Situation-Aware Stop Signal

Final Presentation

Group 3

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Motivation

- Protecting the lives of the drivers that cross our roads – our families, our friends, and our neighbors
- "1/3 of all intersection crashes in the United States, and more than 40% of the fatal ones, occur at intersections controlled by stop signs." (Insurance Institute for Highway Safety)

We believe that **advances in technology**, now made more affordable through manufacturing improvements, present **an opportunity to revolutionize the way we advise, warn, and alert drivers** on the small roads of our community.

Rethinking traffic control at small intersections

Project Description

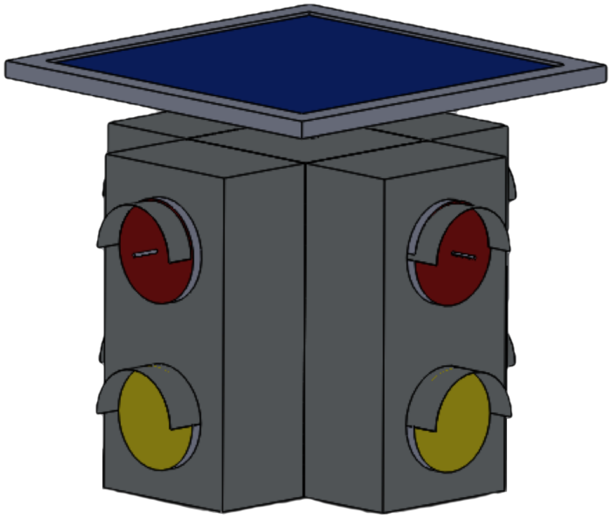
A device that uses sensors to track cars up to 20 meters away to control traffic and prevent accidents

Influenced by technology found in existing traffic lights and autonomous cars

Focused towards small intersections that are currently controlled by stop signs

Concept of Operation

- Uses LiDAR and RADAR to detect cars
- Detects when it is safe for a car to cross an intersection
- Schedules right-of-way
- Recognizes possible threats



Objectives

Marketing Objectives

Accurate

Self-sustaining

Efficient

Low cost

Technical Objectives

Prevent

Protect

Schedule

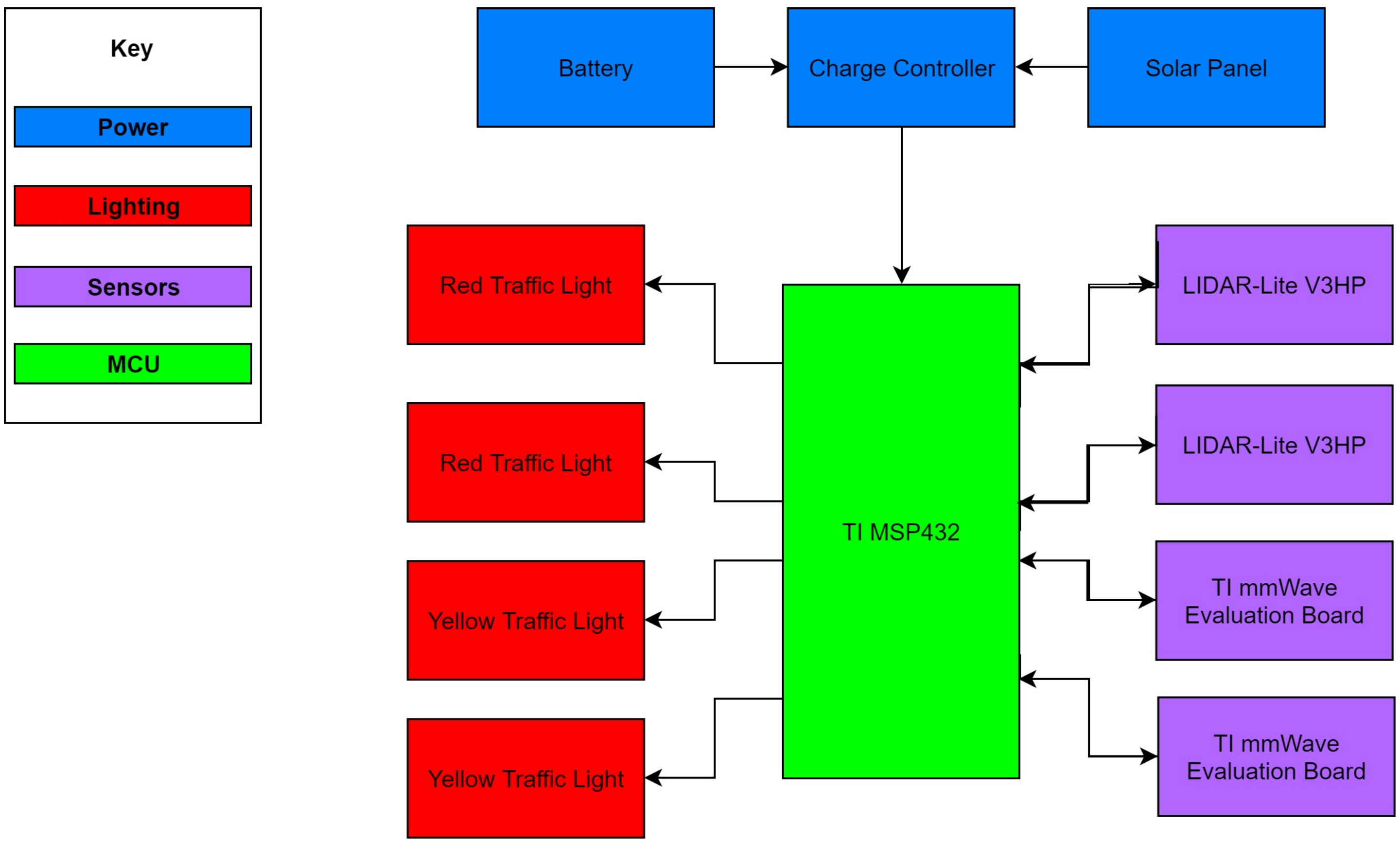
Key Requirements Overview

Design Requirements	Operational Requirements	Power Requirements	Safety Requirements
One centralized unit	Responsive in real-time operation	Solar panel shall output greater than 12V and 40W	Abide by road sign laws specified in the Manual for Uniform Traffic Control Devices (MUTCD)
Visible during the day and night	Maintain operability between 0°C and 60°C	Battery shall hold enough power for minimum of 1 day of operation	Detect vehicles that are traveling up to 13 m/s
Shall be operable 24/7	Detect an oncoming vehicle within 25 meters		

Engineering Requirement Targets

Target	Verification	Units (if applicable)
Obedience to Traffic Law	Complies with USDOT MUTCD rules and regulations	
Power Consumption	< 20	Watts
Self-Sustained Solar Power (generated)	0.48	kWh/day
Sensor Accuracy	90	% within 25 meters
Cost	< 1800	$US
Modular Structure (installation)	< 30	minutes

Block Diagram



Team Distribution

Name	Primary Function	Secondary Function
Jonathan Ling	Power, Mechanical Design	PCB
Annabelle Phinney	PCB	Mechanical Design
Trent Sellers	SASS Software	Sensor Software
Joseph Walters	Sensor Software	SASS Software

Power Design

Solar Panel

- Low cost
- Monocrystalline - High efficiency
- Over 80W power supply
- 25 solar cells at 0.6V each
- 6A current supply
- 28 x 28 in.
- Mounted on a hinge to adjust to the optimum angle

Battery

- Lithium Ion
- High energy density
- High charge efficiency
- Fast charge time
- High thermal threshold
- Long discharge cycles
- Long lifespan
- 12V
- 20Ah

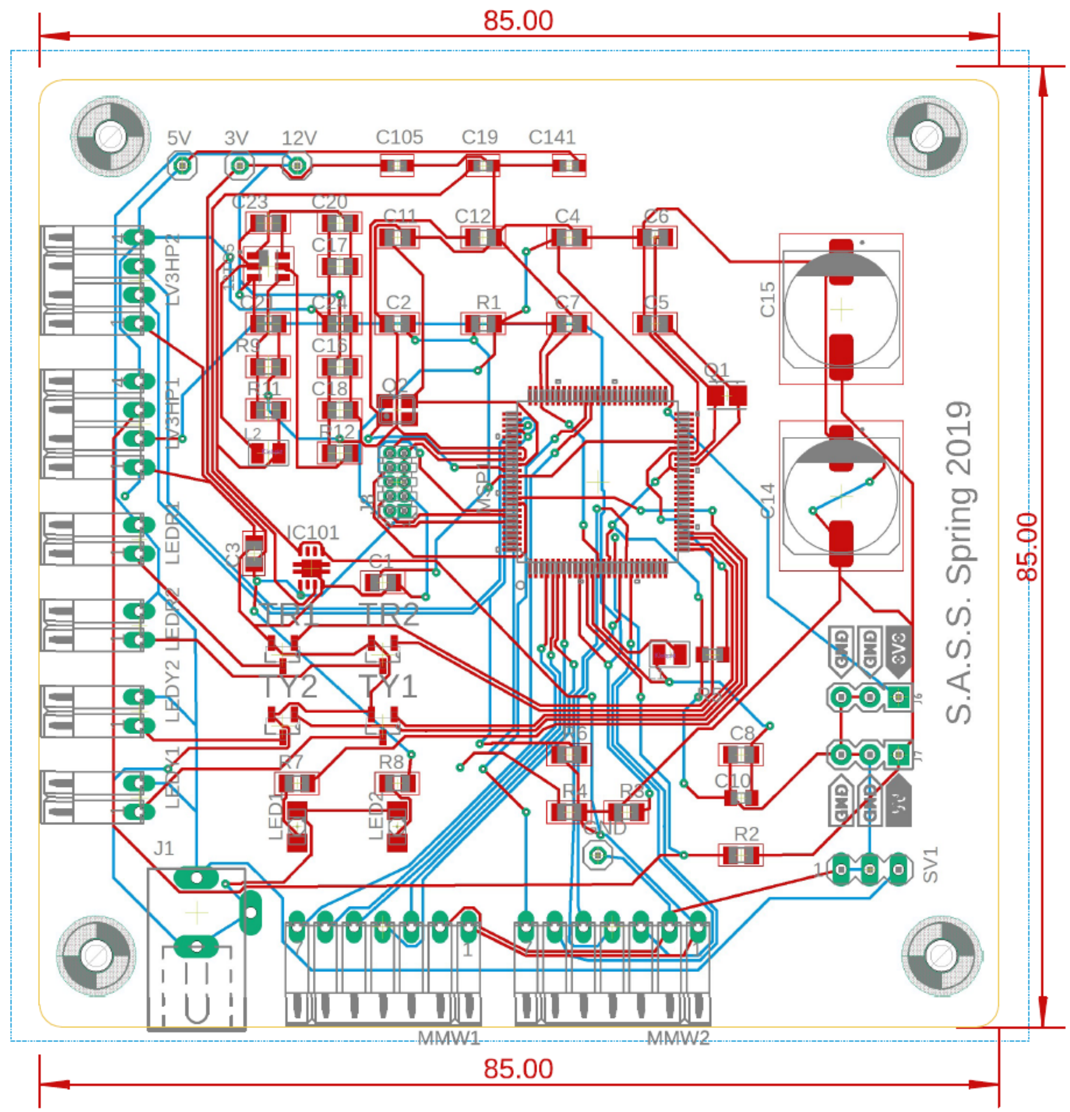
Charge Controller

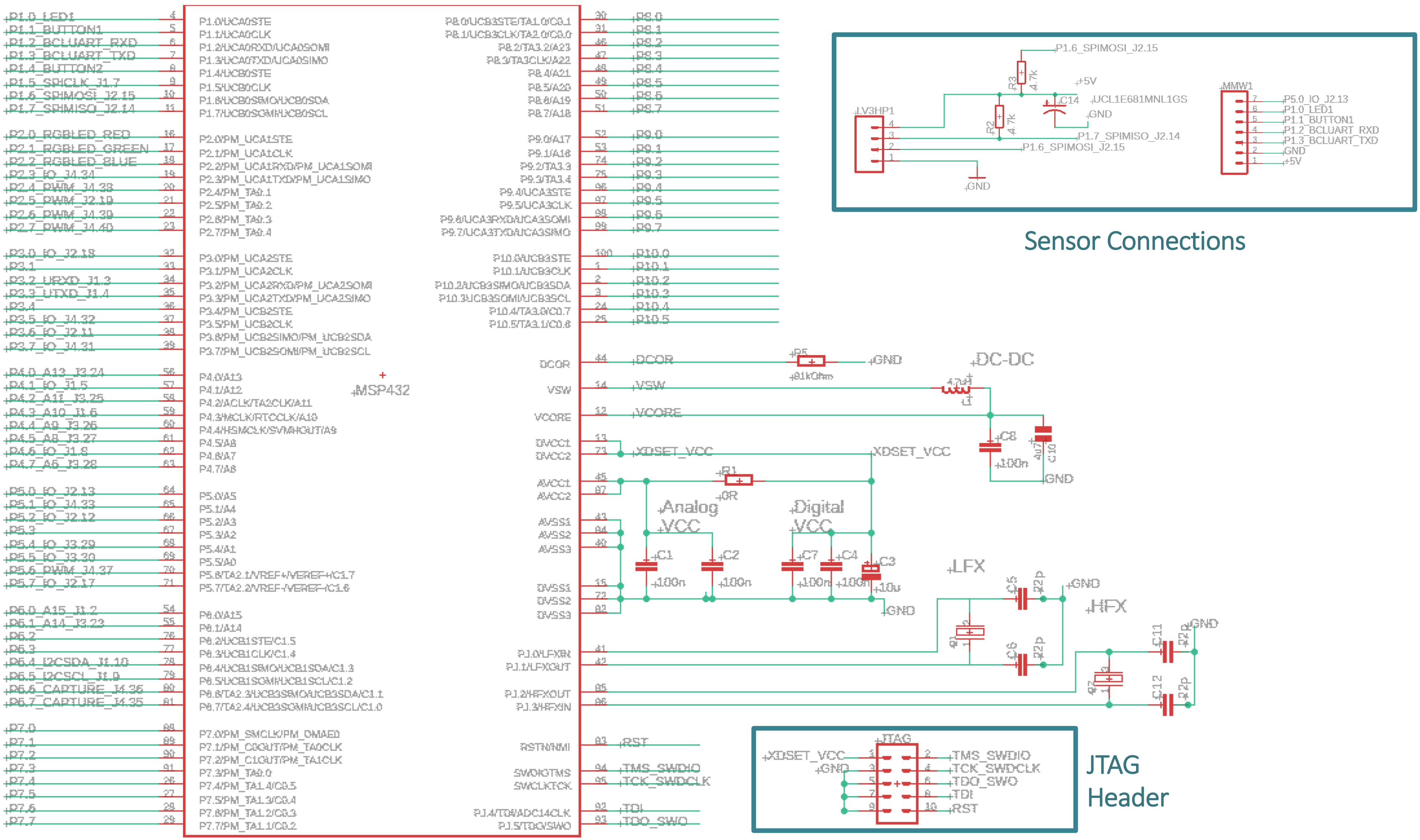
- MPPT - Maximum Power Point Tracking
- Highest efficiency ~ 99%
- Extends battery life
- Converts excessive voltage into additional current
- More expensive
- More parts than a 1-stage controller or PWM charge controller

Hardware Design

PCB Layout

- Two layer PCB used to lower cost
- All components were mounted on the top layer while bottom layer was used as a ground plane
- Used larger components for quick prototyping
- Large space between components
- Connectors placed on sides for easy access and secure connection




P1.0_LED1
P1.1_BUTTON1
P1.2_BCLUART_RXD
P1.3_BCLUART_TXD
P1.4_BUTTON2
P1.5_SPICLK_J1.7
P1.6_SPIMOSI_J2.15
P1.7_SPIMISO_J2.14
P2.0_RGBLED_RED
P2.1_RGBLED_GREEN
P2.2_RGBLED_BLUE
P2.3_IO_J4.34
P2.4_PWM_J4.38
P2.5_PWM_J2.19
P2.6_PWM_J4.39
P2.7_PWM_J4.40
P3.0_IO_J2.18
P3.1
P3.2_URXD_J1.3
P3.3_UTXD_J1.4
P3.4
P3.5_IO_J4.32
P3.6_IO_J2.11
P3.7_IO_J4.31
P4.0_A13_J3.24
P4.1_IO_J1.5
P4.2_A11_J3.25
P4.3_A10_J1.6
P4.4_A9_J3.26
P4.5_A8_J3.27
P4.6_IO_J1.8
P4.7_A6_J3.28
P5.0_IO_J2.13
P5.1_IO_J4.33
P5.2_IO_J2.12
P5.3
P5.4_IO_J3.29
P5.5_IO_J3.30
P5.6_PWM_J4.37
P5.7_IO_J2.17
P6.0_A15_J1.2
P6.1_A14_J3.23
P6.2
P6.3
P6.4_I2CSDA_J1.10
P6.5_I2CSCL_J1.9
P6.6_CAPTURE_J4.36
P6.7_CAPTURE_J4.35
P7.0
P7.1
P7.2
P7.3
P7.4
P7.5
P7.6
P7.7
MSP432
P8.0
P8.1
P8.2
P8.3
P8.4
P8.5
P8.6
P8.7
P9.0
P9.1
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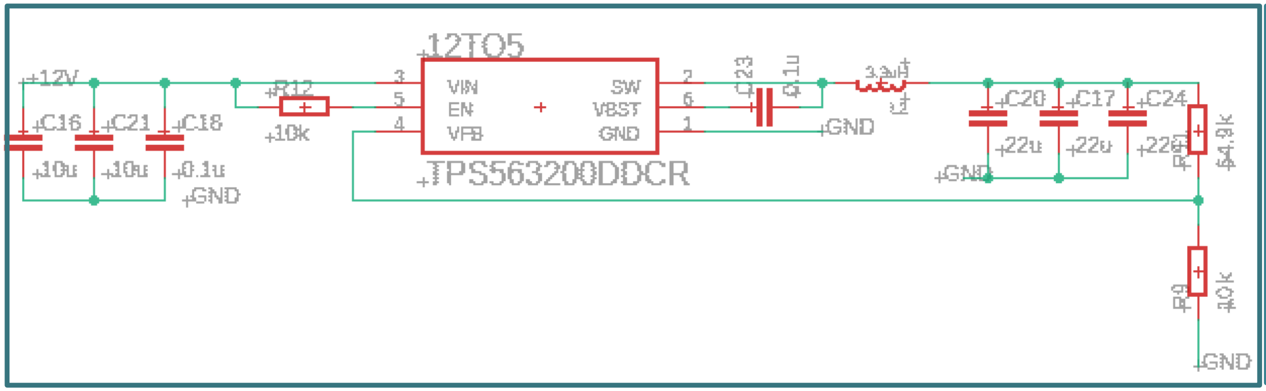
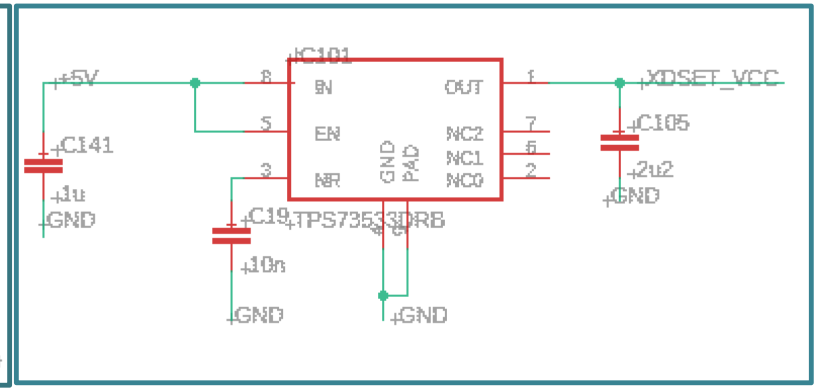
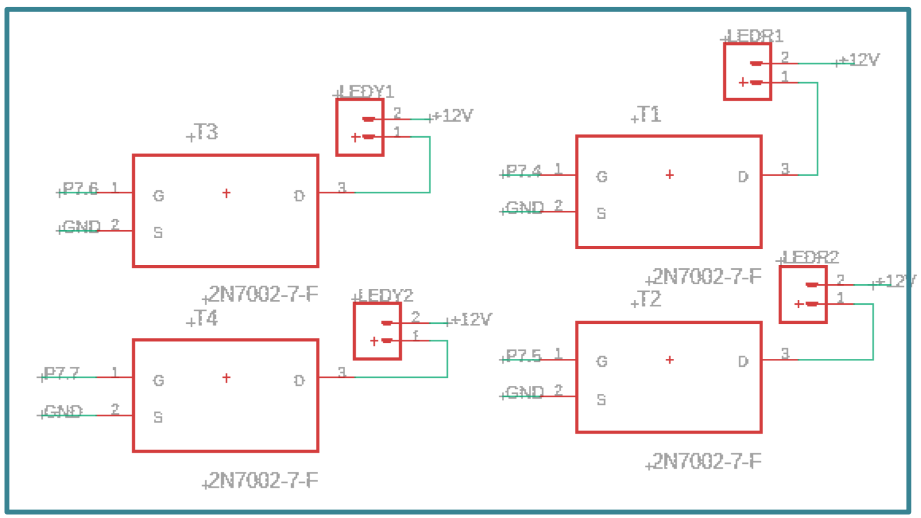
P9.4
P9.5
P9.6
P9.7
P10.0
P10.1
P10.2
P10.3
P10.4
P10.5
DCOR
VSW
VCORE
XDSET_VCC
RST
TMS_SWDIO
TCK_SWDCLK
TDI
TDO_SWO
DC-DC
Analog VCC
Digital VCC
LFX
HFX
GND
Sensor Connections
LV3HP1
MMW1
P5.0_IO_J2.13
P1.0_LED1
P1.1_BUTTON1
P1.2_BCLUART_RXD
P1.3_BCLUART_TXD
+5V
UCL1E681MNL1GS
P1.7_SPIMISO_J2.14
P1.6_SPIMOSI_J2.15
JTAG
JTAG Header



12V to 5V Switching Regulator



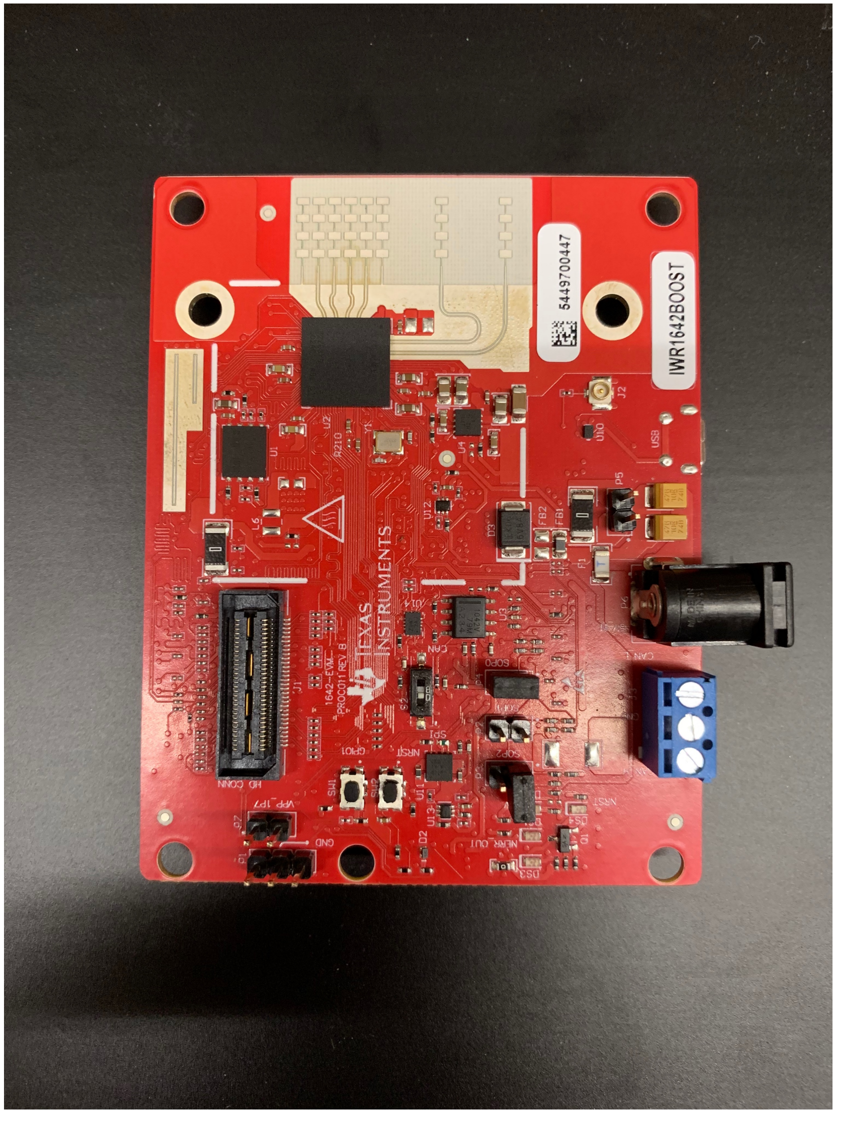
5V to 3.3V Linear Regulator



Transistors and LEDs

Light Selection

- Standard 01 from Section 4D.07 of the MUTCD states that there shall be two nominal diameter sizes for vehicular signal indications: 8 inches and 12 inches
- According to Section 4.1 of the ITE, the minimum lumen requirement for 8 inch bulbs is 10 lumens for a red LED and 45 lumens for a yellow LED
- Red and yellow are easily understood by drivers
- Device does not include a green light

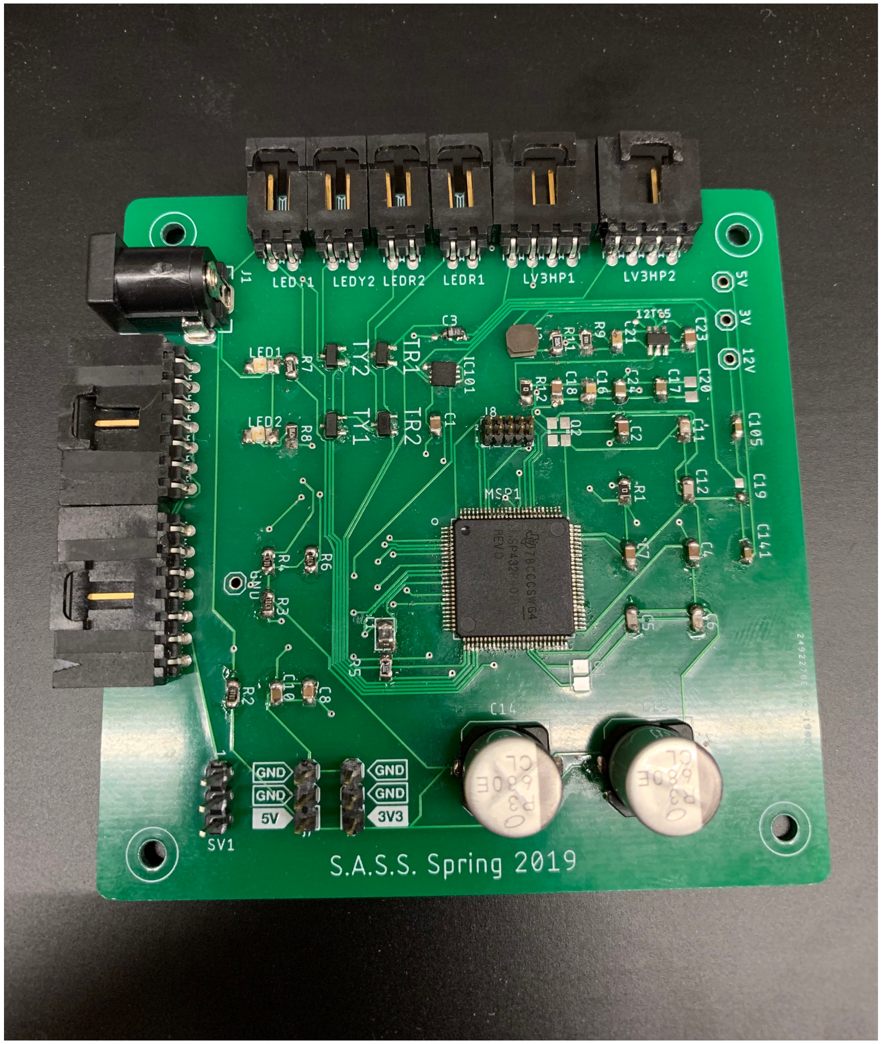


Sensors and Gathering Data (RADAR)

- IWR1642 mmWave EVM by TI
- Frequency Modulated Continuous-wave Doppler Radar
- Wide field-of-view
- Configurable
- High Accuracy (< cm)
- Can detect multiple objects

Sensors and Data Gathering (LiDAR)

- LiDAR-Lite v3HP by Garmin
- ”Time-of-Flight” sensor.
- Near infrared light
- Narrow field of view (<cm)
- High accuracy (cm)



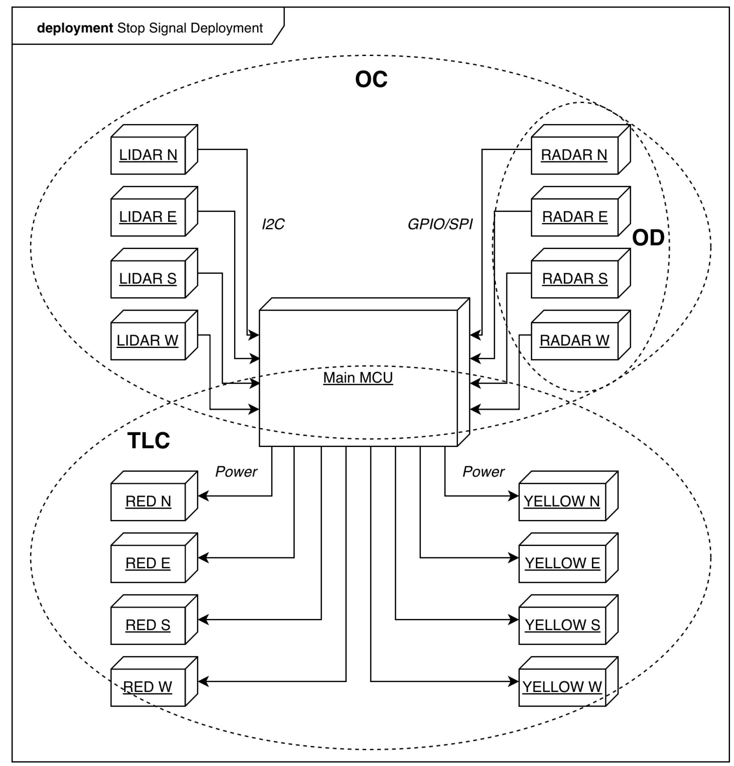
MSP432

- Low Power : High Performance
- 48MHz allows for fast processing of real-time data
- Granular control over microcontroller
- More memory compared to ATMega2560
- Supports **TI-RTOS**
- Supports C/C++
- Supports POSIX threading

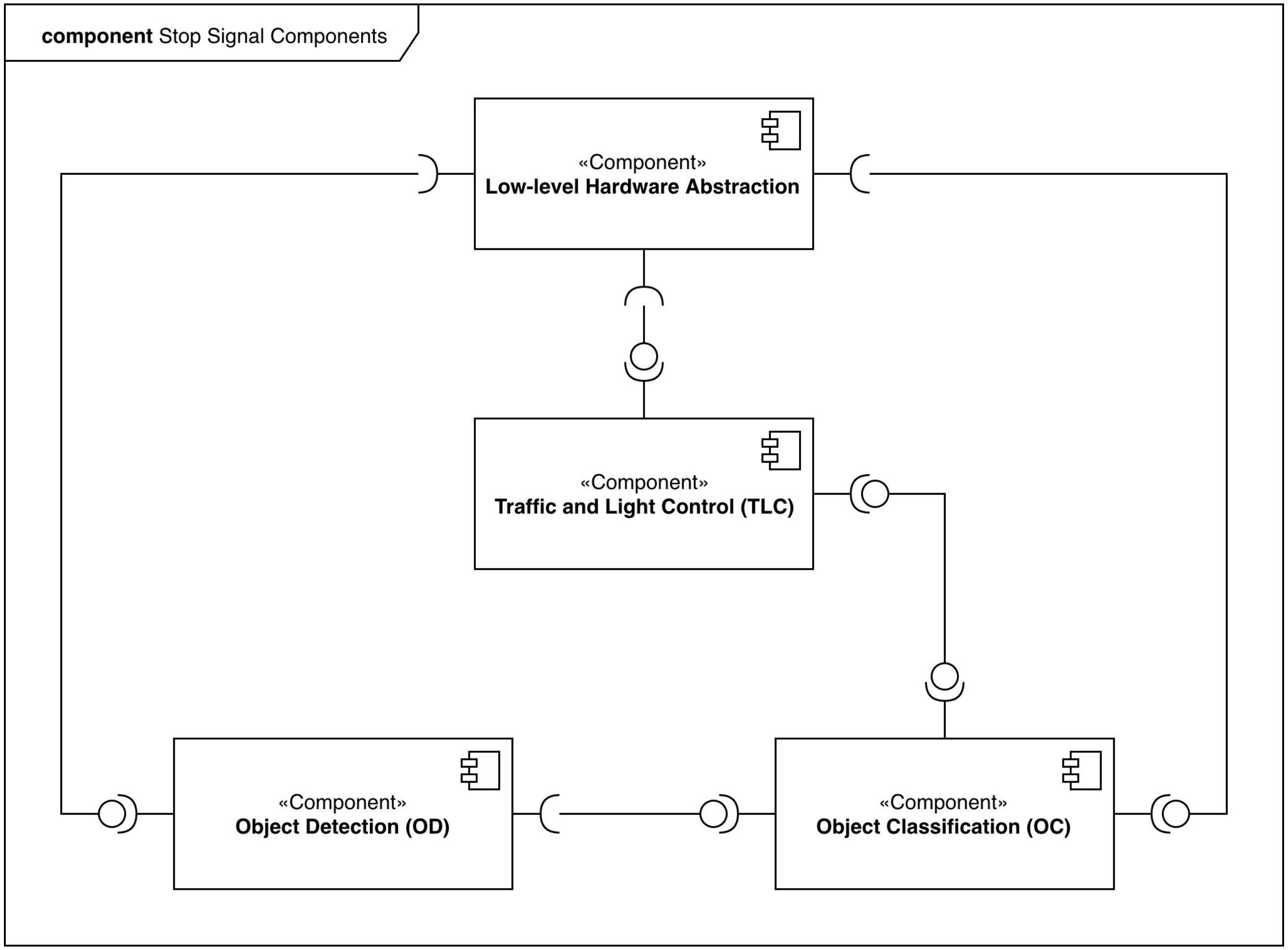
Software Design

Stop Signal Software

- Written in **C++**
- Uses **Texas Instruments SimpleLink SDK**
- Managed by **TI-RTOS** (multithreaded)
- 4 manageable components:
  - Low-level Hardware Abstraction (**LLHA)**
  - Object Detection (**OD**)
  - Object Classification (**OC**)
  - Traffic and Light Control (**TLC**)



Deployment Diagram



System Component Diagram

Low-Level Hardware Abstraction (LLHA)

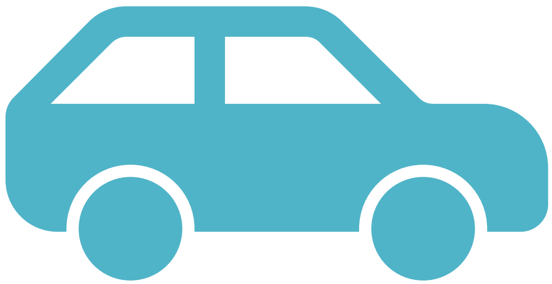
- Utilizes the built-in SimpleLink SDK and TI-RTOS libraries
- Abstracts hardware specific implementations away from the heart of the software in a consistent manner
- This ultimately simplifies our job as the project grows in complexity
- Custom API Calls:
  - I^2C (LIDAR-Lite v3HP)
  - GPIO HWI (mmWave)
  - GPIO (Light Controls)
  - Back-Channel UART (Debug & Logging)

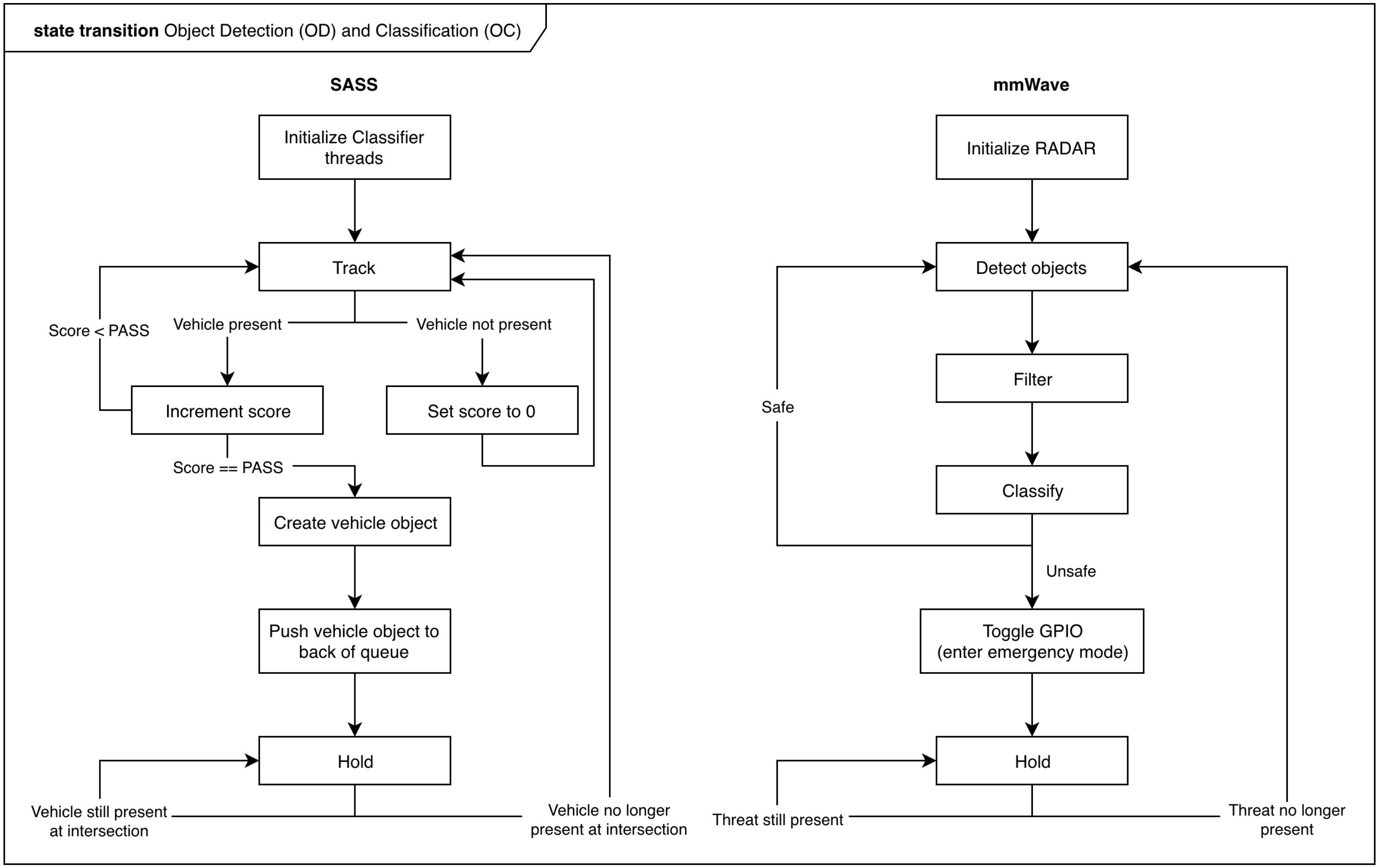
Object Detection (OD)

- RADAR detects:
  - Distance to object (up to 30m)
  - Velocity of object (up to 13m/s)
- LiDAR detects:
  - If object is detected near or on the stop bar
  - If object leaves the stop bar

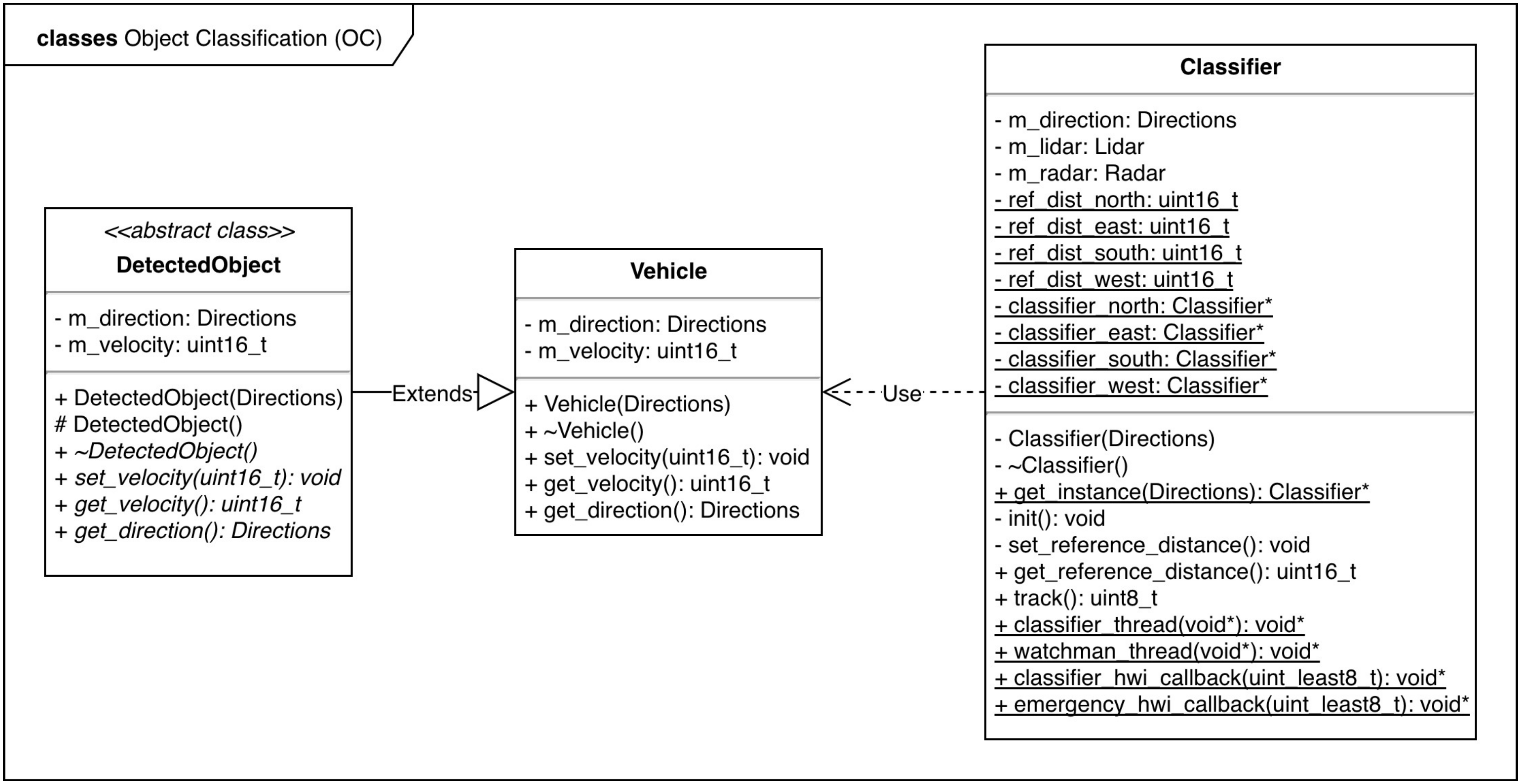
Object Classification (OC)

- Using gathered sensor data, the system can:
  - Track up to 1 vehicle per side
  - Determine if vehicle is able to stop in a timely manner
- Vehicles are tracked from the moment they are detected until the moment they stop (or otherwise exit the intersection)
- Classifying:
  - Vehicles moving too fast at too close distance
  - Vehicles moving at safe speed at safe distance
  - Stopped vehicles





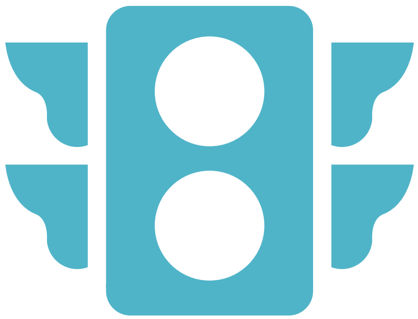
System State Transition Diagram

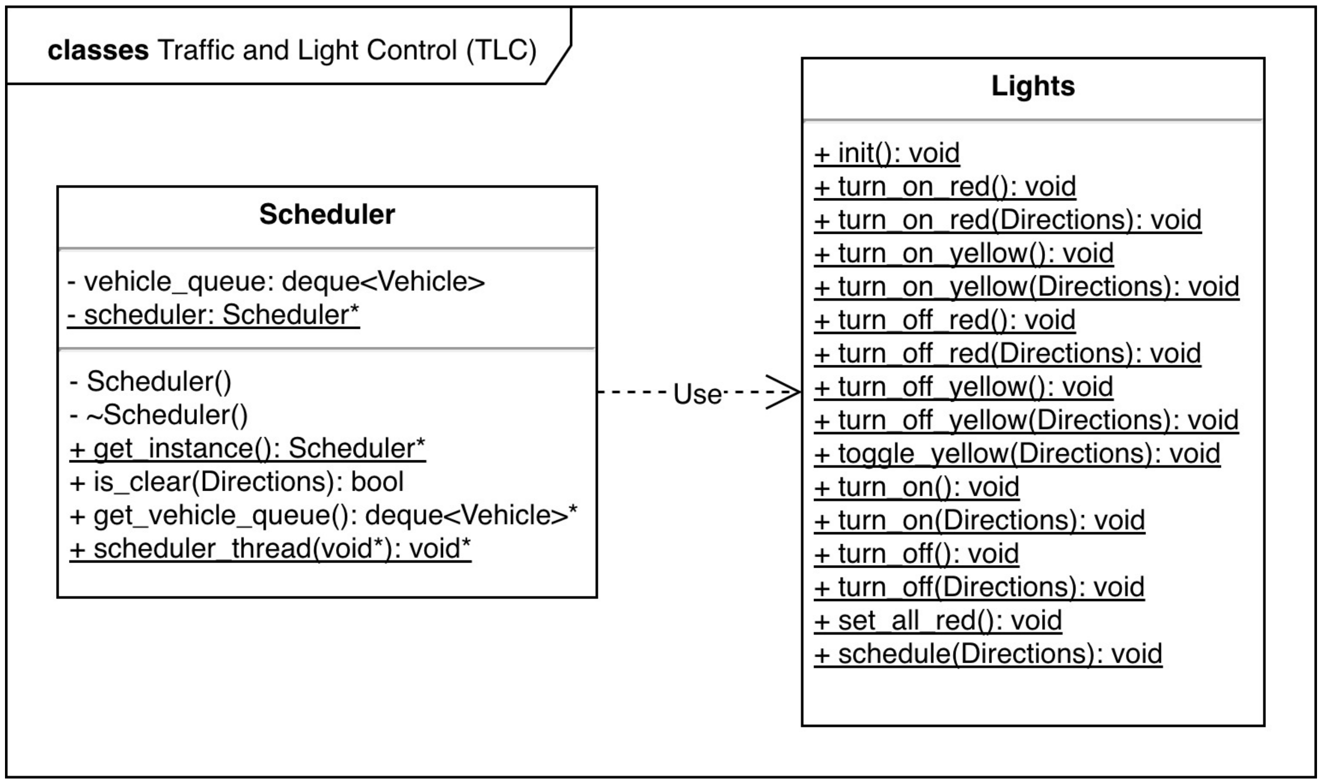


Object Classification Class Diagram

Traffic and Light Control (TLC)

- Designed around a scheduler that utilizes the OC and LLHA components of the system
- Once a vehicle enters the intersection and stops, it is entered into a queue
- The queue ensures fair scheduling and no deadlocks in the intersection

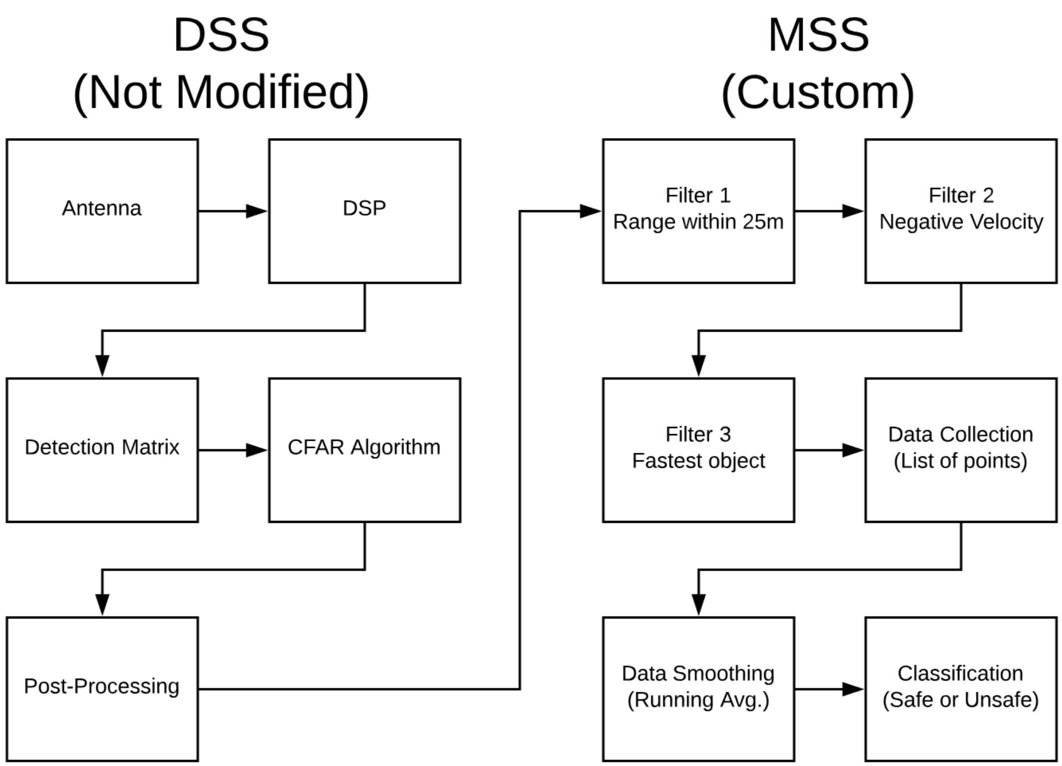




Traffic and Light Control Class Diagram

mmWave Sensor Software

- Written in **C**
- Uses **Texas Instruments mmWave SDK**
- Managed by **TI-RTOS** (multithreaded)
- Two ARM processors utilized:
  - DSS - Controls DSP and Pre-Processing
  - MSS - Controls filtering, data analytics, and communication



- Utilized TI's implementation of:
  - DSP Processing
  - Inter-processor communication
- Filtered data from point cloud down to a single usable object
- Smoothed resulting data to eliminate noise

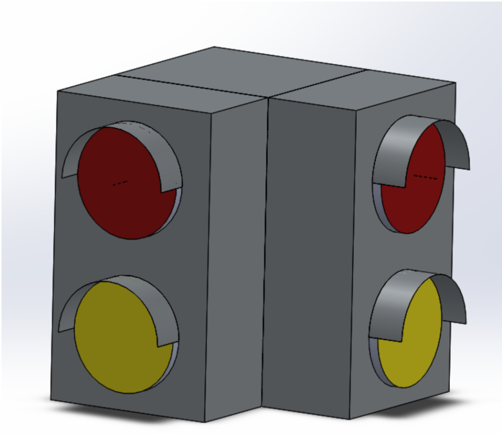
- Unsafe velocity determined with:

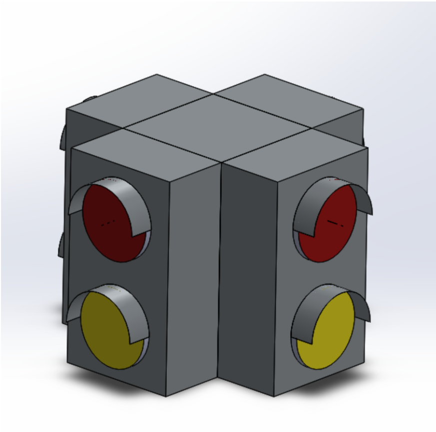
$$v_{unsafe} > \sqrt{2 * range * \mu_f * g}$$

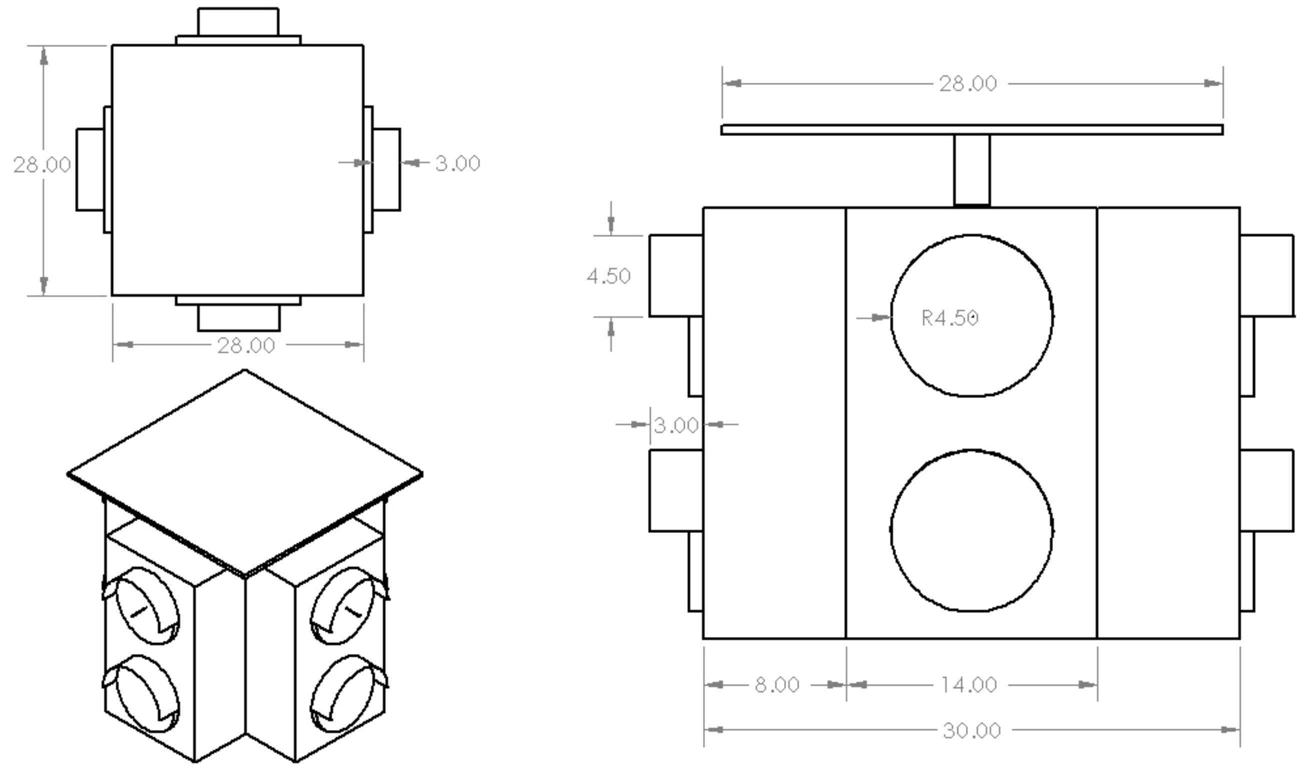
Mechanical Design

Design Decisions

- Modular design – helps achieve low cost
- Modeled after traditional traffic lights
- Prototype designed for quick replication and assembly
- Prototyped for a 2-way stop
- Modeled for testing – back sides open for easy sensor and PCB access



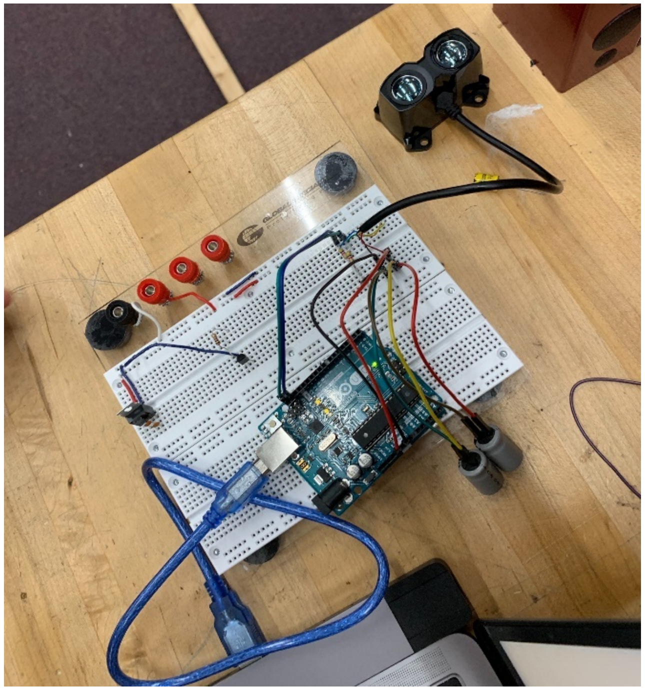


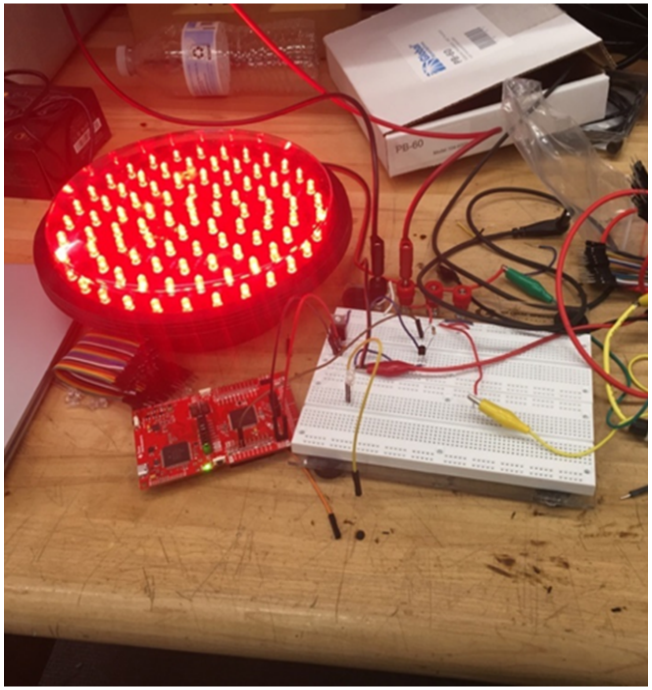


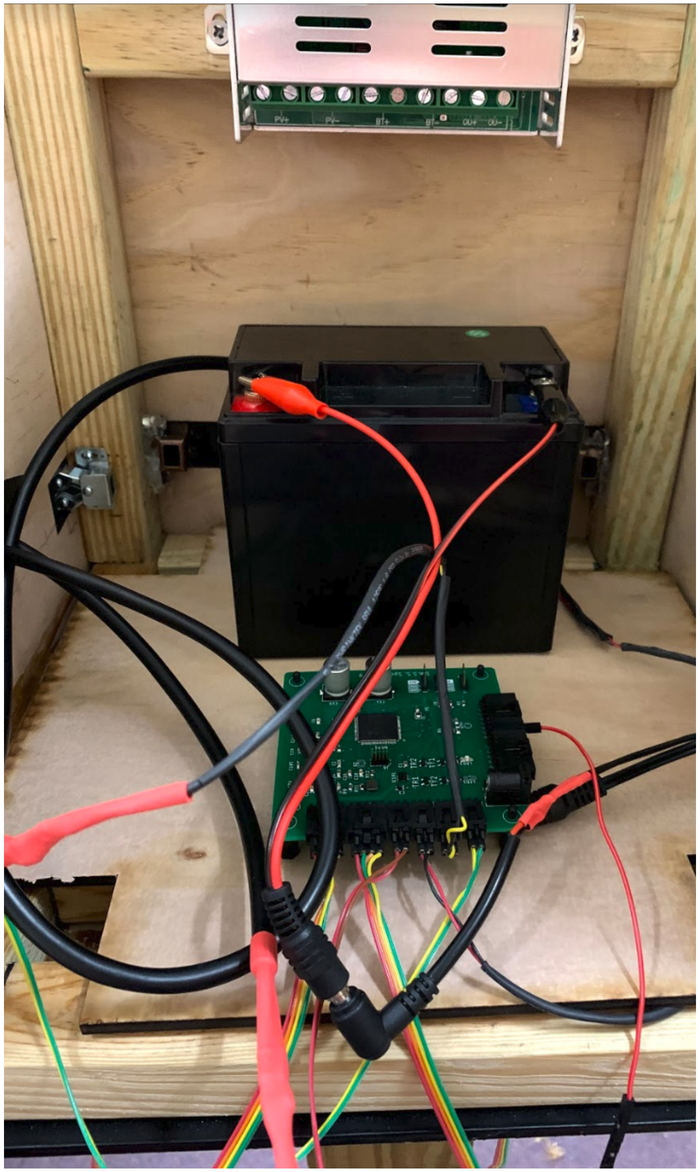
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Jon Ling	11/25/2018	
	CHECKED			TITLE:
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL Acrylic	COMMENTS:			SIZE A · DWG. NO. S.A.S.S · REV
FINISH Black				
DO NOT SCALE DRAWING				SCALE: 1:16 · WEIGHT: · SHEET 1 OF 1

Initial Testing

- Testing LiDAR with Arduino UNO and breadboard
- Used MSP432P401R Evaluation Board to test most software components
- Tested, lights, and sensors with MSP432P401R before testing with PCB







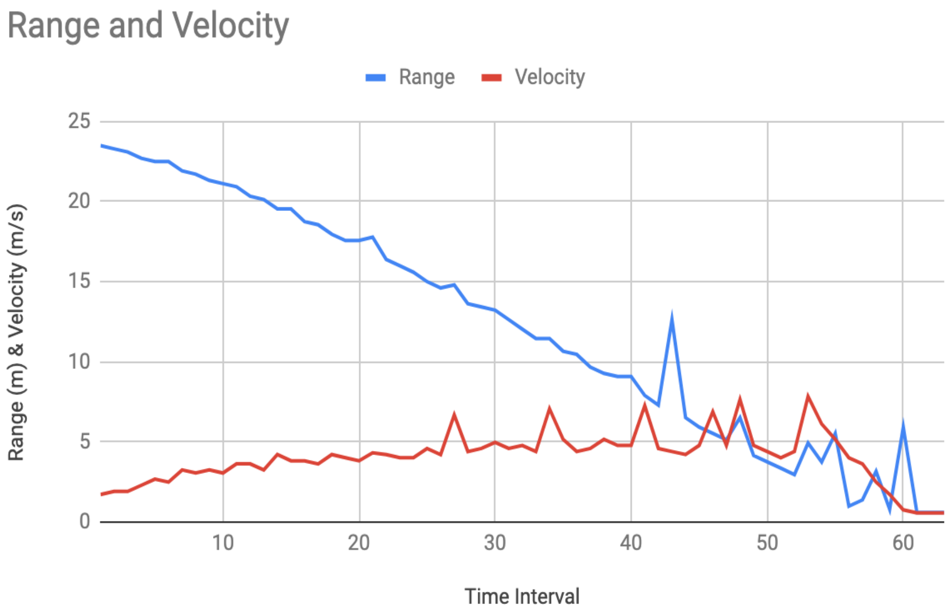
Prototype Testing

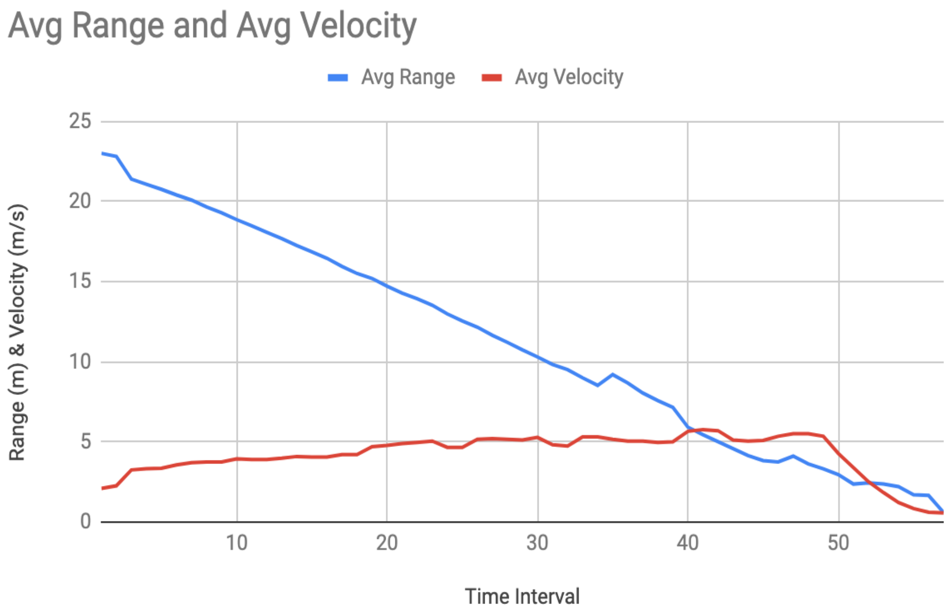
- Integrated PCB into design and tested power using both a function generator, then our battery
- Supplied the appropriate amount of power to both LiDAR and RADAR sensors to run sample code
- Tested MCU by loading a code to flash on board LED

Integration Testing

- After fully assembling the device, it was tested with people and bikers acting as both threats and safe drivers
- We then tested with cars going both safe (~4.5m/s) and unsafe speeds(~8.9m/s).
- Both LiDAR and RADAR sensor angles were found through trial and error by adjusting the sensor bracket

Data Analytics & Visualization





Budget

Product	Subsystem	Quantity	Unit Cost	Total Cost
Solar Cell	Power	28	$4.13	$115.64
Lithium Ion Battery	Power	1	$87.00	$87.00
MPPT Solar Charge Controller	Power	1	$69.45	$69.45
LED Traffic Light	Hardware	4	$42.75	$171.00
TI mmWave Evaluation Board	Hardware	2	$0.00	$0.00
Garmin LIDAR-Lite V3HP	Hardware	2	$149.99	$299.98
TI MSP432P401R	Hardware	1	$0.00	$0.00
PCB	Hardware	2	$20.00	$40.00
Minor Components	Hardware	1	$90.00	$90.00
Physical Building Material	Mechanical	1	$100.00	$100.00
Misc.	Misc.	1	$50.00	$50.00
Total				**$1033.07**

Resolved Issues

Issue	Resolution
Difficulty communicating via I^2C	Created custom drivers for the Lidar-Lite v3HP
Complexity and difficulty in programming mmWave RADAR (cutting-edge technology)	Dedicated extra time to find documentation on the sensor and the technologies used
Heat dissipation from the PCB	A switching regulator was used instead of a large linear regulator
Access violations encountered in multithreading	Scheduler and Classifier threads were refactored to eliminate concurrent use of Lidar objects
Critical placement and orientation of mmWave RADAR	Sensor angle was tested manually to see max range; optimum of 15 degrees tilt downward was found

Questions

Demonstration

[redacted]

References

“Drivers Often Stop but Don't See.” *IIHS*, 2002, *www.iihs.org/iihs/sr/statusreport/article/37/9/4*.