SATELLITE

ECE 445 Spring 2017

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Introduction

- Model train popularity surged through 1930s-1950s
- Declining number of hobbyists
- More room for innovation in this toy

Objective

- Combat train derailment
- Autonomous adjustment of speed
- Incorporate path-mapping

High-Level Requirements

Requirement 1	Requirement 2	Requirement 3
Train must detect obstacles on the track and halt motion 98% of the time.	Train must detect speed limit signs and adjust speed accordingly 98% of the time.	Train must map the track and estimate the position of the train within a 7.5 cm radius of its actual position.

Features

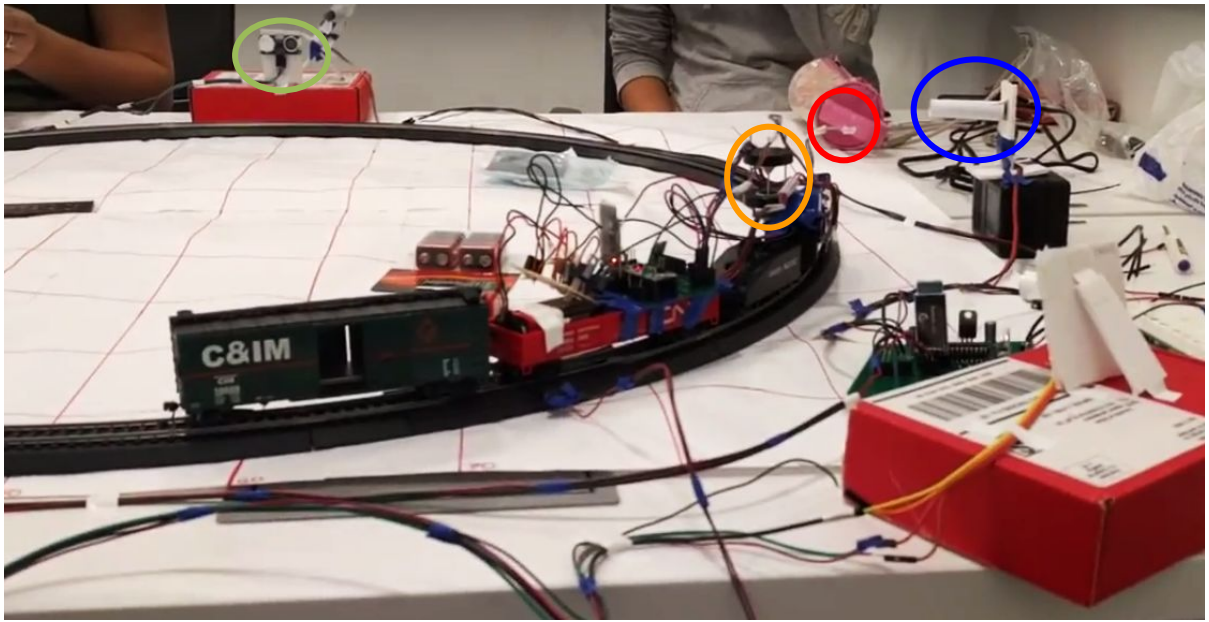
Speed Detection
- IR LED
- IR Receiver (x3)

Speed Control
- L298 Full-Bridge Driver
- Bluetooth Low Energy (BLE) HM-10 Module

Obstacle Detection
- Infrared (IR) Laser Time of Flight (ToF) Sensors (x2)
- BLE HM-10 Module

Track Mapping
- RF Transmitter and Receiver
- Ultrasonic Transmitter and Receiver (x3)

SATELLITE System



Legend

Ultrasonic Receiver

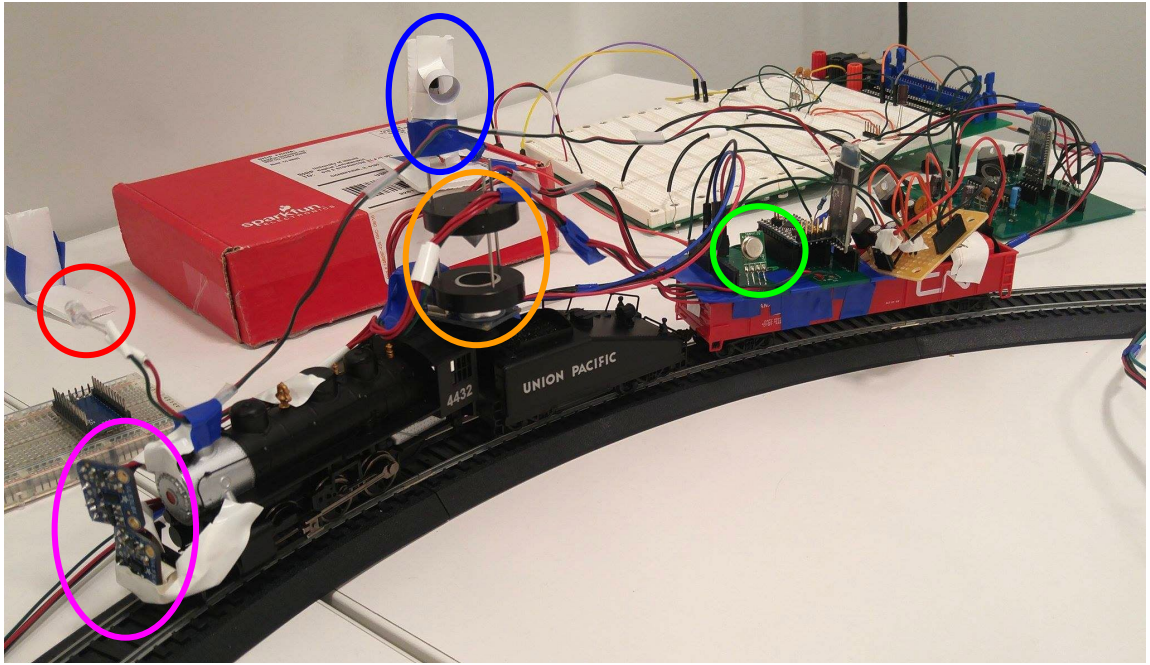
Ultrasonic Transmitter

IR LED

IR Receiver

Not pictured:
RF Transmitter and Receiver, Laser ToF Sensor

SATELLITE System



Legend

Laser ToF Sensors

IR LED

IR Receiver

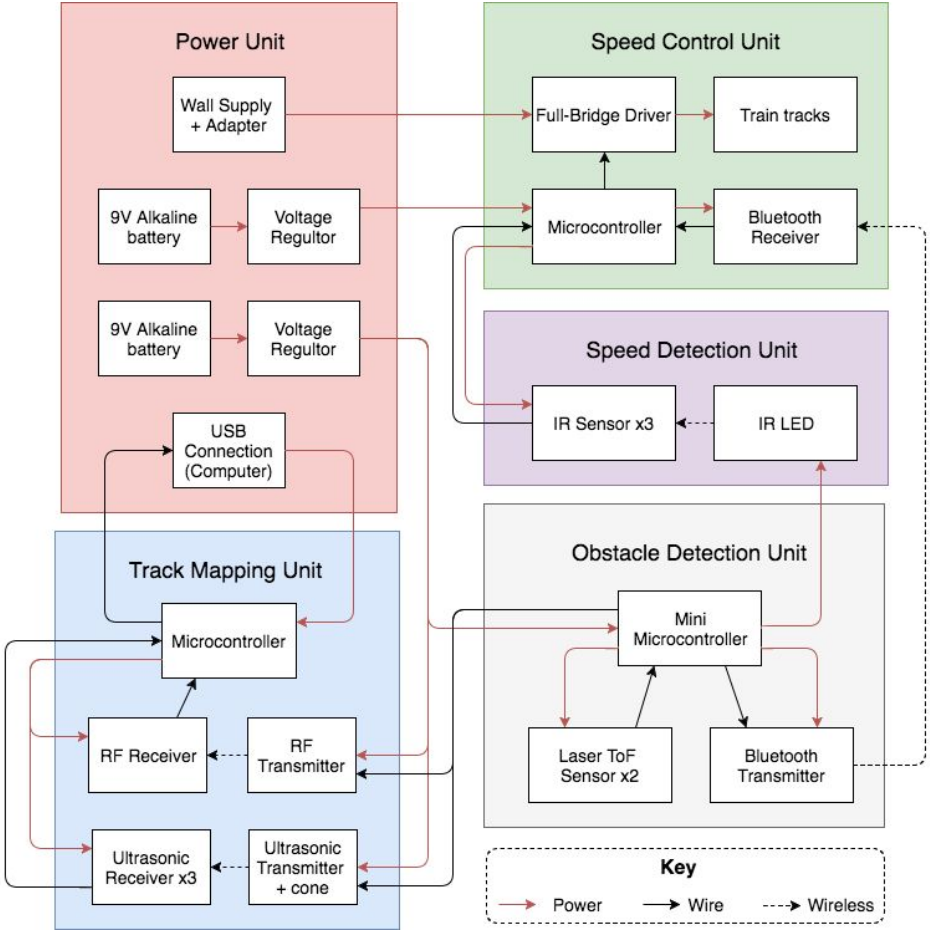
Ultrasonic Transmitter

RF Transmitter

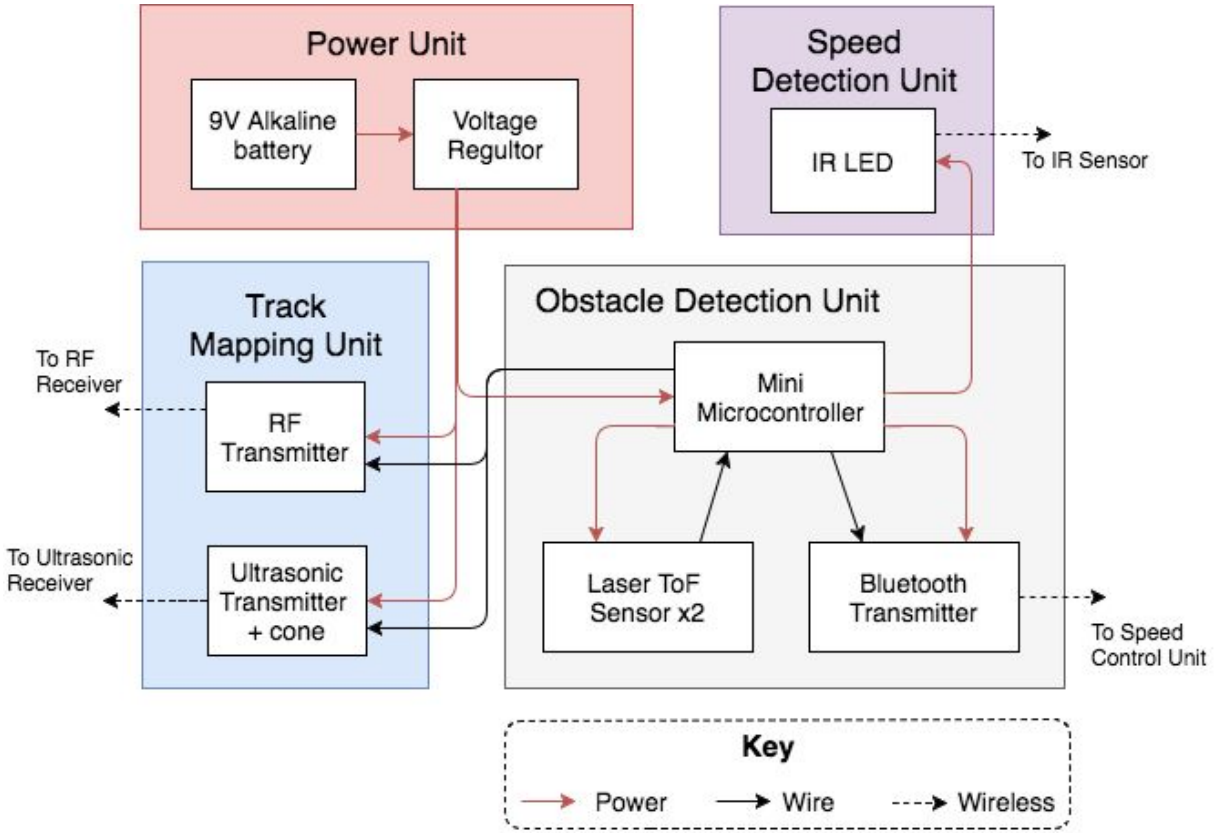
Not pictured:
RF and Ultrasonic Receiver

Design

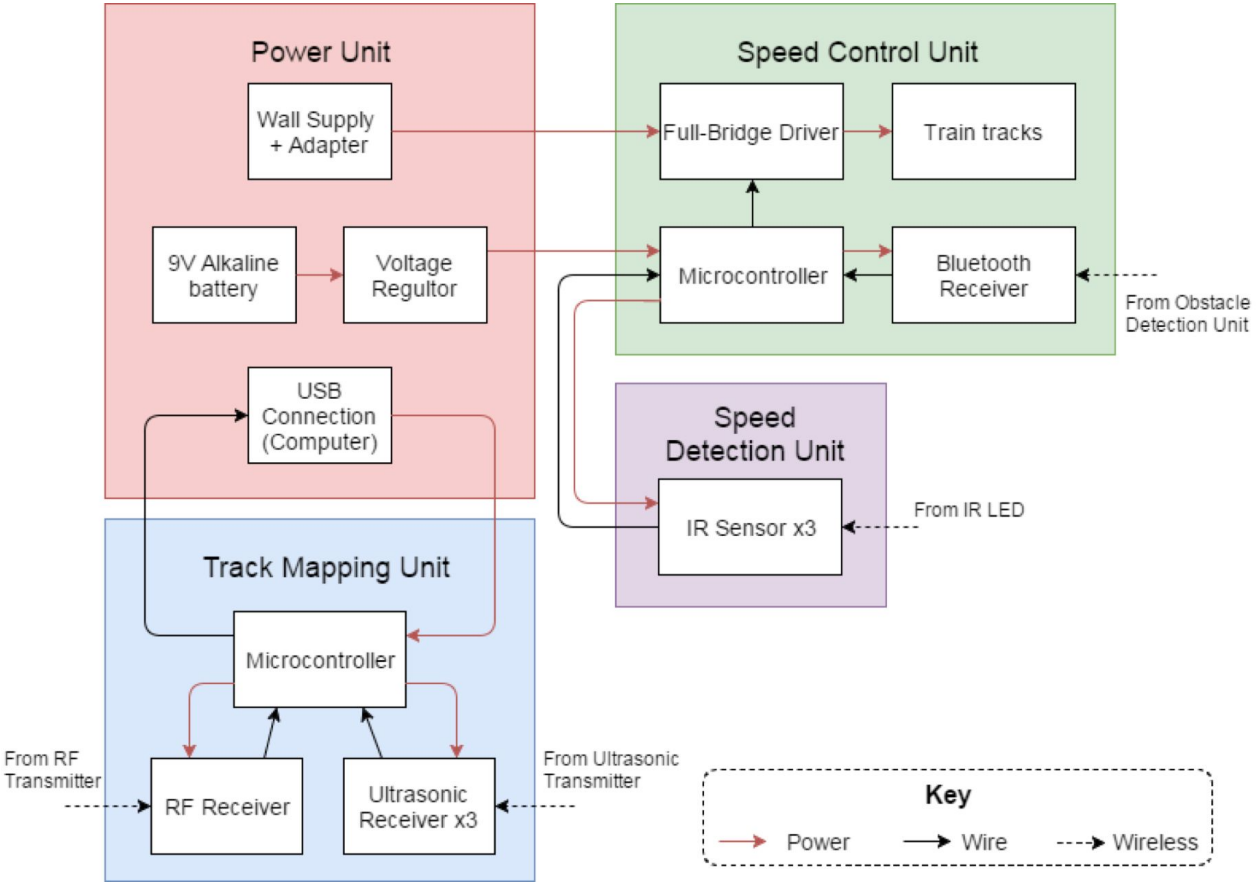
Block Diagram



On-Train Block Diagram



Off-Train Block Diagram



Speed Detection

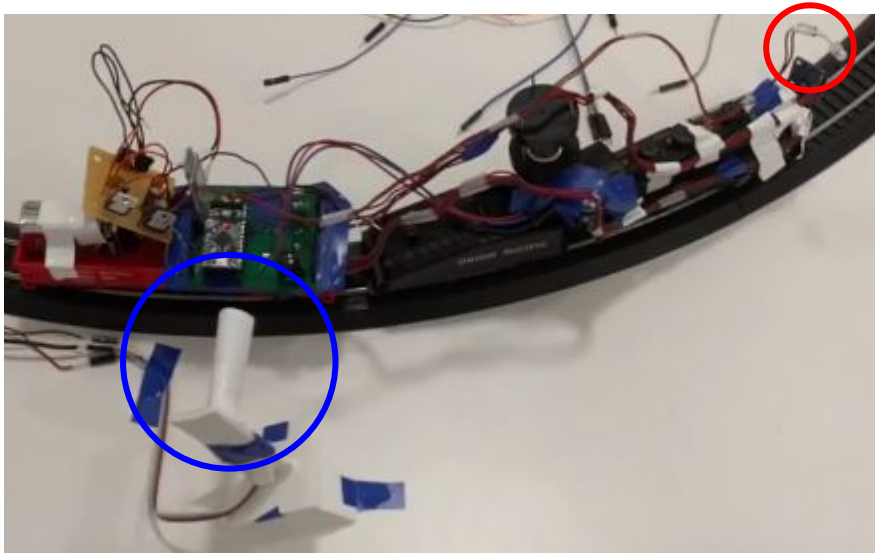
Speed Detection

Three IR Sensors

- Located along tracks
- Cylindrical shield from IR noise
- 8 cm above track

One IR LED

- Located on train (near the front)
- In series with 10 kΩ



Above: Red = LED, Blue = Receiver

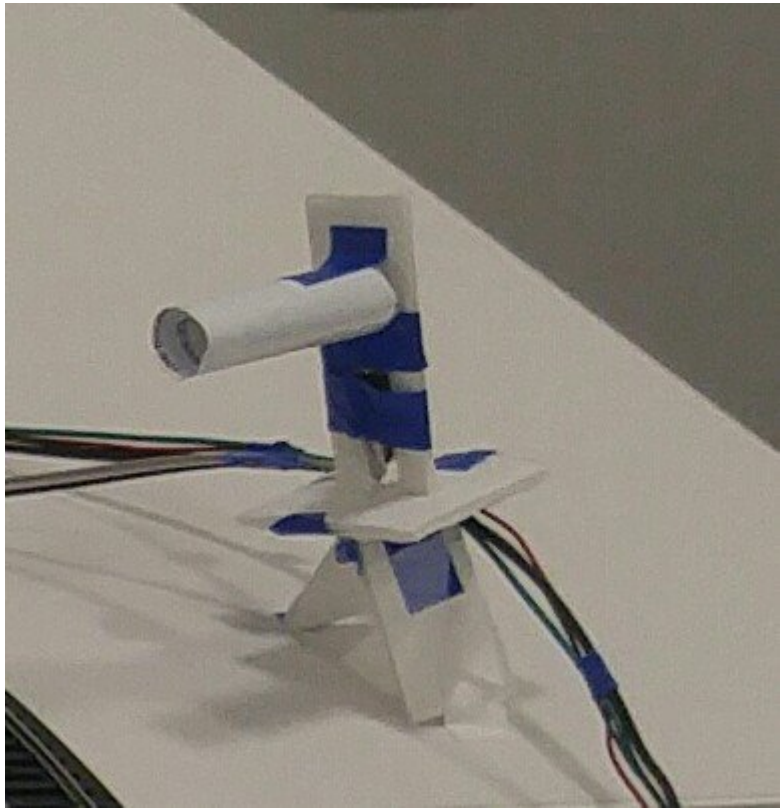
Speed Detection Verification

Fully functional

- With cylindrical shield
- When LED passes cylindrical opening
- When train speed is high

Partly functional

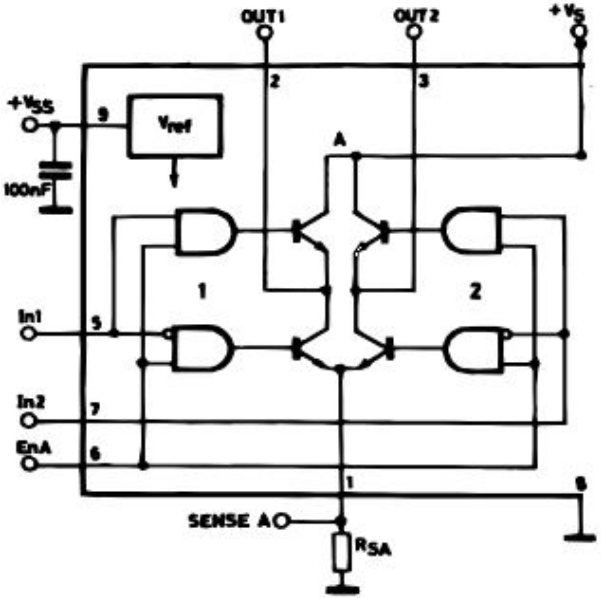
- Without cylindrical shield



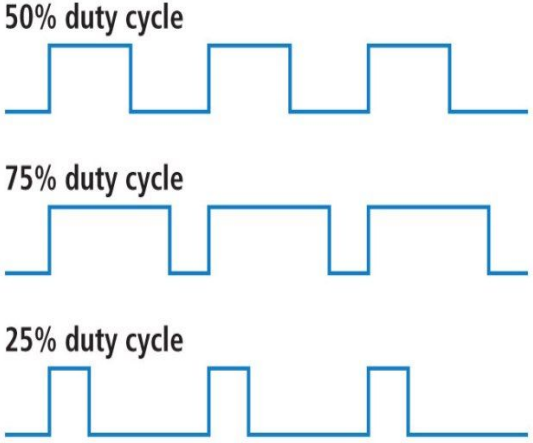
Speed Control

Speed Control

- Bit-banged enable (EnA) at 100 Hz
- Duty-cycle of EnA sets speed
- In1/In2 set stop/go



In1 ≠ In2

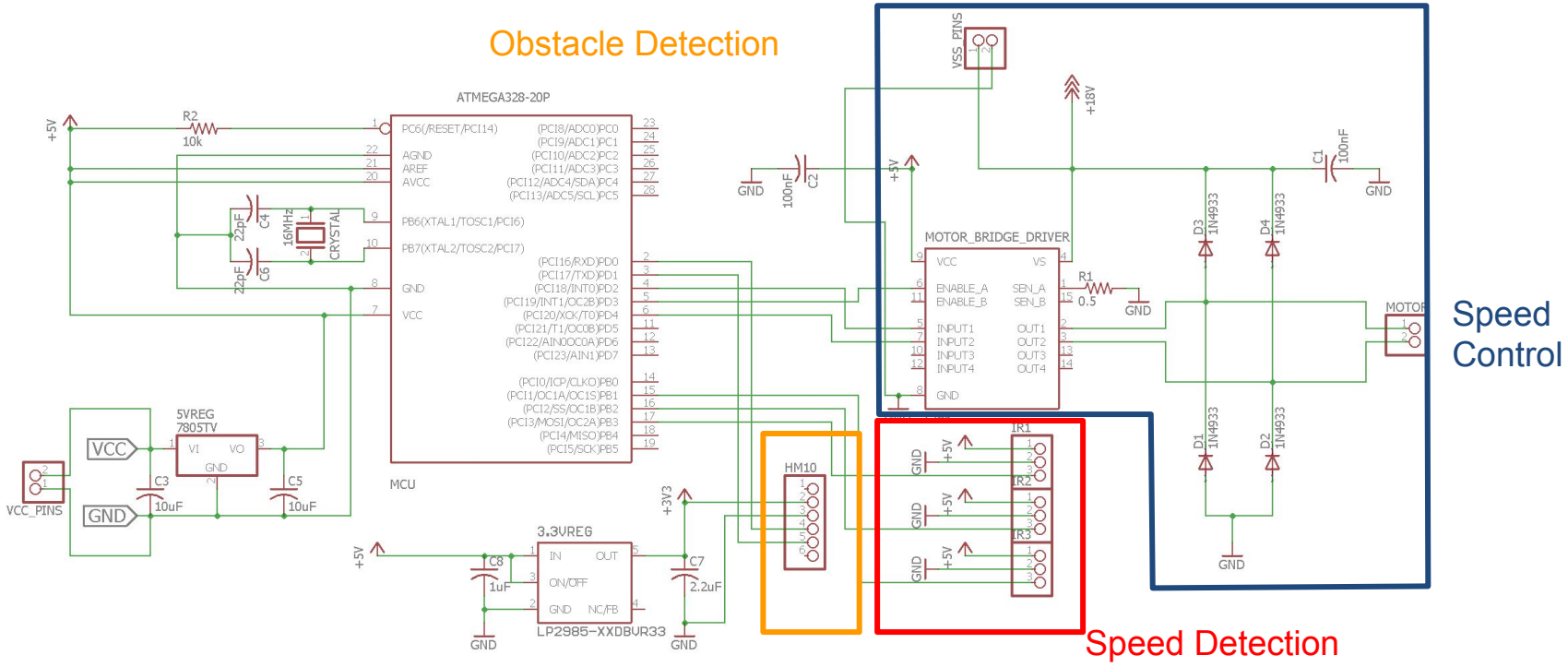


In1 = In2

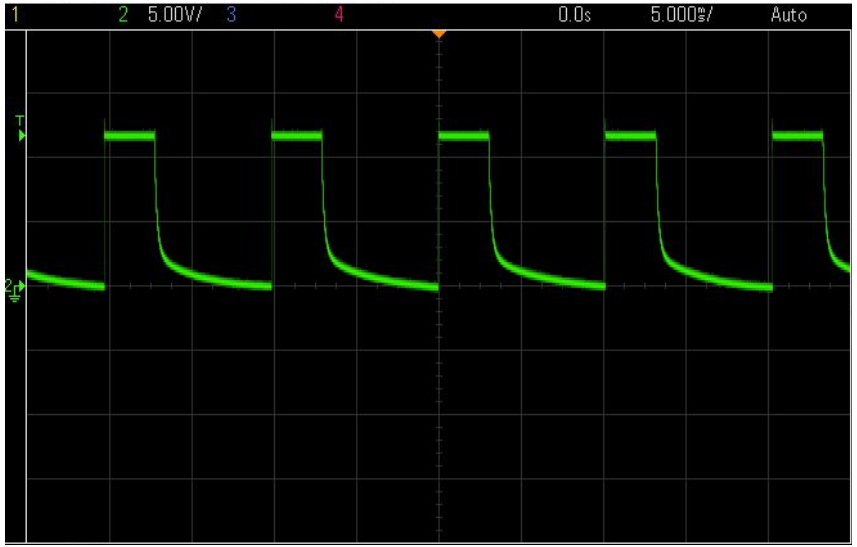
Brake

https://learn.sparkfun.com/tutorials/pulse-width-modulation
https://www.sparkfun.com/datasheets/Robotics/L298_H_Bridge.pdf

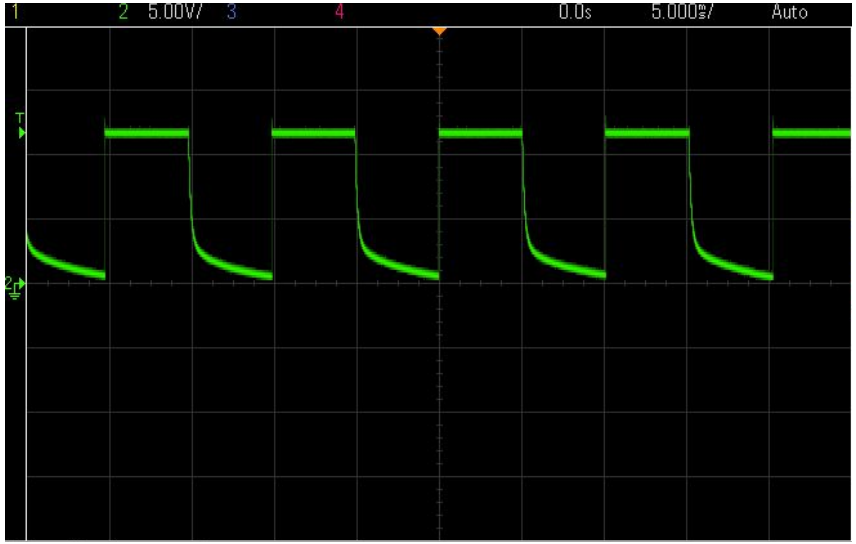
Speed Control PCB Schematic



Speed Control Verification



Slowest
30% Duty Cycle



Medium
50% Duty Cycle

Speed Control Verification

Fastest
100% Duty Cycle

Brake

Obstacle Detection

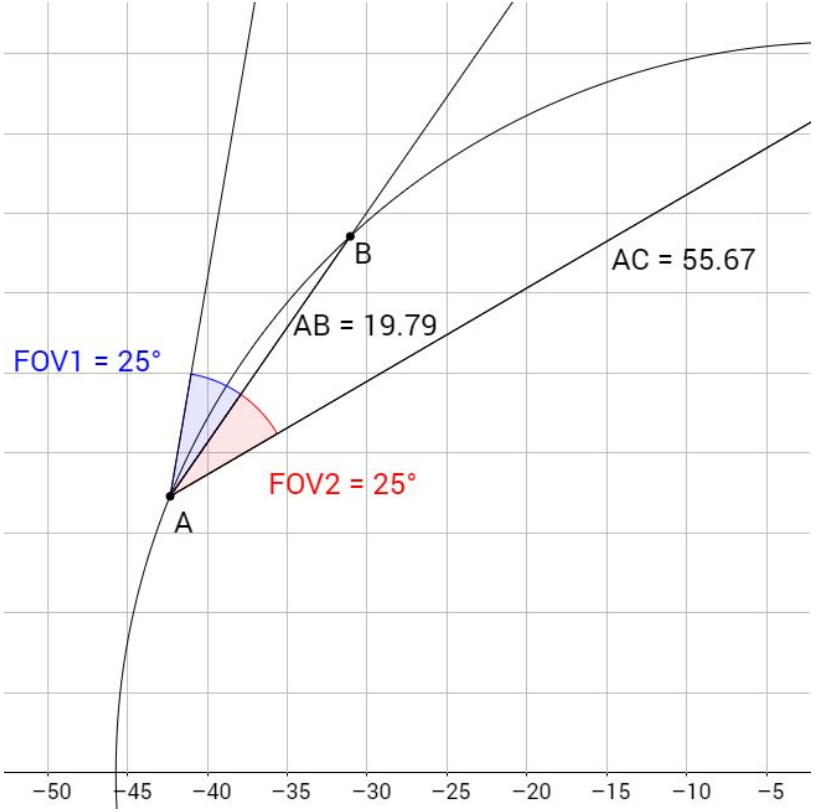
Obstacle Detection

Two laser ToF sensors

- 25º field of view (FOV)
- Located at front of train
- One oriented 25º inward

FOVs intersect on track

- 19.79 cm ahead
- If both lasers see object ~20 cm ahead, then obstacle detected



Obstacle Detection

VL53L0X Laser ToF Sensor

- 25º FOV
- 940 nm VCSEL
- 3-100 cm ranging
- 33 ms timing (every 2 cm at top speed)
- I2C Communication

Ranging inaccuracy

- Estimated max of 12%
- 12% of 19.79 cm = 2.4 cm
- Use of 21 cm worked best

Table 12. Ranging accuracy

	Indoor (no infrared)			Outdoor		
Target reflectance level (Full FOV)	Distance	33ms	66ms	Distance	33ms	66ms
White Target (88%)	at 120cm	4%	3%	at 60cm	7%	6%
Grey Target (17%)	at 70cm	7%	6%	at 40cm	12%	9%

https://www.adafruit.com/product/3317

Obstacle Detection Verification

Fully functional

- Pencil pouch
- Hand
- Foot

Not functional

- Pencil
- Any object with height on order of pencil width or less
- Wire connections need improvement

Track Mapping

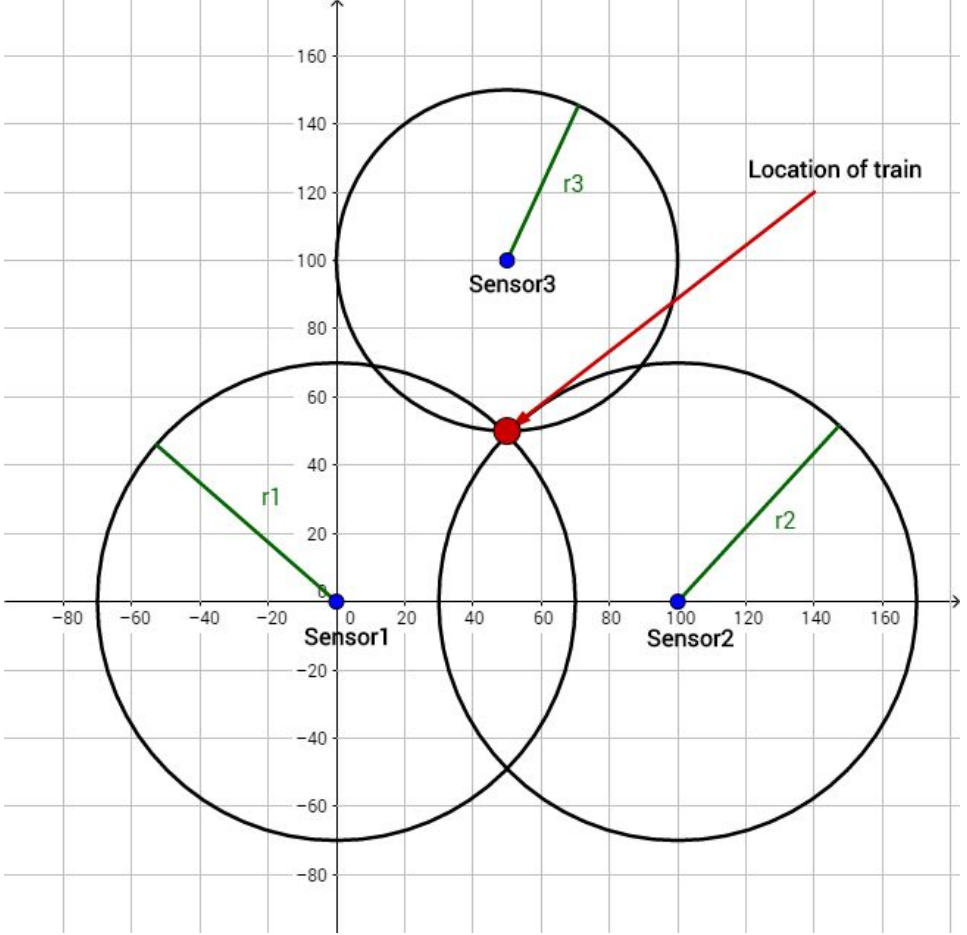
Track Mapping Module

Trilateration using RF and ultrasonic sensors

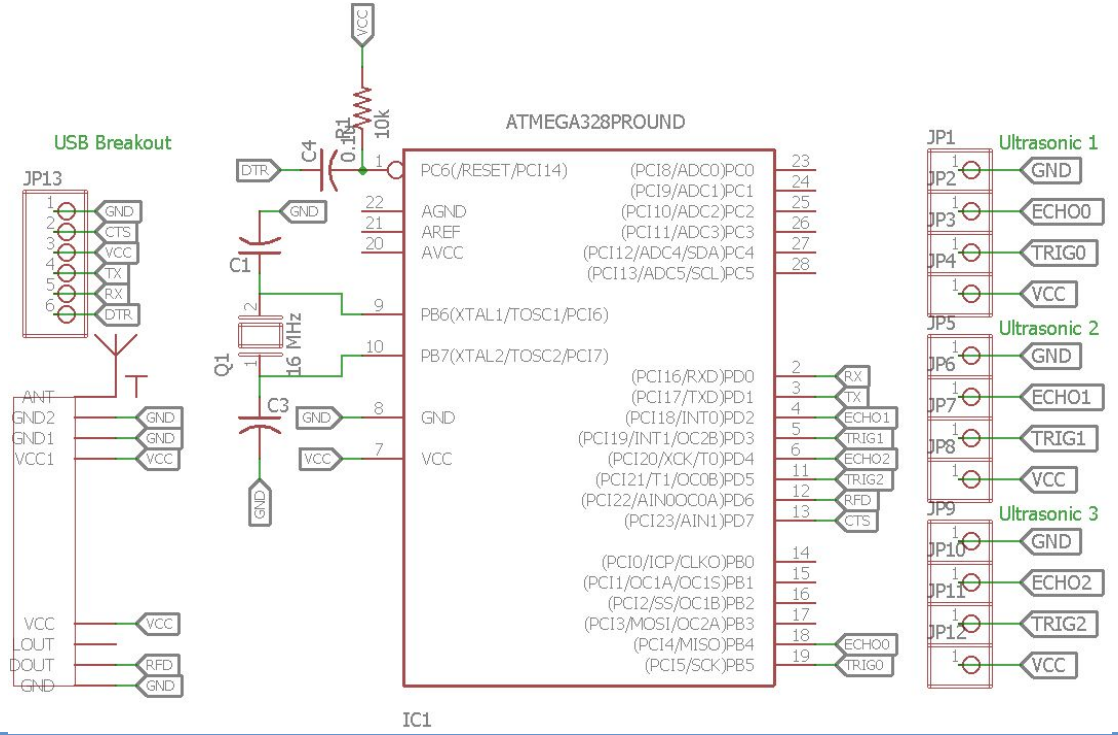
$$x = \frac{r_1^2 - r_2^2 + d^2}{2d}$$

$$y = \frac{r_1^2 - r_3^2 + i^2 + j^2}{2j} - \frac{i}{j}x$$

Sensors at: (0,0), (d,0), (i,j)
d =100, i = 50, j = 100



Track Mapping Module



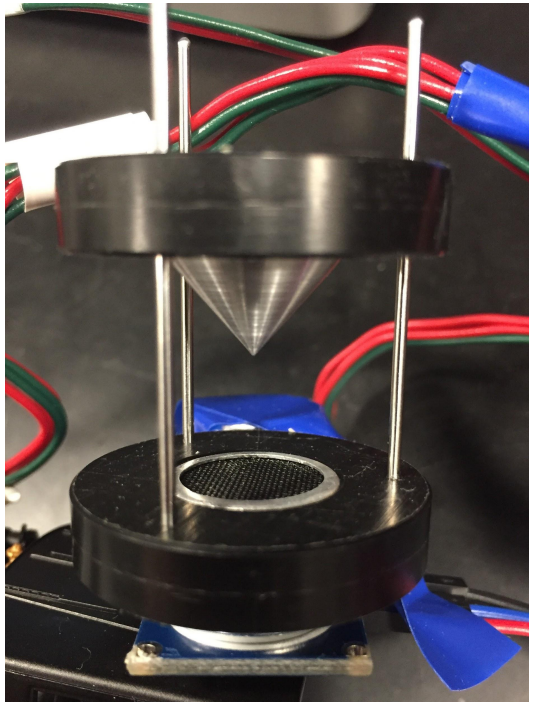
Track Mapping Verifications

Fully Functional:

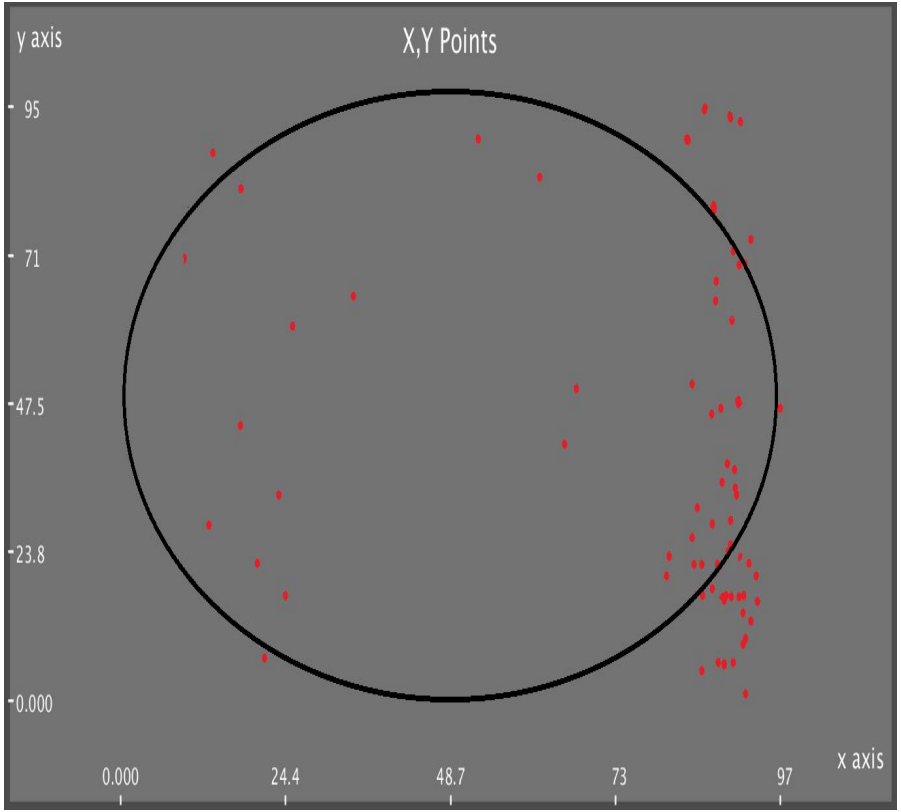
- RF Communication
- RF + single ultrasonic sensor

Partly Functional:

- RF + 3 ultrasonic sensors



Track Mapping Results



Conclusion and Future Work

Conclusion

- Obstacle detection fully functional when the obstacle is tall
- Speed detection and control fully functional
- Track mapping tested and verified
  - RF communication fully functional
  - Ultrasonic communication does not work at certain train locations

Train Operation Video (Click)

Future Work

- Improve accuracy of track mapping
- Combine off-track PCBs
- Integrate the on-train components for aesthetic improvement

Credits

- Professor Seth Hutchinson
- Zipeng (Phoenix Bird) Wang
- Michael Fatina
- Machine Shop staff

Thank You