Light Saver

Pedestrian Safety Smart Sign

Senior Design 2: Critical Design Review

Group 15

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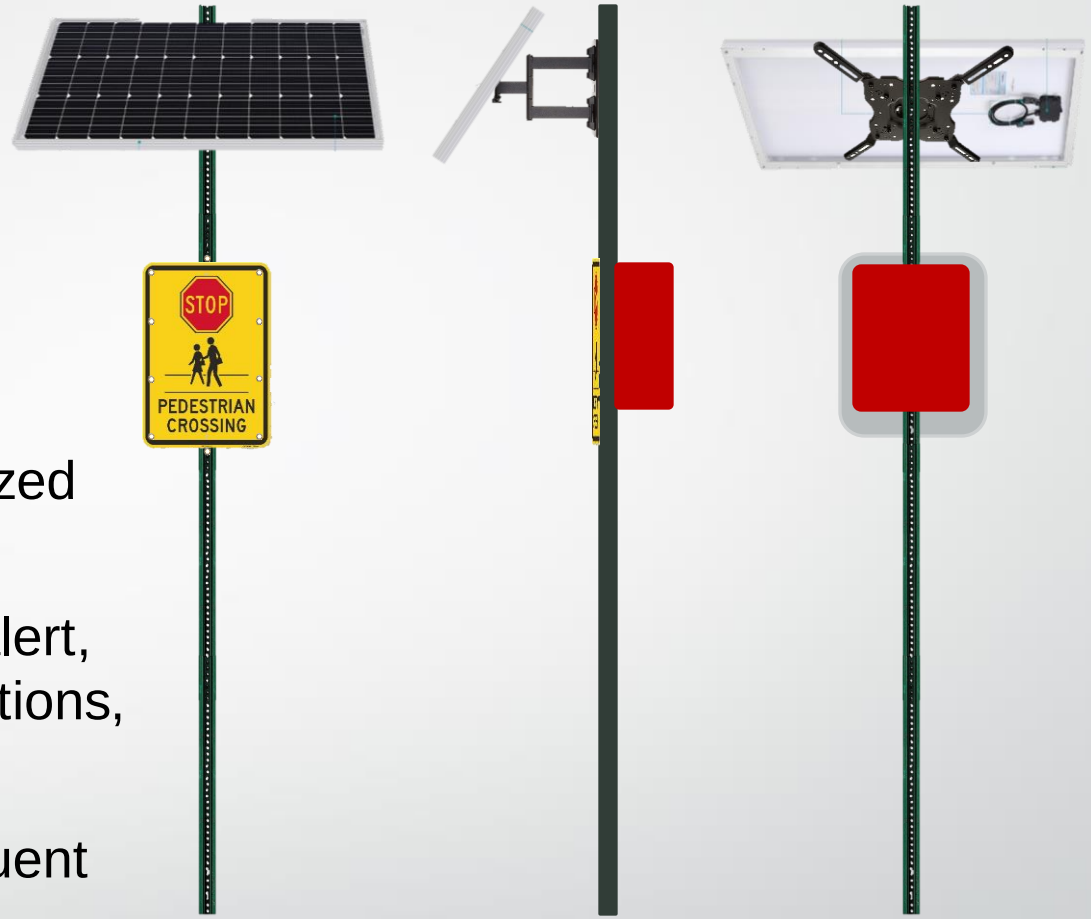
Motivation

- Pedestrian safety is a paramount concern for the National Highway Traffic Safety Administration (NHTSA).
- NHTSA reported 6283 pedestrian fatalities in 2018 (17.2% of traffic deaths annually).
- According to the Insurance Institute for Highway Safety, adoption of Right-Turn-On-Red (RTOR) laws contributed to 60% increase in pedestrian crashes.
- Pedestrians have a right-of-way at crosswalks, regardless of RTOR laws.
- As pedestrians ourselves, we have encountered hazardous right-turn intersection conditions.
- We want to improve pedestrian safety at crosswalks and signalized intersections.

Solution



- We propose a smart device integrated signalized sign to alert vehicles to pedestrian presence.
- Features include embedded LEDs for visual alert, computer vision analysis of intersection conditions, motion sensor for pedestrian presence, etc.
- Installation at high-risk intersections with frequent pedestrian traffic.
- Integrates with existing measures such as crosswalk timers and pedestrian signs.

Goals and Objectives

To alert vehicles to the presence of pedestrians at crosswalk and create safer conditions for pedestrians at intersections.

To raise awareness to the right-of-way of pedestrians, whether RTOR scenario.

To be portable and power self-sufficient, allowing for integration at existing locations.

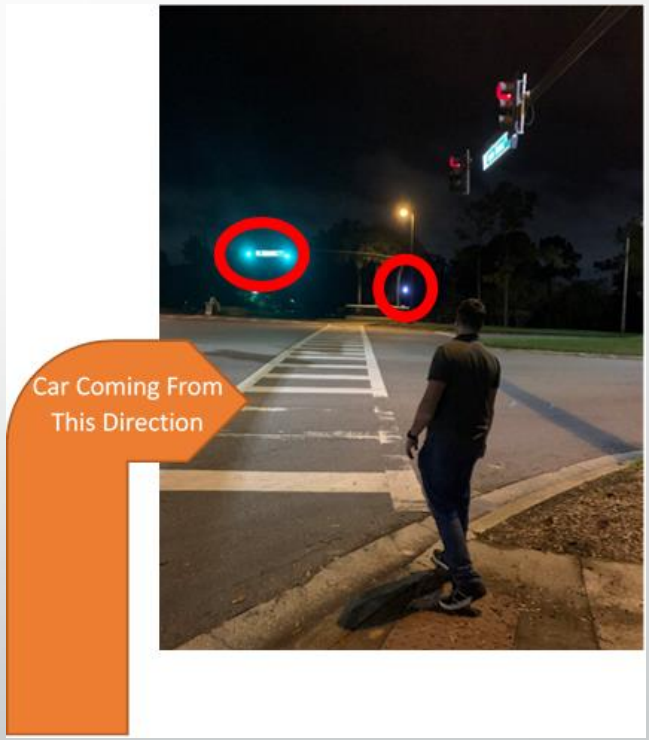
To be an active alert system, analyzing real-time conditions for engagement, and operating in low-power mode if conditions are not met.

Comply with NHTSA rules and standards.

Real World Scenarios

Scenario 1

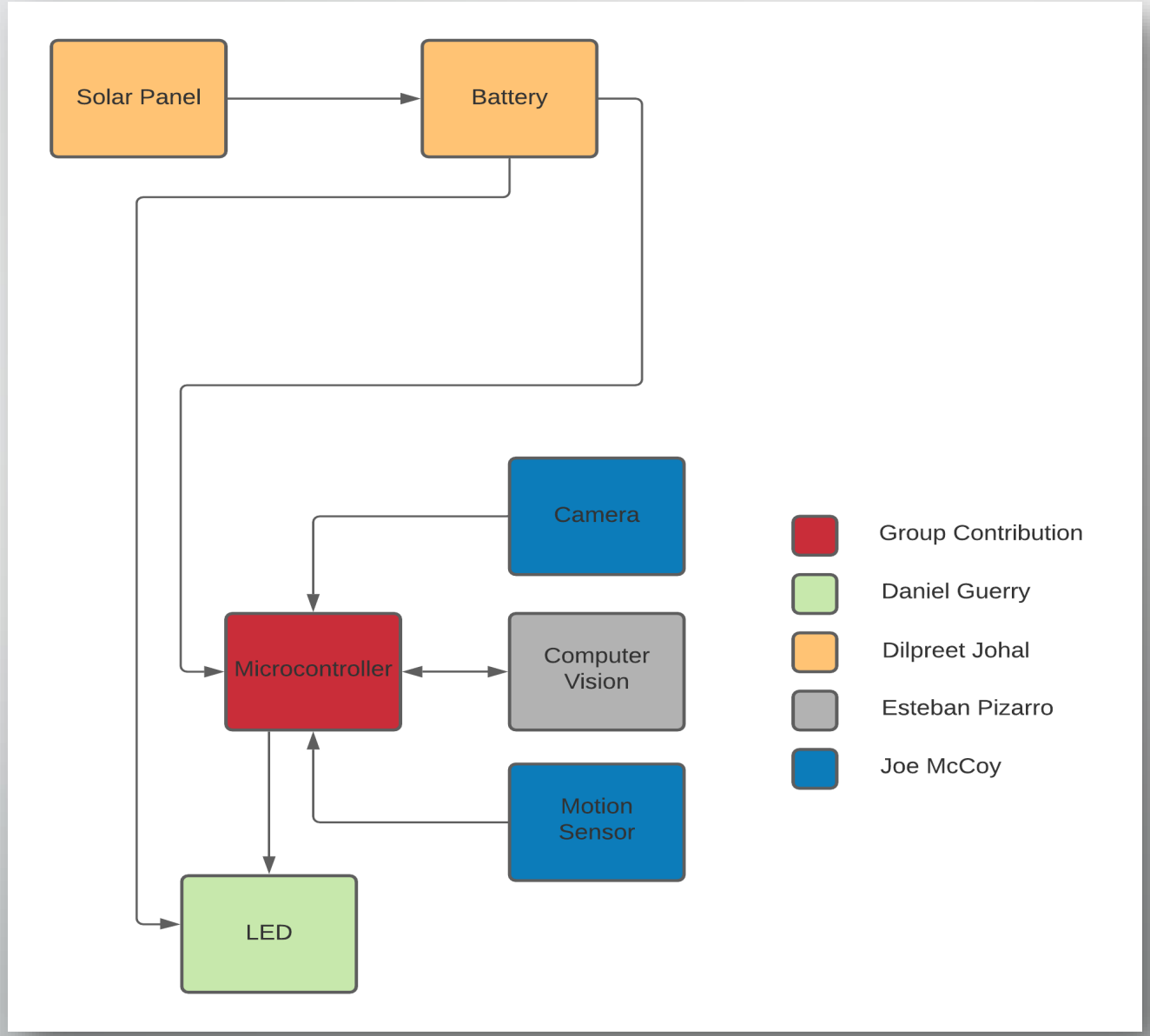
Scenario 2



General Specifications

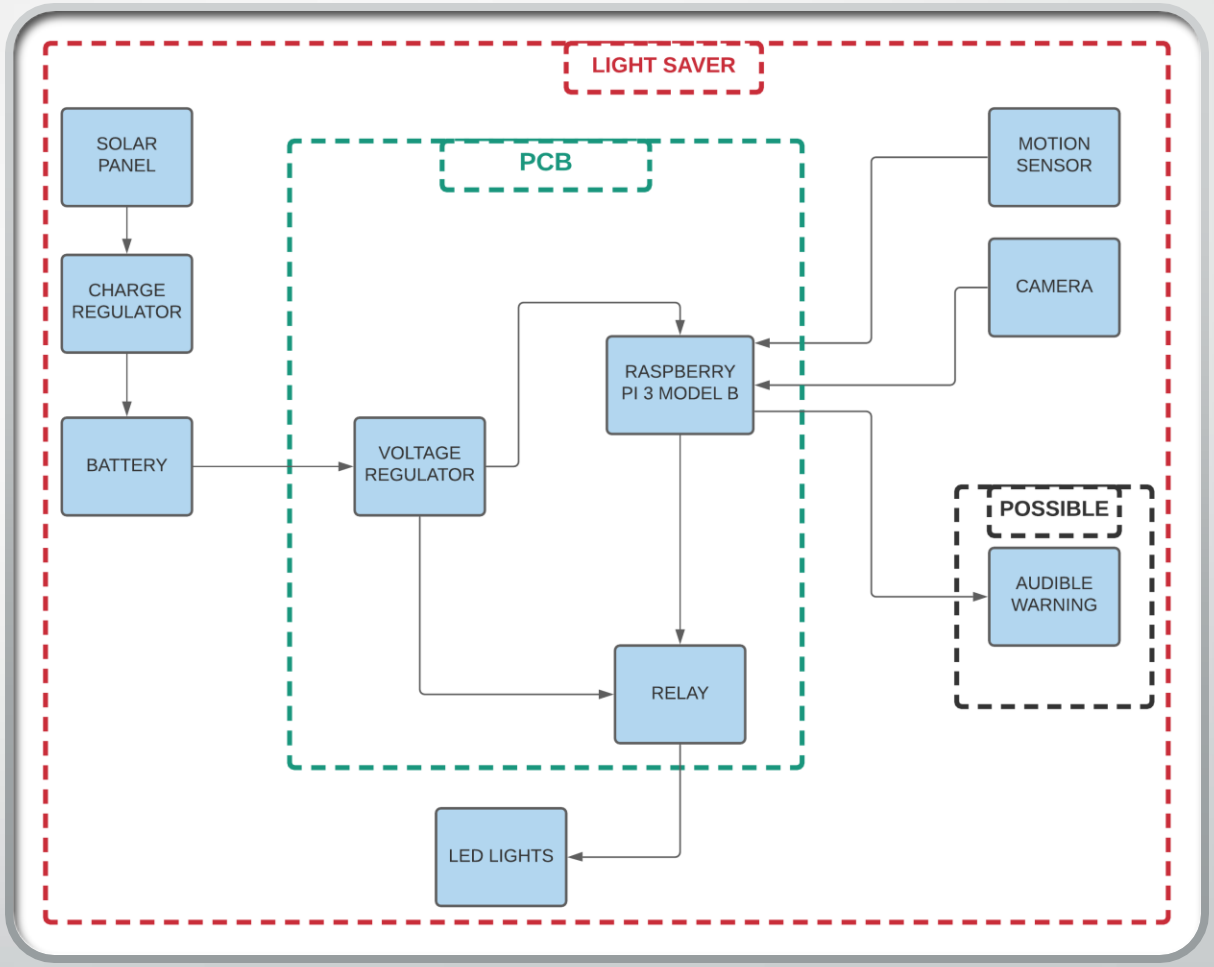
- Detect pedestrians at crosswalk within 5 feet, 100° FOV using PIR sensor
- Alert vehicles of the presence of pedestrians using 10 mounted LED lights (matching color of sign base)
- As per MUTCD, LEDs must flash between 50-60 times per minute
- 12V, 100W Solar Panels
- 24-hour functional operating time
- Mounting pole not less than 5 feet in height
- Sign area max 600 square inches
- Engineer grade reflective aluminum wrap
- Computer vision will analyze when the Crosswalk signal status
- Engaging in alert mode only when all input conditions from peripherals met

Block Diagram



Hardware Block Diagram

- Optimize power efficiency, to prolong operation time on battery
- Require multiple power rails for different voltage inputs, 12V, 5V
- Minimize power distribution through Pi 3 to prevent damage



Power System Design

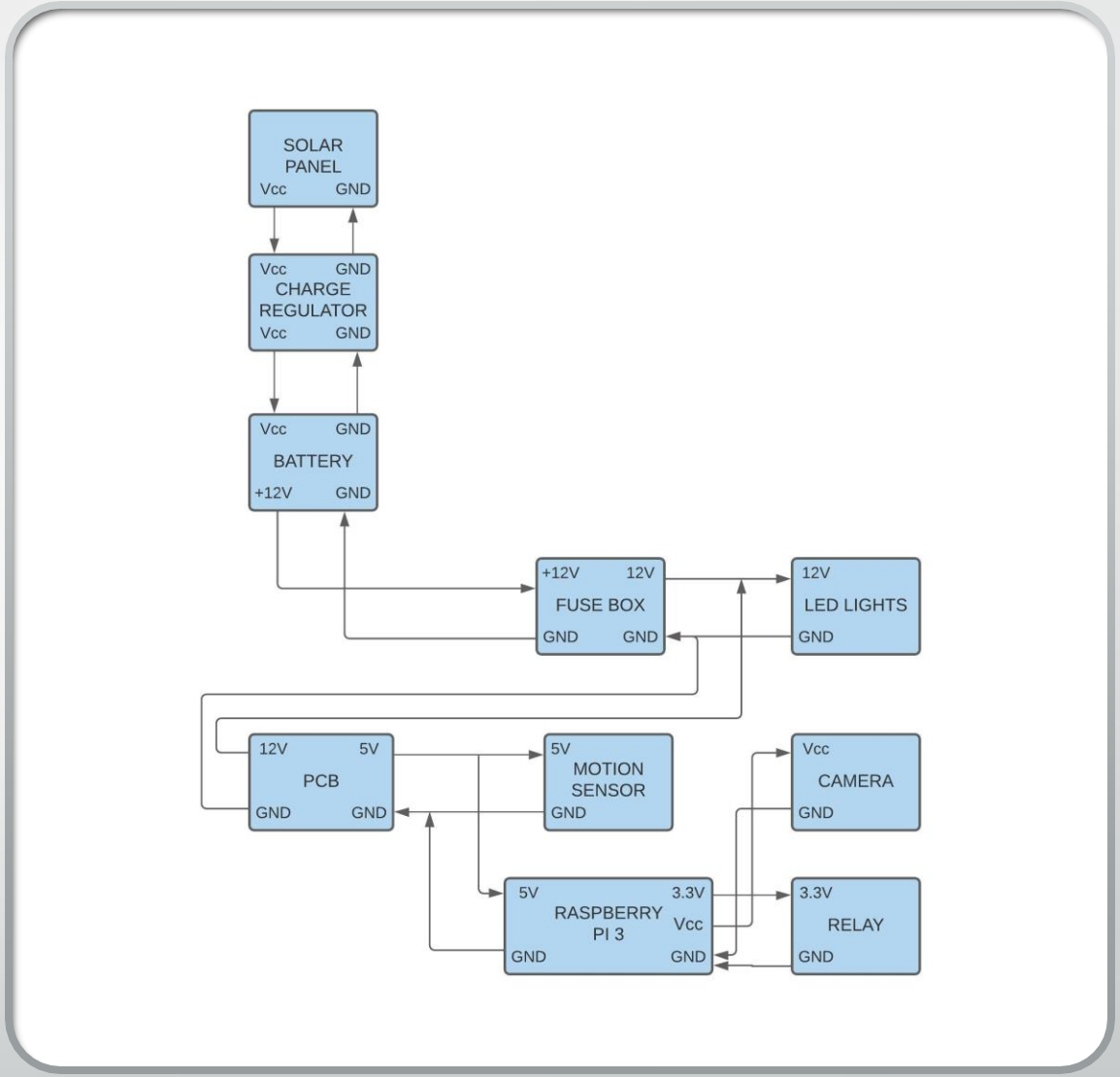
- Off Grid (Portable)
- Power Storage
- Charging System
- Two power rails - 12V and 5V
- 24-hour operation time

Power Supply Requirements

	Input Voltage	Input Current	Total Power	Supply Method
Raspberry Pi 3	5 V	0.72A	3.6W	PCB
Motion Sensor	5V	20mA	0.1W	PCB
Camera	5V	0.25A	1.25W	Pi 3 Board
LED (x10)	12V	0.07A	8.4W	PCB
Relay	3.3V	0.07A	0.231W	Pi 3 Board
Total Power			13.581W	
(24 Hours)			325.95W	

Power Systems Implementation

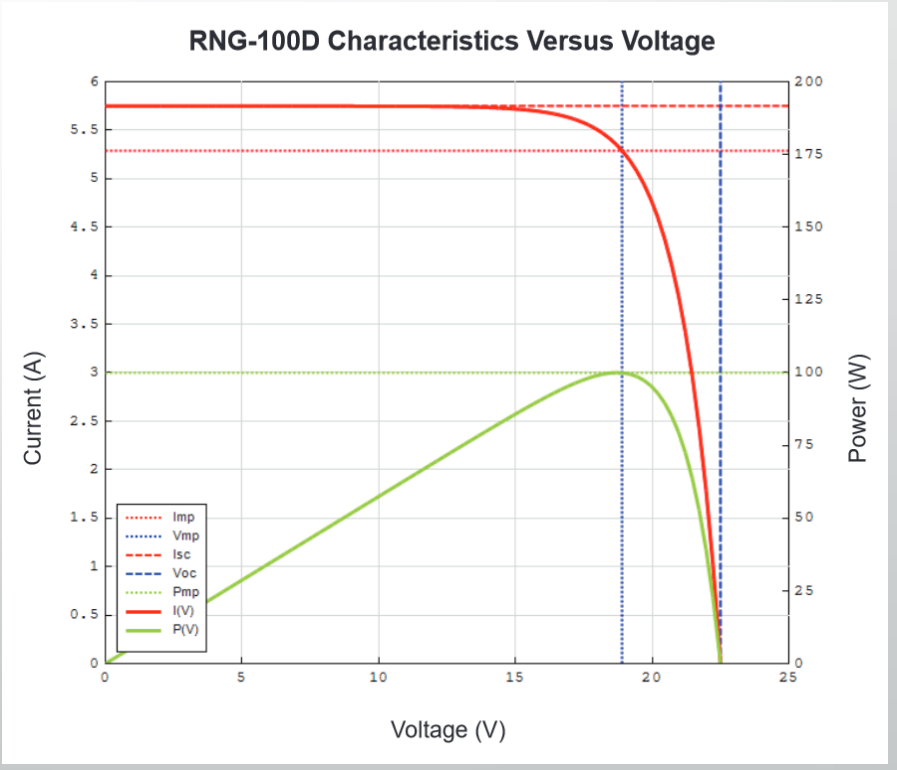
- The PCB will take 12V from battery through the fuse box and convert into 5V to power the motion sensor and Pi Board
- Pi Board will supply the camera and the relay
- LEDs will receive power via fuse box (controlled via relay on PCB)



Solar Panel

Model: Renogy 100 Watt

- Monocrystalline Silicon (High Conversion Efficiency)
- Designed for 12 V battery implementation
- Optimum Operating Voltage: 18.9 V
- Optimum Operating Current: 5.29 A
- Operating Temperature: -40°F - 176°F
- V_{OC} = 22.5 V
- I_{SC} = 5.75A
- Dimensions: 47" by 21.3" by 1.4"
- Weight: 16.5 lbs
- Cost: $103.02



Choosing the Right Battery

- Different parameters to consider are capacity, power density, longevity.
- Rechargeable vs Non-Rechargeable
- Lead-Acid, Nickel- Cadmium, Nickel Metal Hydride, Lithium Ion
- Advantages of Lead Acid
  - Lower cost per AH ($2 per Ah, vs $9 per Ah of comparable Li-Ion battery)
  - Long shelf life (Discharge rate ~40% per year),
  - Long Battery Life (~8+ years) safer operating conditions and
  - No memory effect
  - More safe and stable vs Li-Ion
- Advantage of AGM vs Flooded or Gelled (Lead Acid Batteries)
  - No maintenance
  - Non-hazardous, no toxic spill if container broken
  - Sealed against toxic fumes

Battery Specifications

- Brand: Mighty Max
- Model: L50-12
- Parameters: 12 V, 50AH
- Type: SLA - AGM battery
- Weight: 30 lbs
- Dimensions: 7.8" x 6.5" x 6.9"
- Ideal Operating Temperature: 25°C
- Internal Resistance: 8mΩ
- Price: $99.90

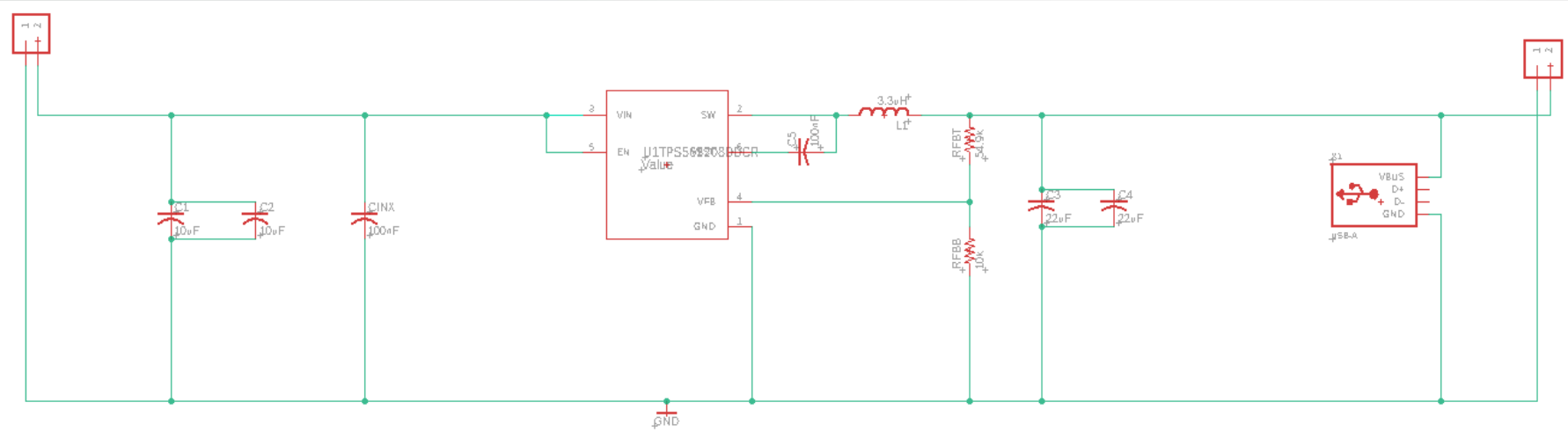
Charge Controller

- Necessary to maintain correct charging voltage output to battery
- Direct connection between solar panels and battery will result in damage
- Parameters to consider are conversion efficiency, cost, battery type, etc.

Charge Controller Specifications:

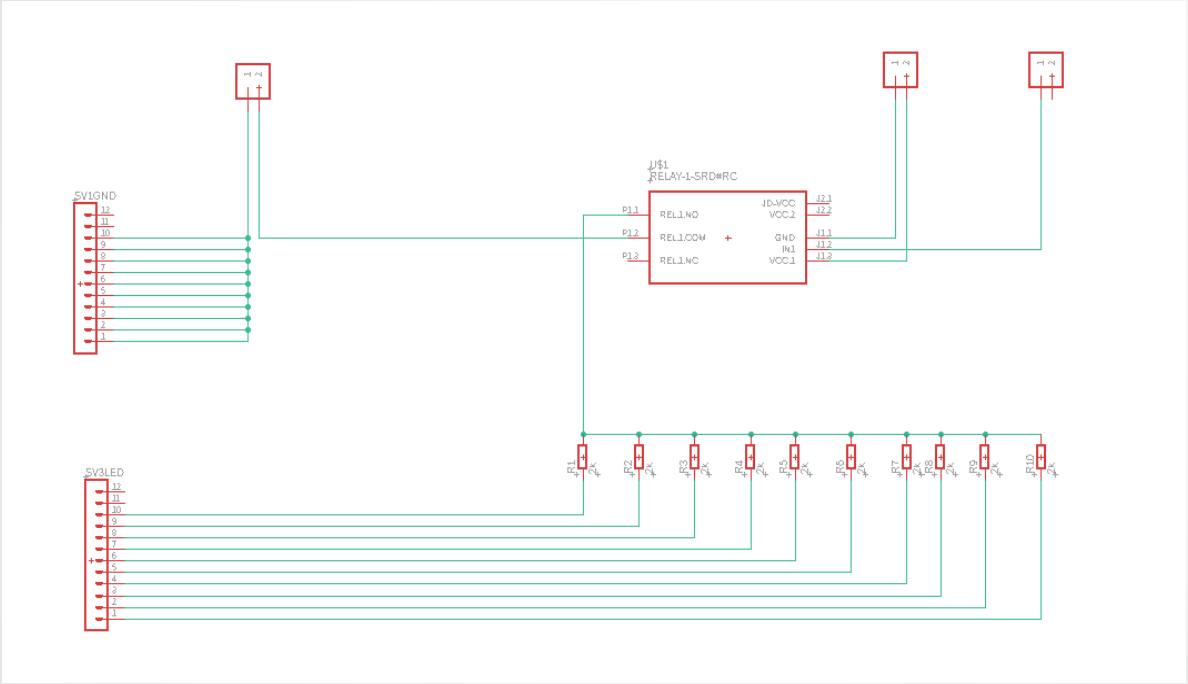
- Brand: Renogy
- Model: RCC20VOYP-G1
- Parameters: 12 V, 20AH
- Type: 4-stage PWM
- Dimensions: 6.08" x 3.83" x 1.4"
- Discharge Stop: 10.7 V
- Compatibility: Lead-Acid battery
- Price: $20.00

Voltage Regulator



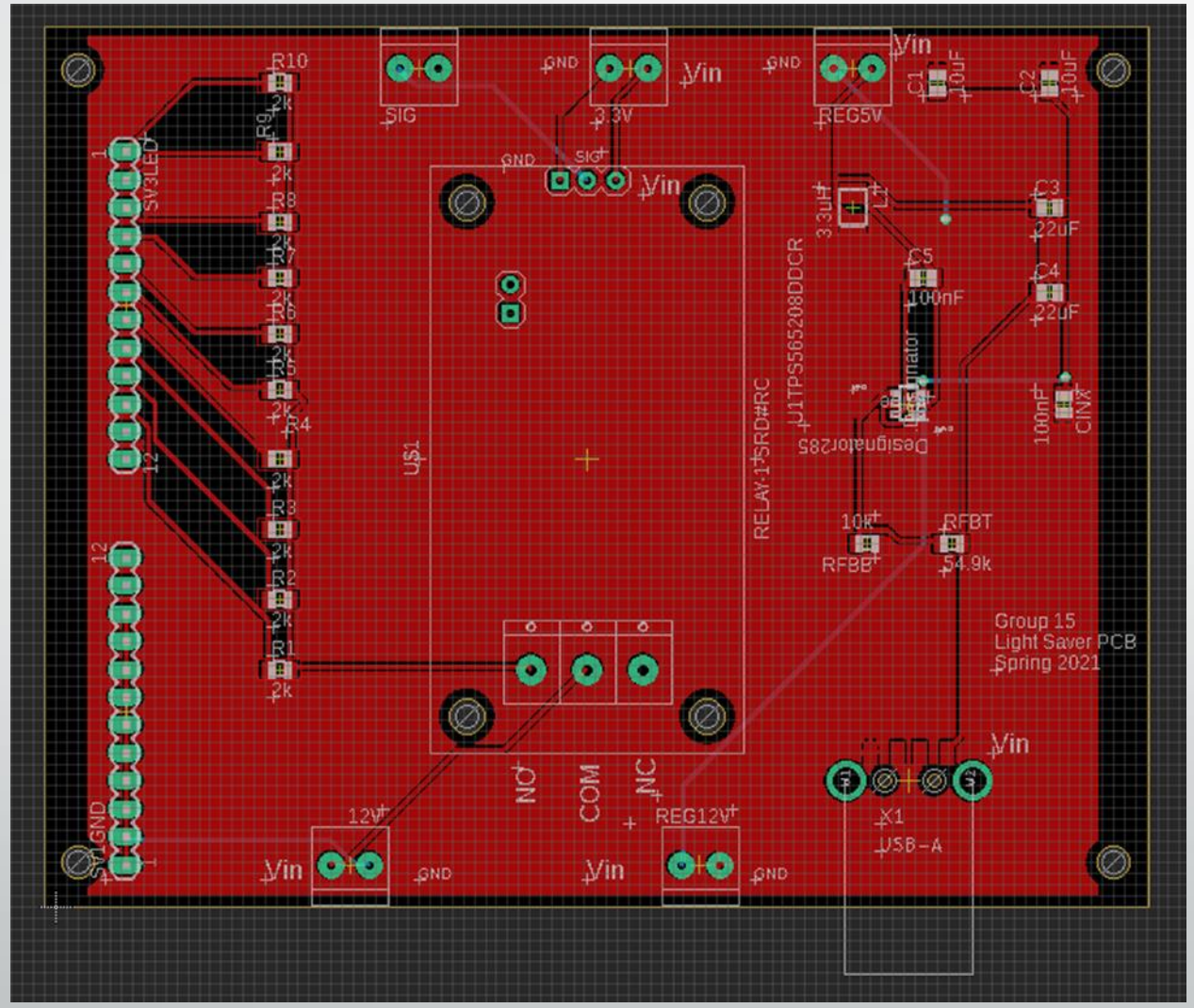
- Schematic for voltage regulation 12V to 5V
- Designed using TPS565208DDCR Buck convertor and TI Webench program
- Terminal block connectors and USB 2.0 to provide output connections
- Efficiency 94.8%, an important consideration

LED Implementation



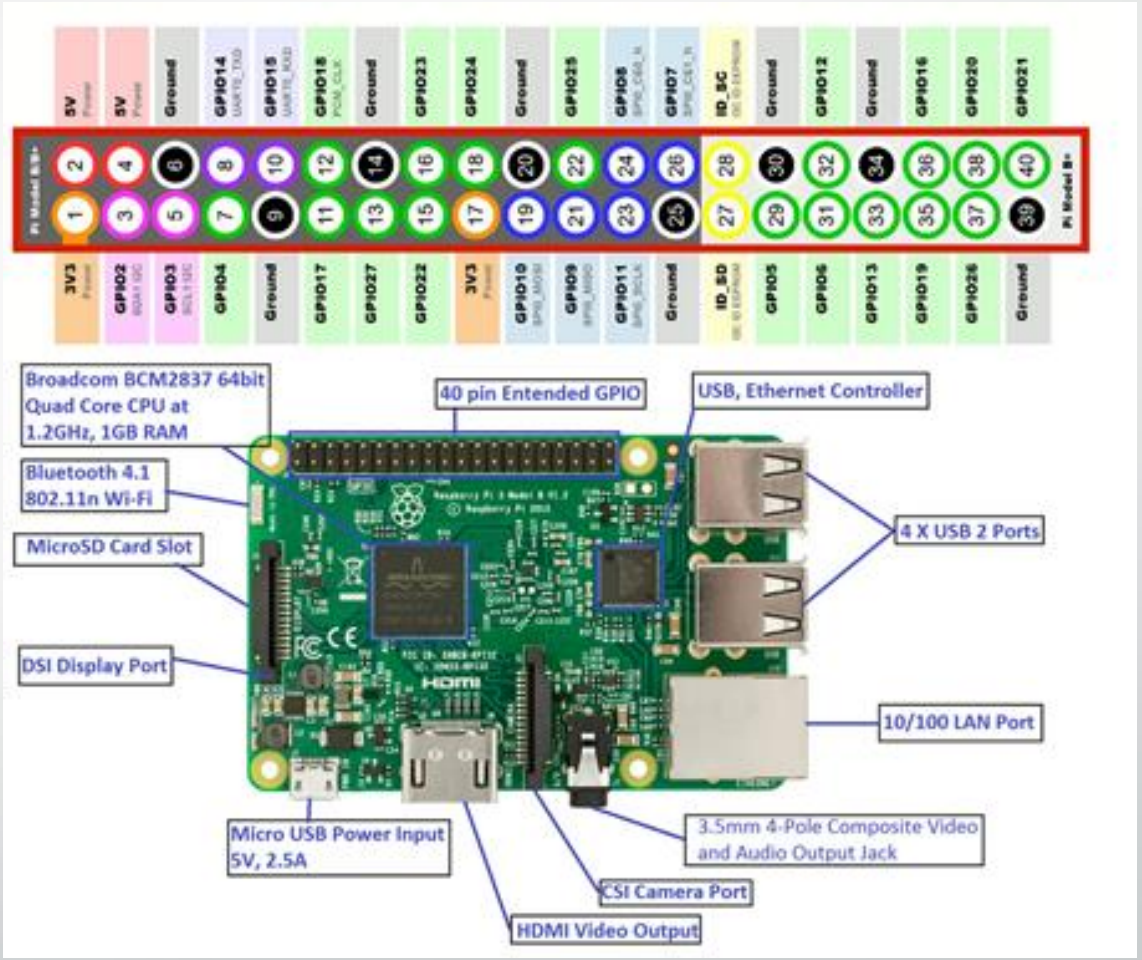
- Require method to avoid power surge through microcontroller
- Need to toggle LEDs through software
- Solution is circuit design utilizing relay

PCB Layout


R10
2k
R9
R8
R7
R6
R5
R4
R3
R2
R1
SV3LED
SV3GND
U$1
SIG
GND
3.3V
REG5V
Vin
C1
10uF
C2
10uF
C3
22uF
C4
22uF
C5
100nF
3.3uH
L1
U1TPS565208DDCR
RELAY-1FSRD#RC
Designator285
100nF
CINX
10k
RFBB
RFBT
54.9k
Group 15
Light Saver PCB
Spring 2021
NO
COM
NC
12V
REG12V
X1
USB-A

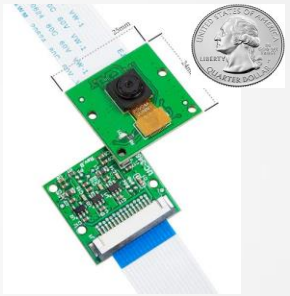
Raspberry Pi 3

- Need video processing capability (MIPI CSI)
- Fast processing to run real-time analysis of video feed (1.2 GHz)
- Efficient power consumption(~3.6 W)
- Wide operating temperature range (0-50 degrees Celsius)



Camera

- Many different parameters, i.e., Color, scan, semiconductor type, resolution
- Compared 3 color cameras, CMOS semiconductor chips
- Selected Arducam OV5647
- Good video capturing day/night
- Cost effective



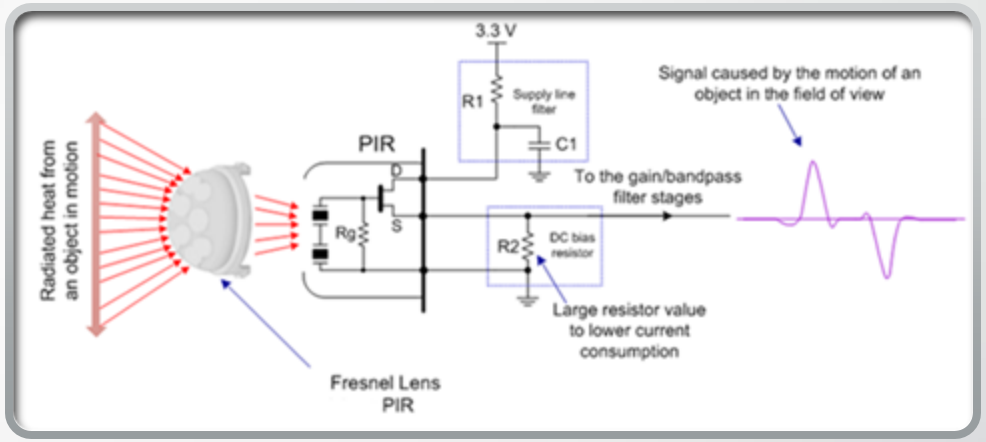
	OV5647	**C920**	**Pi HQ Cam**
Brand	Arducam	Logitech	Raspberry Pi
Resolution	5MP	2.07MP	12.3MP
Size	34mm x 24mm	43mm x 94mm	38mm x 38mm
Weight	20 gm	162 gm	53 gm
Cost	$9.99	$79.99	$50.00

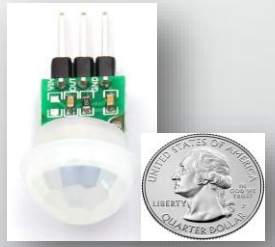
Motion Sensor

- Ultrasonic, Tomographic, Microwave, Infrared
- Passive Infrared Sensors commonly used in control systems
- PIR preferred due to detecting blackbody radiation
- Range 0-7 meters
- Angle (FOV) : 100-140 degrees

Motion Sensor Specifications:

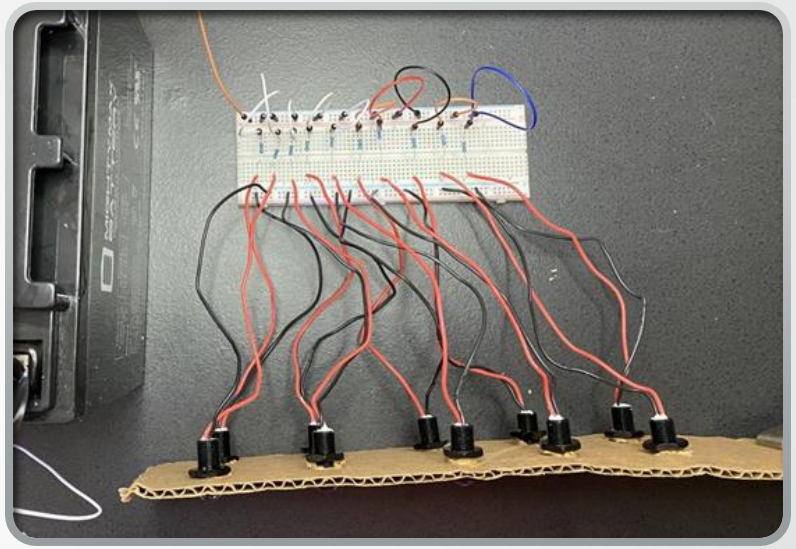
- Model: Dafurui AM312
- Parameters: 5 V, 0.1 mA
- Type: PIR sensor
- Dimensions: 25 mm x 12 mm
- Range: 9-16 ft
- FOV: 100 degrees
- Operating Temperature: -20°C to 60°C
- Price: $6.00





LEDs

- We want Low power consumption <1 W
- Durability to weather elements
- Meets standards according to NHTSA guidelines for light-embedded signalized signs

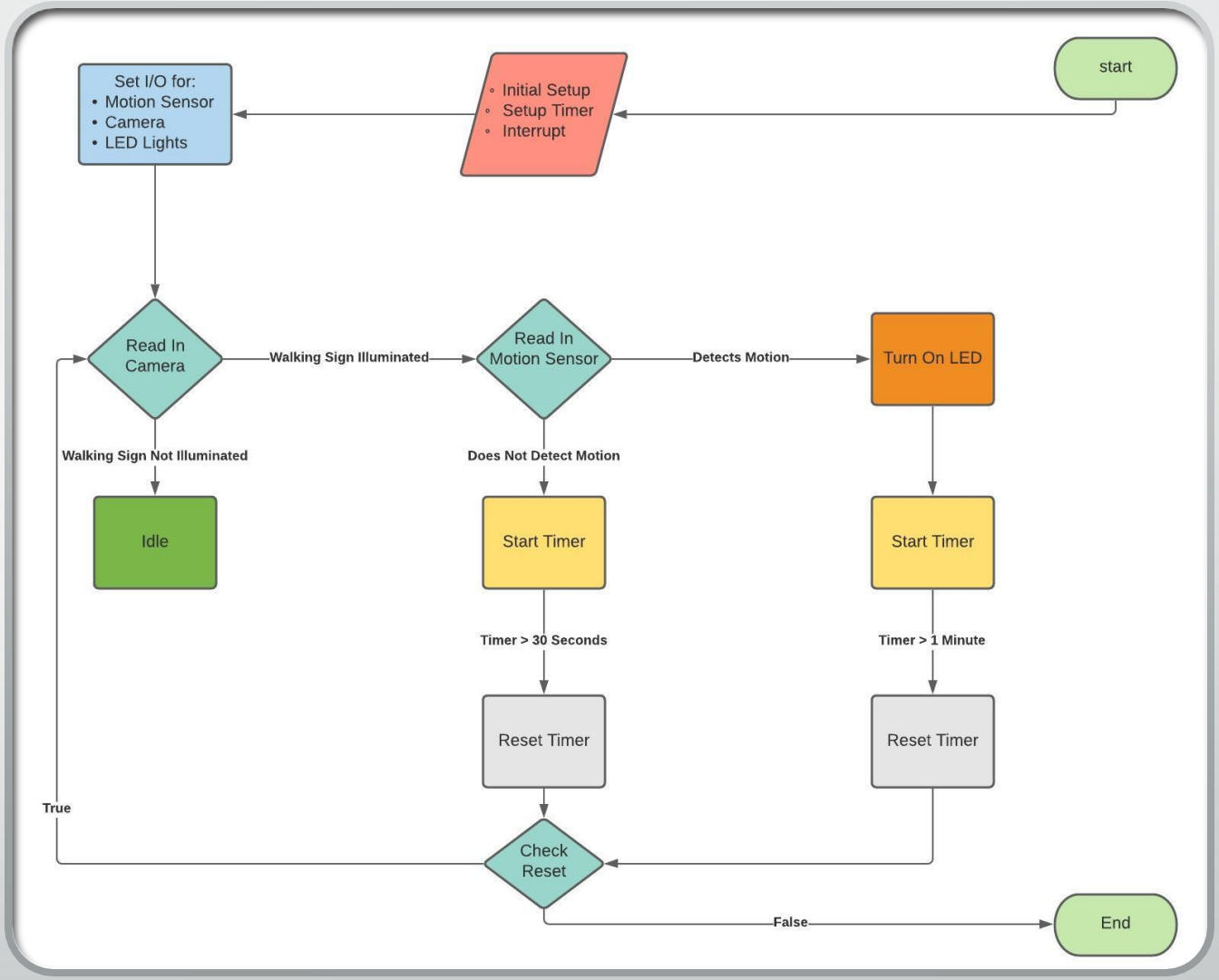


LED Specifications:

- Model: SuperBrightLEDs 12B-RB
- Voltage: 9 -14.5 V
- Power Rating: 0.45 – 0.725 W
- Dimensions: 0.45-inch diameter
- Wavelength: 590 nm (yellow-amber)
- Beam Angle: 110 degrees
- Bolt-metal threading, IP65 rated casing
- Price: $2.95 (1 LED)

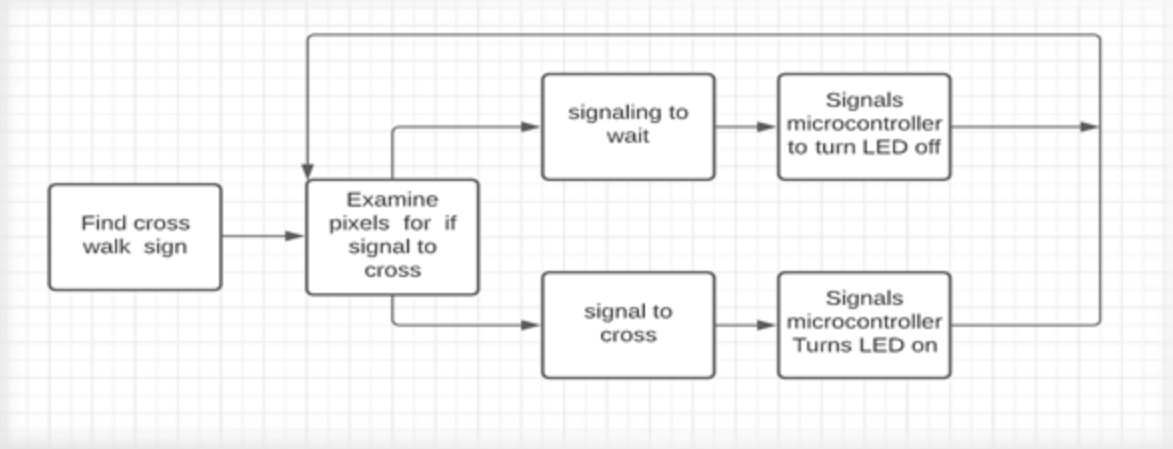
Software Flow Chart

- OpenCV software to use Computer Vision algorithms to analyze video feed
- Software code written in Python
- Engage LED notification only if conditions met



Computer Vision

- We need real-time analysis of crosswalk conditions
- Video feed analysis will help determine parameter- Crosswalk State



- How can we analyze video?
- Utilize open-source computer vision library OpenCV
- Developed by Intel Corp in 1999
- Supports various operating systems, such as Raspbian (Pi Board OS)

OpenCV Software

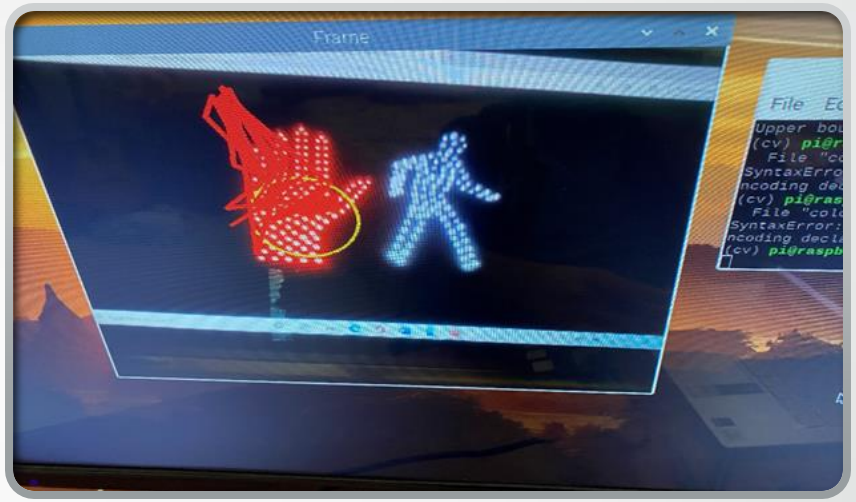
- Library of programming functions useful for real-time computer vision applications
- ~200 MB library size
- Cross-platformed, free to use under Apache 2 License
- Written in C++, but interfaced with Python, Java, MATLAB, etc.

Raspberry Pi 3 Implementation

- We download and compile OpenCV (~2.5 hours)
- We will use Python 2.7
- Utilize virtual environment to operate Python
- Utilize various functions, i.e., color detection, object wrapping, tracking, etc.

Computer Vision Testing

- Distinguish between crosswalk states
- Detect given input, provide state condition for LED decision
- Adjust algorithm based on crosswalk signal types
- Possible stretch goal to track pedestrian crossing the road



Mounting and Enclosure

- Need a secure method to mount solar panel, sign, enclosure
- Consider weather conditions, structural integrity, etc.

Mounting Pole Specifications:

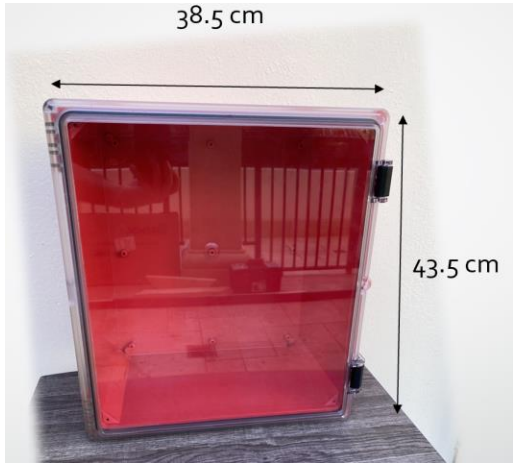
- Brand: Smart Sign
- Model: K-153-8-2
- Parameters: U-Channel signpost
- Type: Steel w/Enamel Coating
- Compatibility: NCHRP 350 compliant
- Price: $70.95

Enclosure Box

- Need weatherproof enclosure to house components such as PCB, battery, etc.
- Require adequate space for components, durability for protection
- Considered various enclosures, metal, PVC, etc.
- For Light Saver, we chose clear panel box to allow visual analysis of component housing during presentation

Enclosure Specifications:

- Brand: Seropac
- Model: 1632HLTCVR
- Type: UV-stabilized Polycarbonate
- Dimensions: 43.5 x 38.5 x 21 cm
- Compatibility: >IP67
- Price: $128.52



Sign with Embedded LEDs

- Require sign to be MUTCD compliant
- Appropriate symbols and conveyance

Sign Specifications:

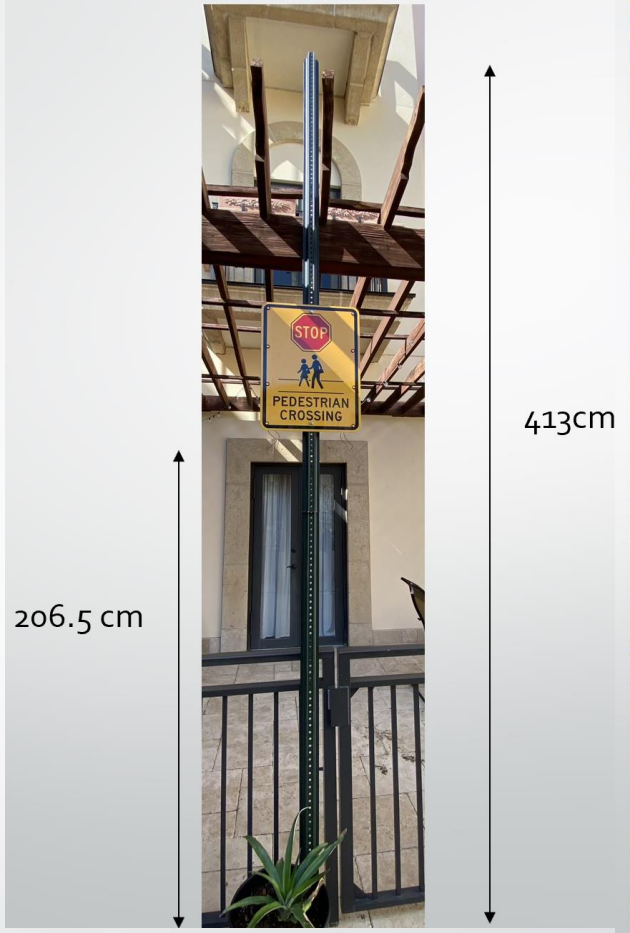
- Brand: SmartSign
- Model: K-2845-EG
- Type: 3M High Intensity Grade Reflective Aluminum
- Dimensions: 61 x 46 x 0.23 cm
- Compatibility: >IP67, Meets DOT FP-85
- Price: $42.36

LED Specification

- We drilled & mounted w/18cm spacing
- Column width 40cm
- Color Yellow/Amber (matches base color of sign)

Assembly and Solar Panel

- Distance of Sign Base from Ground: 206.5cm
- Total Height of Pole: 413cm
- Distance of Box Base from Ground: 226cm
- Solar panel angle/orientation based on optimum incident peak sunlight
- Initially mounted solar panel to the lower end of pole for demonstration



Design Constraints

- Lower budget, self-funded, limit the dispersion of money around different parts
- Shipping & Manufacturing delays due to COVID-19
- Durability to weather conditions
- Energy efficient and sustainable
- Pedestrians and drivers obeying traffic laws
- Ensuring Sign meets all NHTSA guidelines and conveys the correct message
- Computer vision: Concern with people being recorded
- Protection and Safety of the pedestrian
- Device reliability

Current Progress

- Ordered major components
- Raspberry Pi 3 has fully functioning OS and OpenCV installed
- All peripheral devices have been purchased

Upcoming Goals

- Algorithm for peripheral input integration
- Test the PCB
- Integrate power systems into Light Saver

Administrative Content

Work Distribution

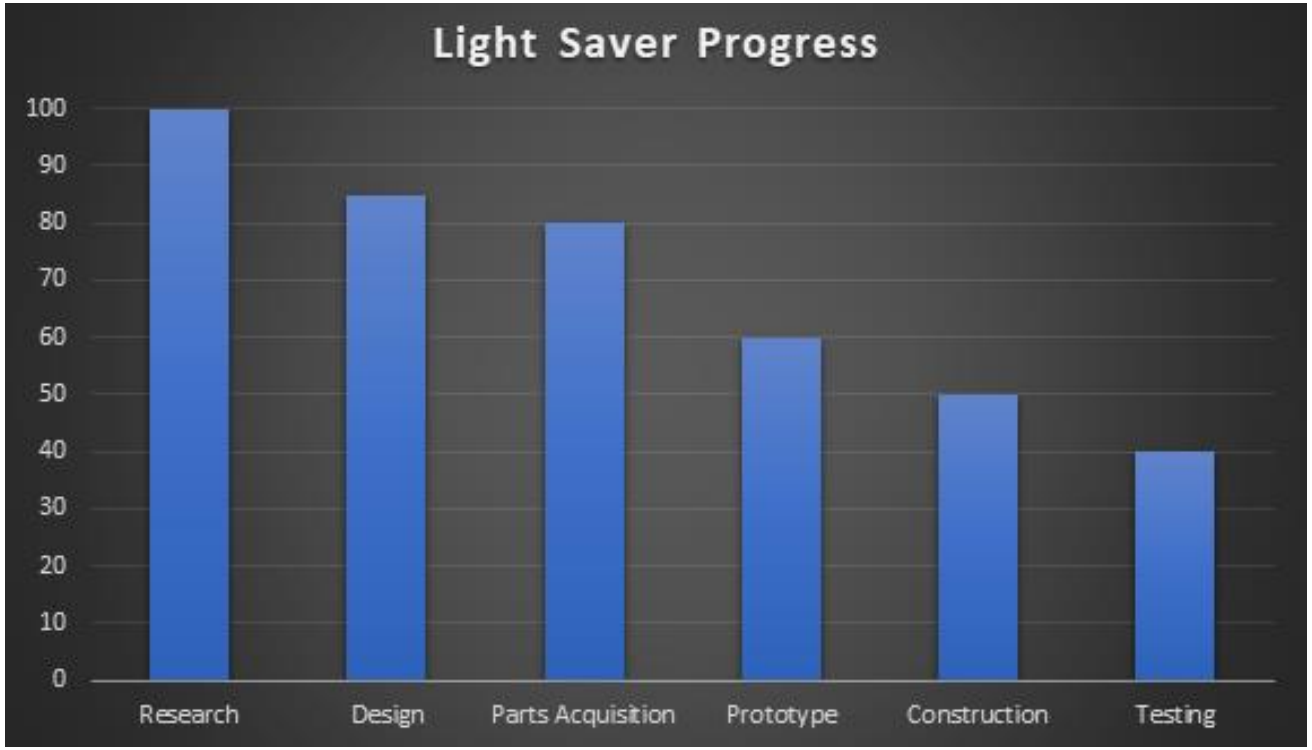
	Power System Design	Sign & LEDs	Mounting & Casing Design	Camera Selection	Computer Vision Processing	Peripheral Integration	Software Coding
Dilpreet	✓	✓					
Daniel		✓	✓				
Esteban					✓	✓	✓
Joe				✓	✓		✓

Project Timeline

The Week of	The Objective
2/4/2021	CDR due on 2/11. Assemble prototype and start testing
2/26/2021	Project Summary Due 2/26
3/5/2021	Ordering all additional parts
3/12/2021	V2 PCB ordered
3/19/2021	V2 PCB assembly
3/26/2021	Housing and waterproofing
4/9/2021	8 page Conference Paper and Committee Form due 4/9
4/20/2021	Final presentation due 4/20, presenting 4/21-4/22
4/27/2021	Final document due 4/27

Project Budget

ITEM	QUANTITY	Vendor	PRICE
Aluminum Sign K-2845-EG	1	SuperSign	$42.36
Mounting Pole	2	Smart Sign	$70.95
Mounting Hardware	1	Lowes	$25
LED mounted lights 12B-R-B	10	Super Bright LED's Inc.	$20.95
Solar Panel (12V) 100W-12V	1	Renogy	$103.02
SLA-AGM Battery L50-12	1	Mighty Max (Walmart)	$99.99
Motion Sensors PIR	1	Dafurui (Amazon)	$6.00
Raspberry Pi 3 Model B	1	Adafruit (Amazon)	$35.00
Charge Controller PWM	1	Renogy	$38.24
Camera for CV OV5647	1	Arducam (Amazon)	$9.99
Custom Enclosure	1	Amazon	$128.52
PCB Fabrication	1	JCLPCB	20.87
TOTAL			~$600.89



Light Saver Progress

Thank You

Questions?