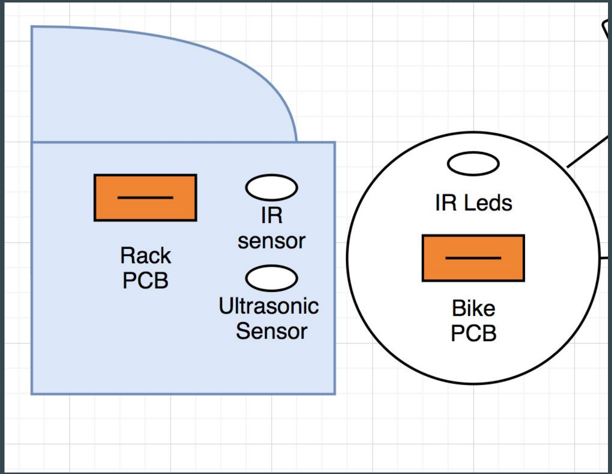
- The ultrasonic sensor is on the rack is measuring the distance between the bike rack and front tire if the bike is inserted into the rack
- If the measurements we read are less than 8 cm, this means that the bike is in the rack and we can start charging



IR Sensor and LEDs

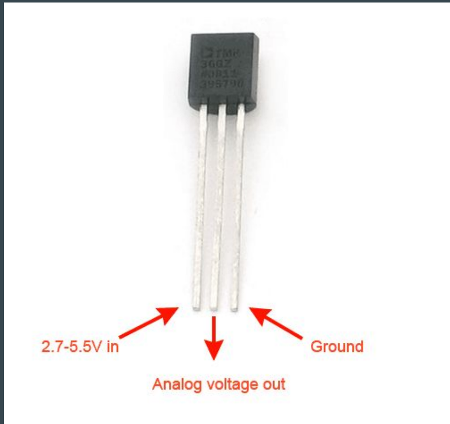
- The IR receiver is on the bike rack and will detect when the bike sends an IR signal.
- Detetcts IR leds with intensity between 120 mW/sr and 160 mW/sr up to 12 cm

- The IR LEDs on the bike will send a signal to the bike rack once the bike is done charging



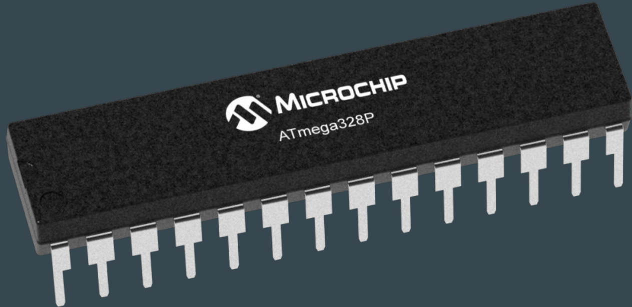
Temperature Sensor

- We placed temperature sensors on the Li-Ion battery pack and on the TX Qi Coil in order to sense temperatures in dangerous areas.
- In cases where we read a temperature higher than 45 C we will turn off power to the Qi Coils



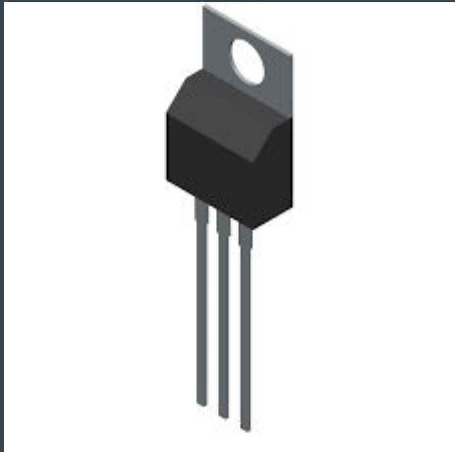
ATMEGA328P-PU

- The microcontroller we used was the ATMEGA328P-PU which takes in voltage readings from sensors and drives apporative outputs. The ATMEGA328P-PU can be tested along with the code by using an Arduino Development Board. The driven outputs are also going to be a voltage.



Voltage Regulator

- The UA7805CKCS voltage regulator was used to step down the power source voltage from 12v to 5v to power the microcontroller and the sensors used.

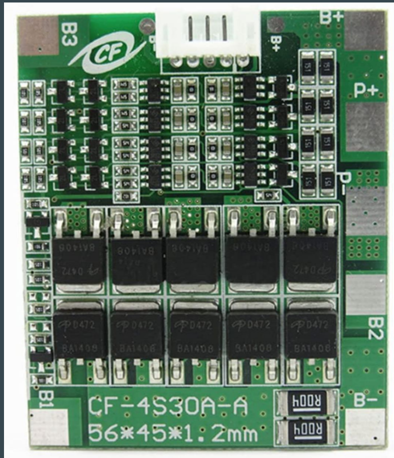


Li-Ion Cells and Battery

- Each cell had a nominal voltage of 3.45 V and a capacity of 3000mAh
- By creating a 4S2P we can make a 13.8V pack with a capacity of 6000mAh
- However, for real E-bikes in use around 20 V batteries with capacities around 10000mAh. For the purpose of cost and the project we will use our 4S2P configuration

Analog BMS

- This BMS stops overcharge at 4.08V +/- .1V per cell, undercharge at 2.55V +/- .05V per cell, overcurrent at 30A and performs cell balancing.
- Charge and discharge are done with back to back NMOS on the BMS
- P+ and P- are ports where charge and discharge of external circuits should be done
- The B+ and B- are ports for the cell stack
- Cell balancing is done by capacitors and the ports are on the top connector



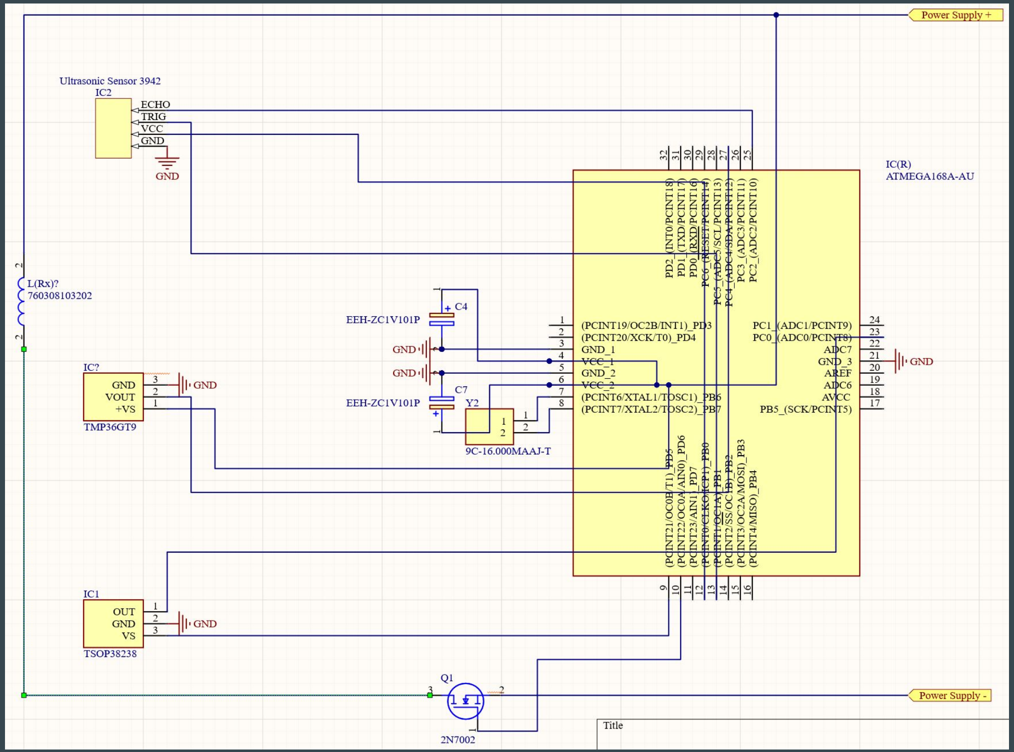
Qi Coils

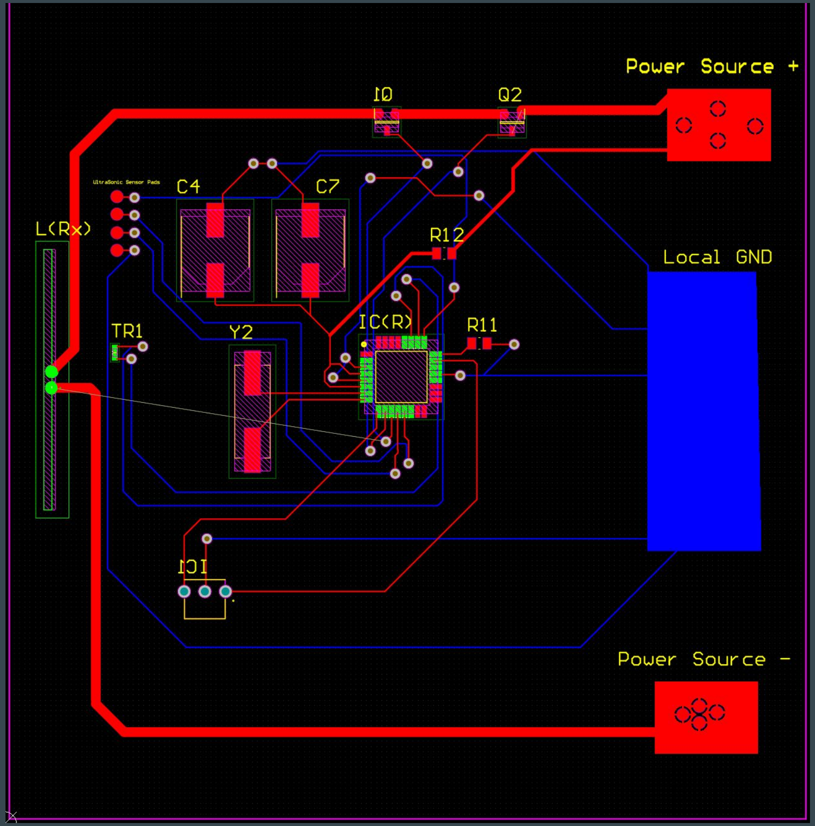
- Rack-side: The TX coil will use a 12 V input and boost the voltage to drive current into the coil to generate a magnetic field
- Bike-side: The coils will generate a current when in a magnetic field , according to Ampere's Law and will produced a 12 V output.

N-Channel MOSFET

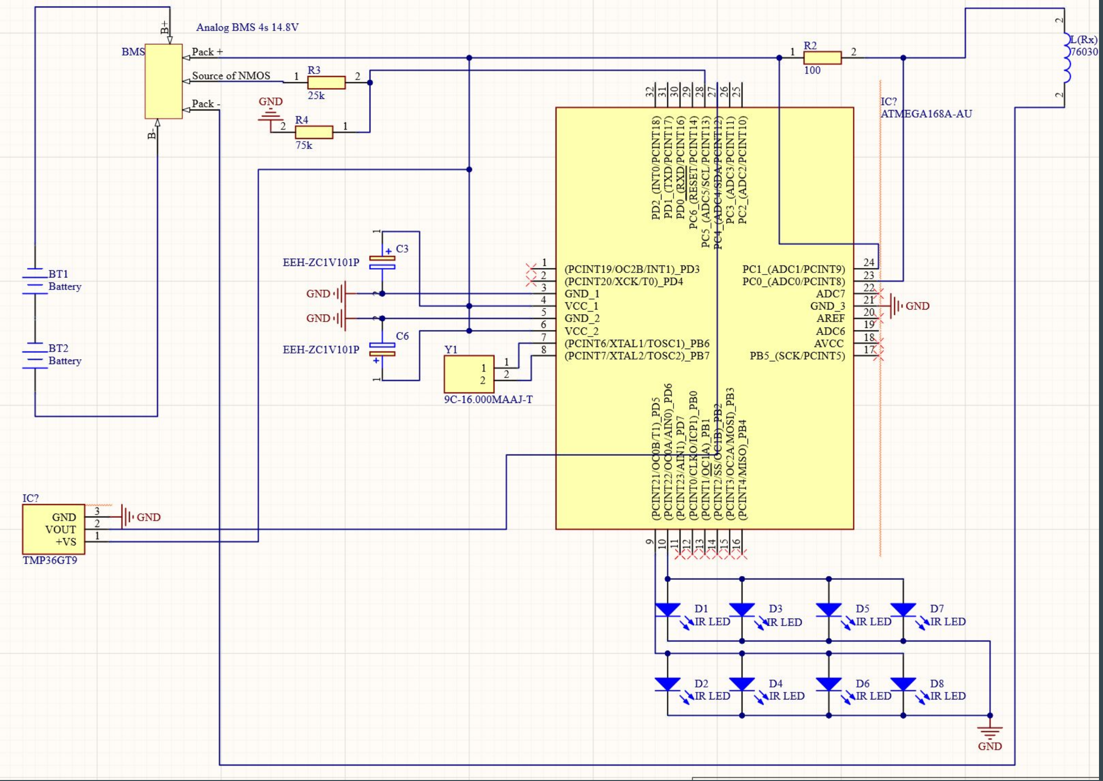
- The MOSFET is used to allow power flow for the TX Qi Coil.
- The drain of the Qi Coil is connected to Coil - and the drain of the MOSFET is connected to ground. The gate is connected to digital pin on the ATMEGA.
- When the digital pin is high it would set the gate to 5V which is over the gate threshold voltage so the MOSFET will be in saturation.
- When the digital pin is low the voltage at the gate is 0V so the MOSFET will be off.

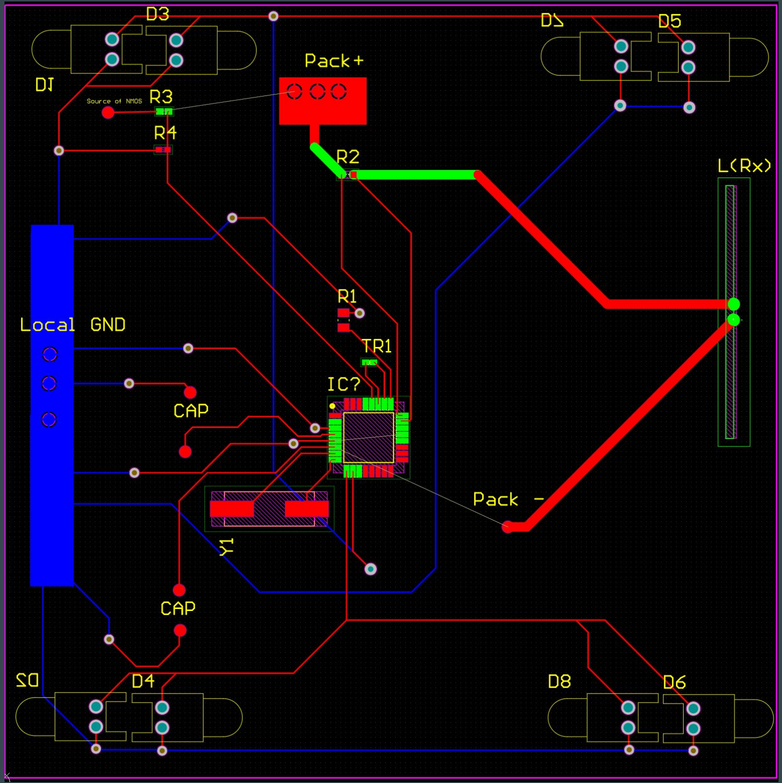
Rack Side Schematic and PCB





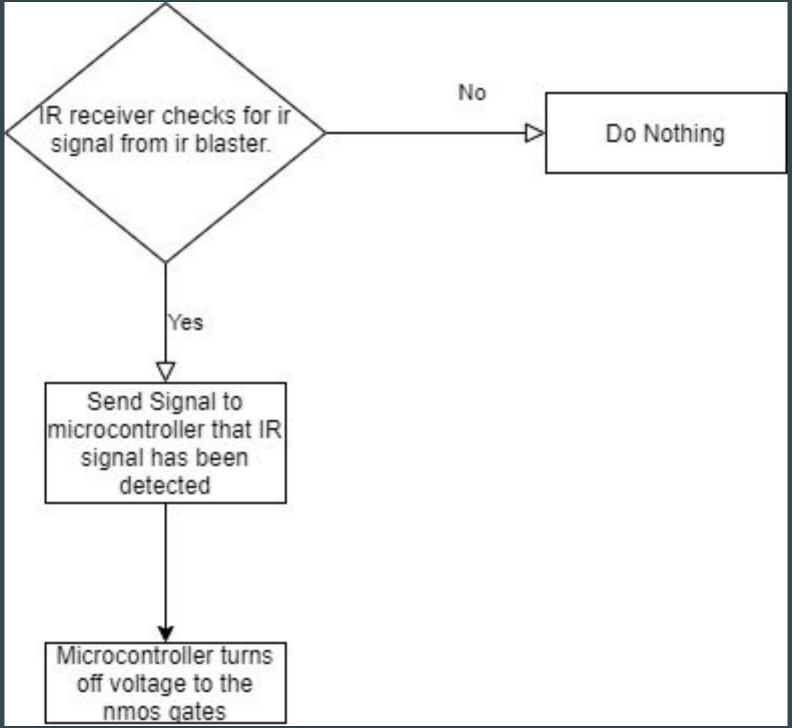
Bike Side Schematic and PCB

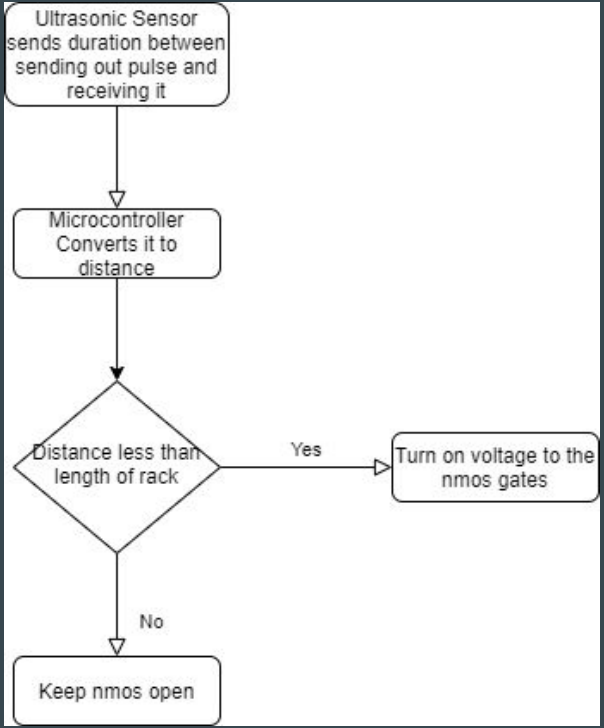




Software Diagrams

Initial diagrams for bike rack sensors.





Bike Rack Pseudocode

- Pseudocode for the infinite bike rack loop.
- Ultrasonic sensor detects distance
- Irrecv.h library used to detect IR signal with sensor
- Temperature sensor measures temperature of coils.
- If bike is in rack and no safety conditions the nmos is connecting the power source and transmitter coil.

```
bikeRackLoop:
    dist = ultrasonicDistance()

    if(irrecv detects signal):
        ir = true
    else:
        ir = false

    tempC = getTemperature()

    if(dist < BIKE_RACK_DIST && tempC < CUTOFF_TEMP && !ir):
        send4VoltsToNMOS()
    else:
        send0VoltsToNMOS()
```

Bike Pseudocode

- Pseudocode for the infinite bike loop.
- Reads voltage of one of the battery cells since BMS keeps them all equal.
- Temperature sensor detects voltage of battery.
- If the battery is charged or the temp is too high the IR leds are turned on.

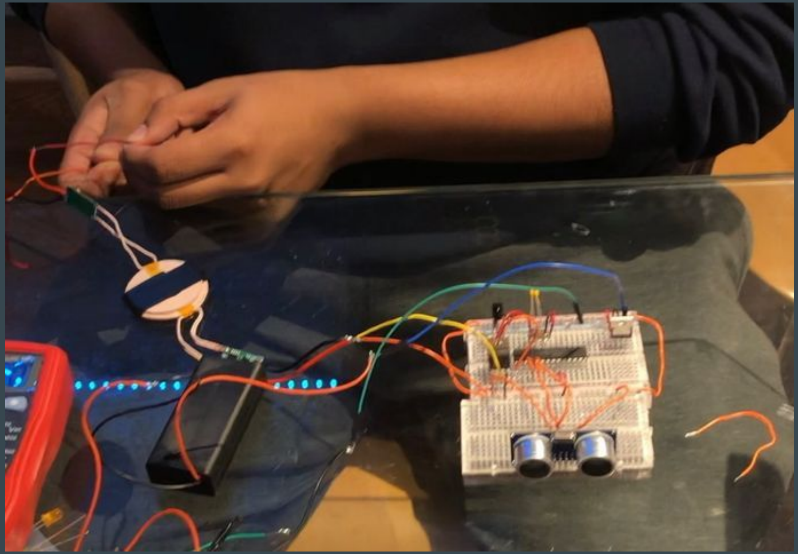
```
bikeLoop:
    voltage = readBatteryVoltage()

    tempC = getTemperature()

    if(voltage > CUTOFF_VOLTAGE || tempC > CUTOFF_TEMP):
        turnOnLedsPin1()
        turnOnLedsPin2()
    else:
        turnOffLedsPin1()
        turnOffLedsPin2()
```

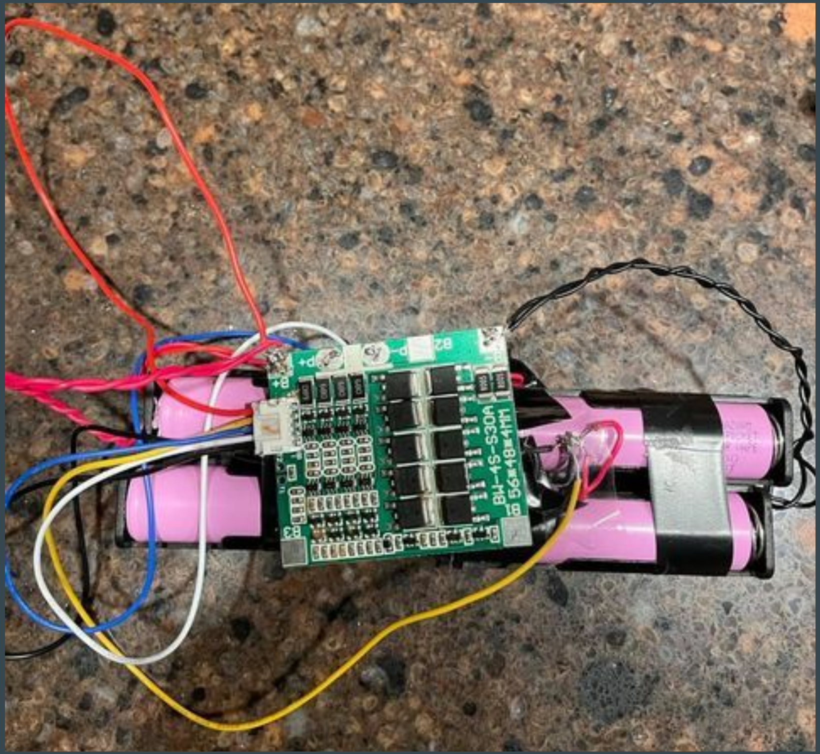
System Testing

- We tested the code and sensors on a breadboard using a visible led
- We tested the entire bike rack system on a breadboard with 5V Qi coils
- We tested the bike system on a breadboard using visible leds



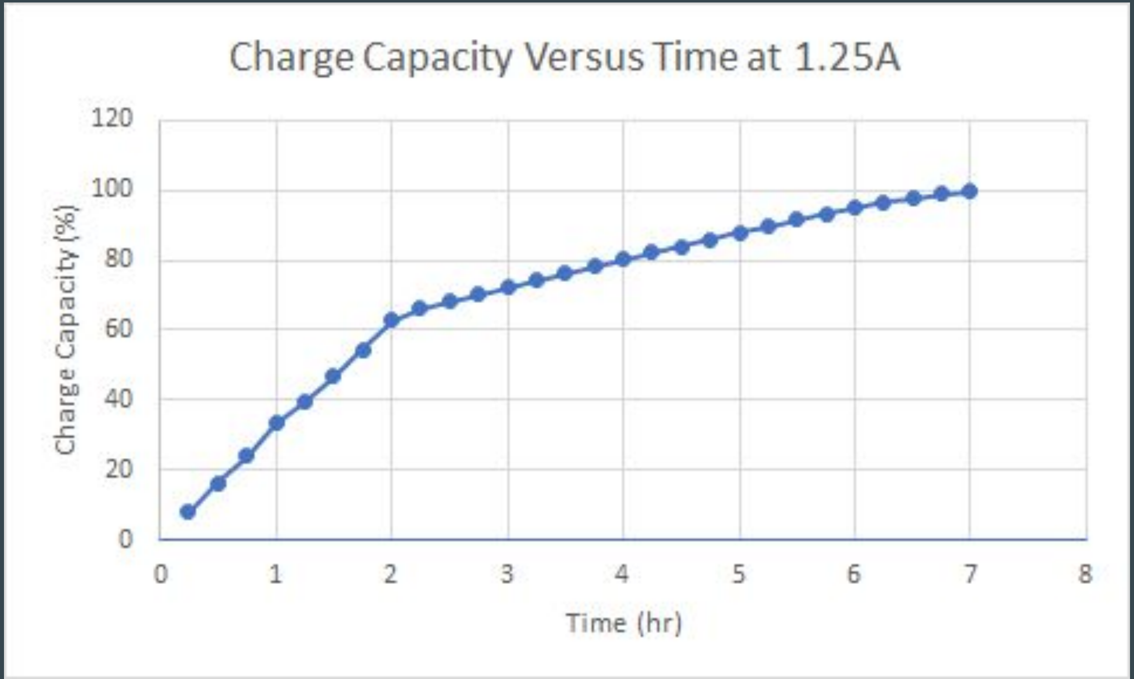
System Testing

- Tested the battery and BMS by discharging a LI-Ion cells and charged to test cell balancing



Charge Capacity Vs Time

- We chose to charge the battery at 1.25A for safety reasons
- The system was around ~60% to 70% efficient when compared to direct wired charging



Challenges

- Testing IR sensor with a TV remote
- Testing IR leds initially when the first sensor didn’t work
- Faulty breadboard
- Soldering and wiring connections (caused us to change MCU from SMT to throughhole)
- MCU broke the night before demo
- Original wireless charging coils did not work as expected

Successes

- The batteries were able to charge using the qi coils.
- The mechanical design was properly integrated with electrical components
- The mechanical design optimized qi coil spacing for charging.
- The bike rack stopped and started charging properly based on conditions.

Ethics

- The bike rack could cause injuries with misuse:
  - Overheating
  - Electrocution
- The magnetic field between the 2 Qi coils could affect credit cards.

Future Improvements

- Chose high power Qi coils that can drive more current (faster charging)
- Design PCB with throughhole MCU rather than SMT
- Chose better IR leds that put out a consistent signal rather than random peaks
- Design bike rack to conceal wires

Questions?