Signal Operated Lock And Security (SOLAS) system

Group 16

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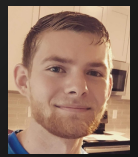
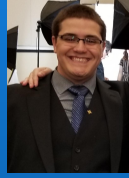
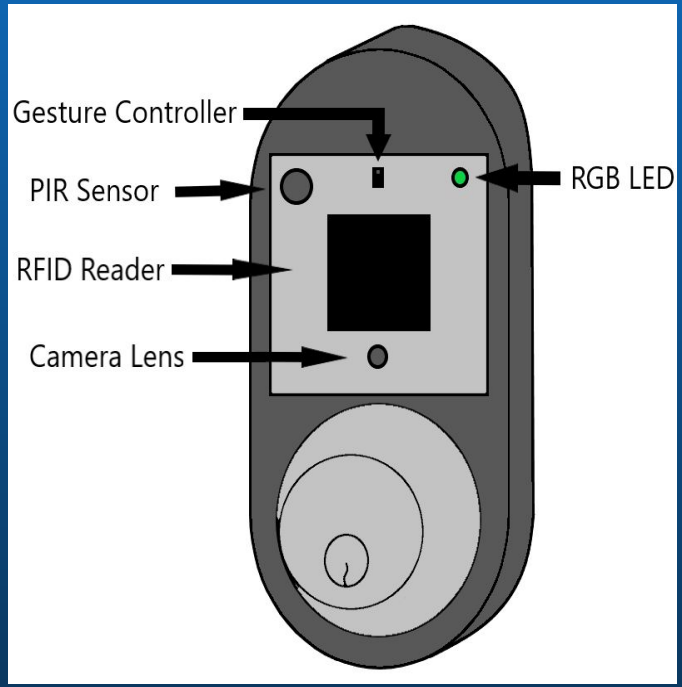




Introduction

- An electronic door lock system consisting of
  - RFID communication
  - Motion sensor
  - Gesture controller
  - Camera
  - User website
- Motivation came from making grocery trips easier
- Inspiration from automatic proximity car door locks



Goals and Objectives

- Goals
  - The main goal for the SOLAS project is to make home entry easier for authorized users, as well as increase security
  - A web application that allows the user to monitor activity outside the door
- Objectives
  - The RFID subsystem eliminates the need to use physical keys and includes an optional gesture password
  - Camera documents all activity at the door, including highlighting when incorrect passwords are entered
  - Low power consumption for long battery life for the system
  - The lock should fit onto standard door designs
  - An RFID bracelet that comes in various sizes
  - Camera to capture clear images of movement which the user can review and identify later
  - Web application to modify lock settings and view photos taken by the camera
  - After 10 seconds of inactivity in any powered on state, the system will return to a power saving mode

Specifications

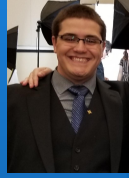
System Specification	Units
How long it takes (on average to open the door)	10 seconds
The RFID reader will detect the tag at a specified distance	18 cm
The proximity sensor will detect motion and wake up the rest of the system at specific distance	1.22m
An adjustable bracelet to house RFID tag, low weight	14 - 20.3 cm, < 4oz
The SOLAS system will have long battery life	1+ year
The system will enter low power mode after inactivity of no RFID tag read or no gesture read	10 seconds
Lock dimensions	4 x 6.6 x 12.2 cm
Power drawn	10-15 watts

Constraints

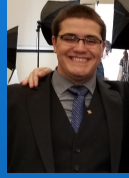
- Three team members
- Cost: Budget funded by project members
- Time: Strict schedule to follow to complete SOLAS on time limits potential design choices
- Team meetings: Distance and other current conditions limit the amount of physical team meetings
- Size: The SOLAS system must fit in a reasonably sized enclosure
    - The system must be able to fit on a standard door

Standards

- RFID wave propagation distance/frequency
  - ISO/IEC 15693-2:2019
- Camera
  - Resolution measurement
    - ISO 12233:2017
  - Shading/color intensity
    - ISO 17957: 2015
  - Magnification distortion
    - ISO 17850:2015
- Motor controller standards
  - EEE Std 3001.11™-2017
- LED Standards
  - ANSI C78.377-2015
- Motion sensor standards
  - IEEE 2700-2017
- C standards
  - IEEE 1666-2011
- Power supply standards
  - IEC 60086-1 and IEC 60086-2
- Microcontroller production standards
  - IEC 61508



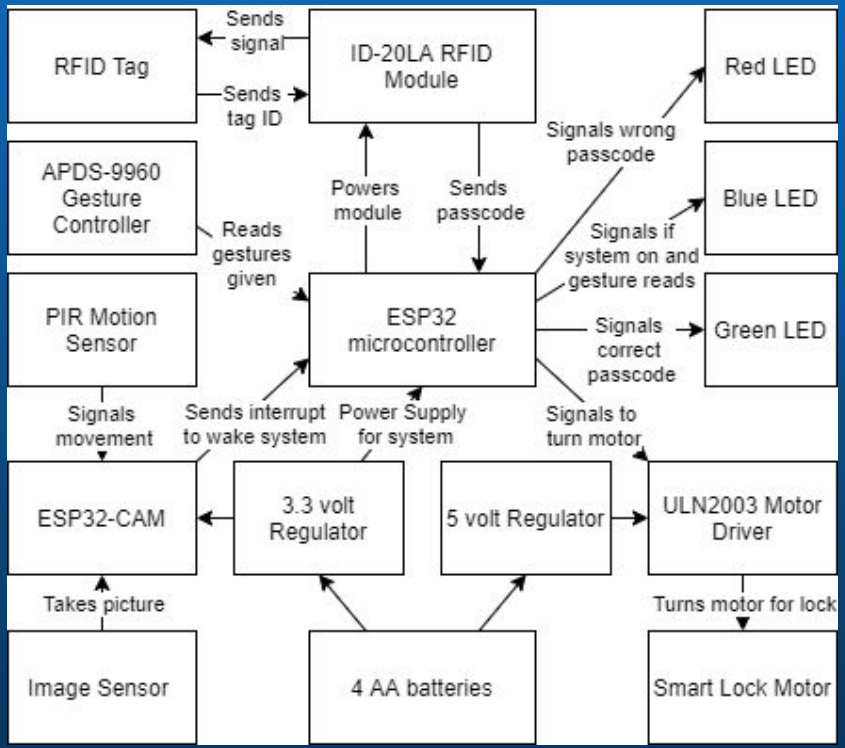
SOLAS
Hardware Design

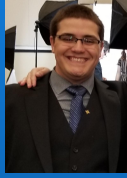


Hardware block diagram

List of Components:

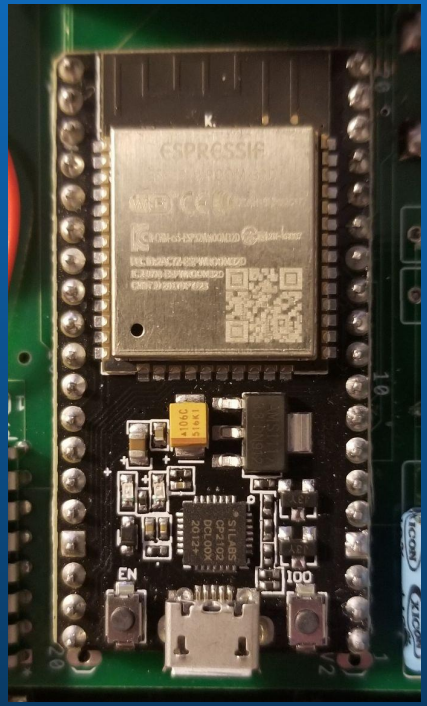
- ESP32 Microcontroller
- ESP32-CAM
- ID-20LA RFID Module
- APDS-9960 Gesture Controller
- ULN2003 Motor Driver
- RGB LED
- BL412 PIR Motion sensor
- LM1117IMPX-5.0 Voltage Reg.
- LM1117IMPX-3.3 Voltage Reg.

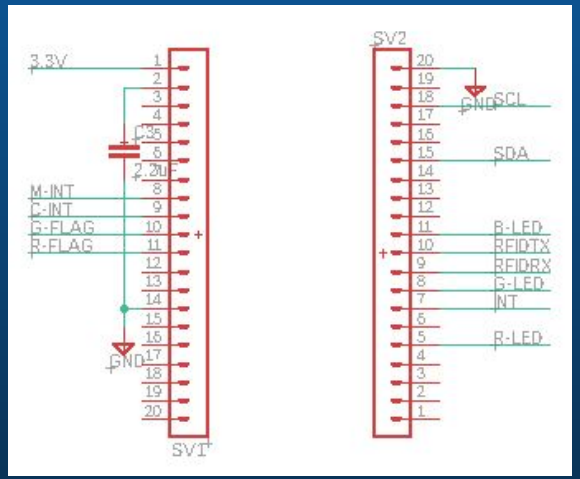




ESP-32S Development Board

- Uses ESP32-WROOM-32D Chip
  - Integrated Wi-Fi and Bluetooth
  - Low power and low cost
  - 34 GPIO pins
  - Various power/sleep modes
  - ROM: 448 KB, SRAM: 520 KB
  - 240MHz clock frequency

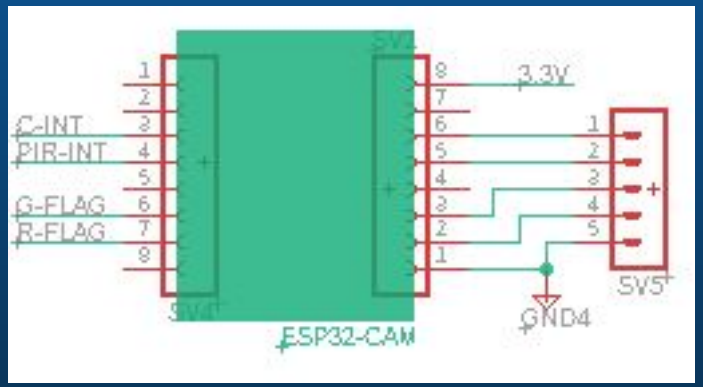




Power Consumption	
Active Mode	0.594 W
Deep-Sleep Mode	0.495 mW

ESP32-CAM Camera Module

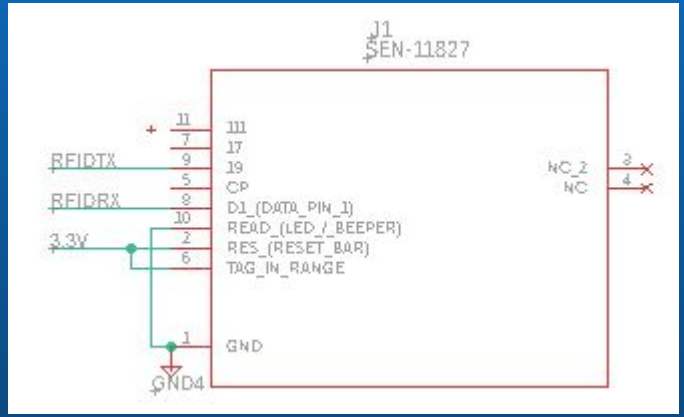
- Capture image when motion is detected
  - OV2640 2MP Image Sensor
  - 1600 x 1200 Resolution
  - WiFi enabled
  - SD card slot

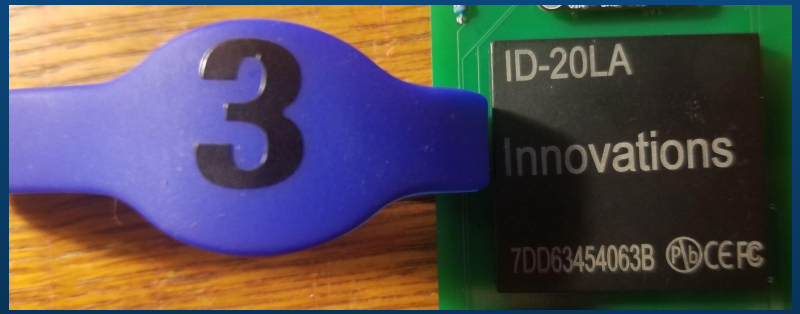


Power Consumption	
Active Mode	0.594 W
Deep-Sleep Mode	0.495 mW

ID-20LA RFID Module, RFID tag

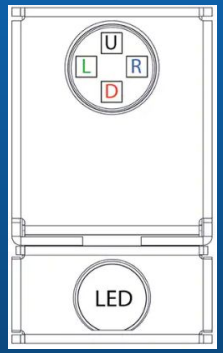
- The RFID subsystem is responsible for regulating who is able to enter the door
  - It was chosen due to it's small size
  - RFID tag uses passive technology for simplicity
  - RFID reader module comes with integrated antenna
  - 18 - 25 cm read range
  - 125 kHz frequency between the reader and tag
  - Power Consumption: 148.5 mW

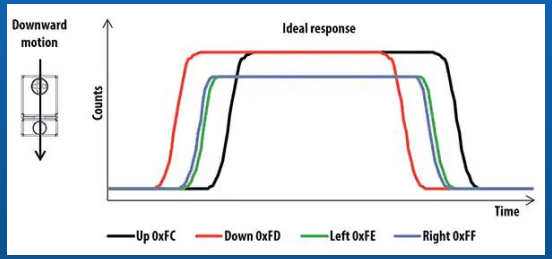


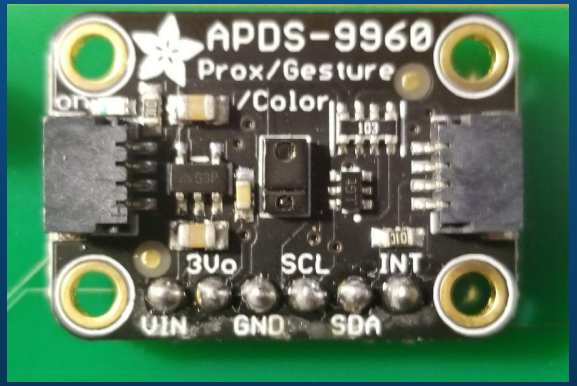


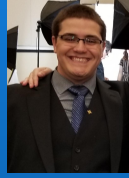
APDS-9960 Gesture Controller

- Used as secondary password
  - Four photodiodes used to detect reflected IR energy generated from an integrated IR LED
  - I2C interface with dedicated interrupt pin
  - Small package size
  - Power Consumption: 82.5 mW



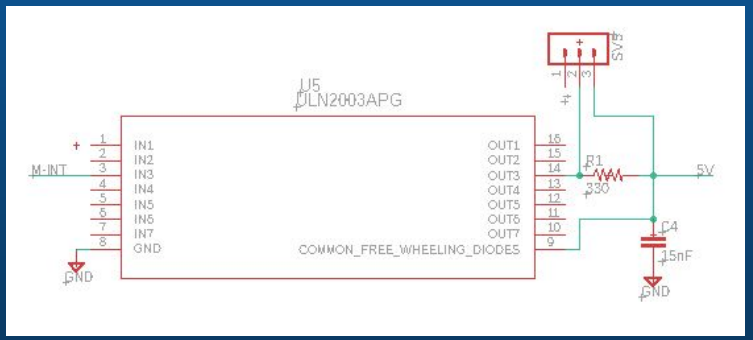




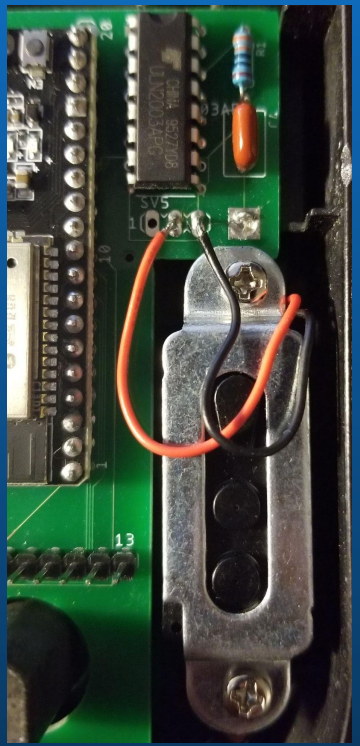


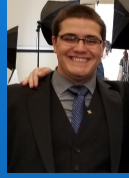
ULN2003 Motor Driver

- Used to operate Motor
  - Used to unlock SOLAS deadbolt
  - GM2215FD-0001 DC Motor



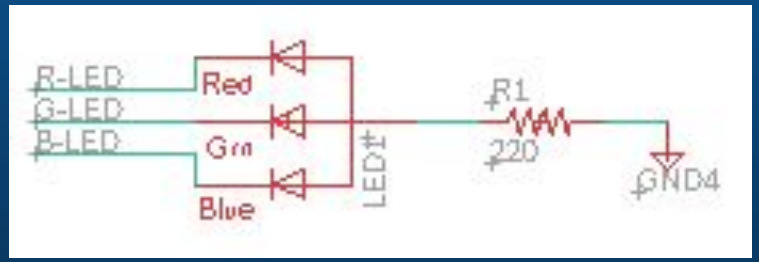
Power Consumption	
Motor Driver	7 mW
Motor	1.75 W



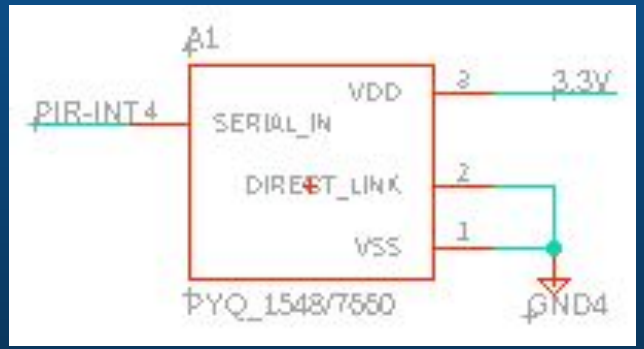


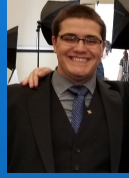
RGB LED & BL412 PIR Motion Sensor

- Used to indicate:
  - When system is on
  - If door is unlocked
  - If RFID tag rejected
- Power Consumption: 9 mW

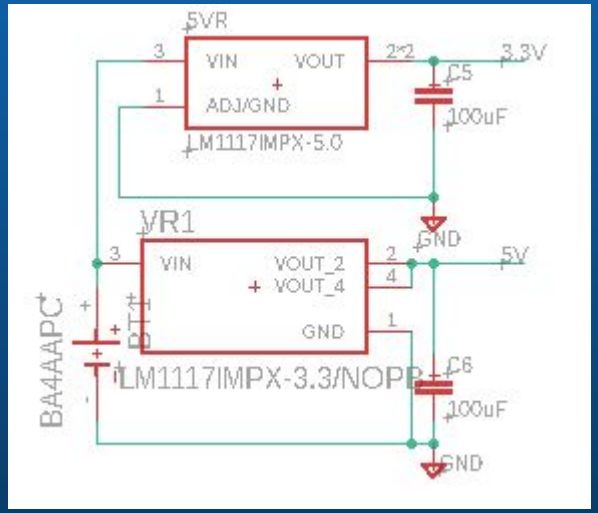


- Used to turn on system
  - Detects changes in infrared radiation to detect movement
  - Long range (5-6 m)
  - Power Consumption: 0.66 mW





Voltage Regulators



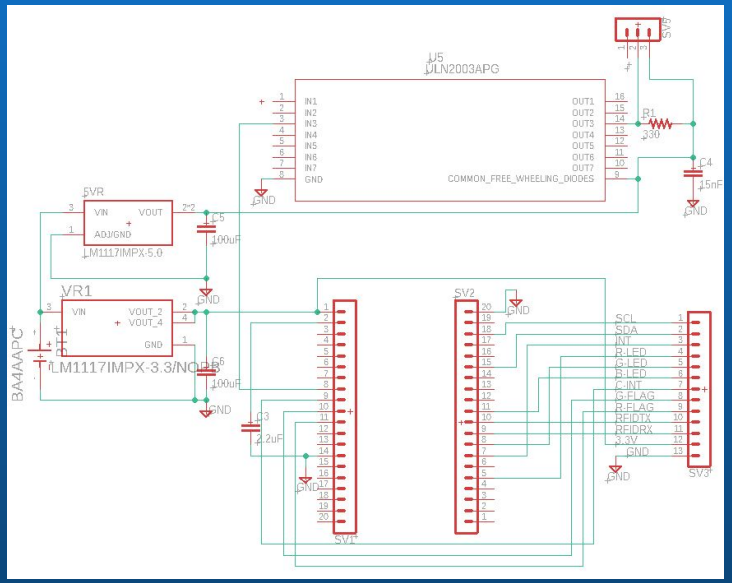
5-Volt regulator

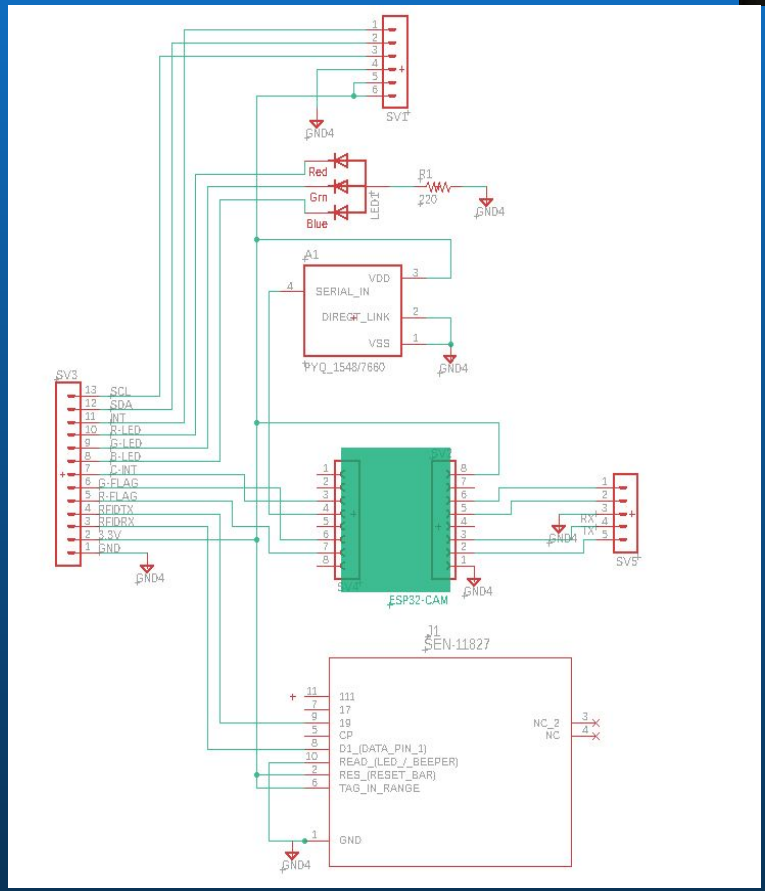
- Powers:
  - Motor Driver
  - Motor
- Efficiency: 87%

3.3-Volt regulator

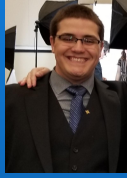
- Powers:
  - ESP32 Microcontroller
  - ESP32-CAM
  - RFID reader
  - Gesture Controller
- Efficiency: 87%

Full schematic from eagle



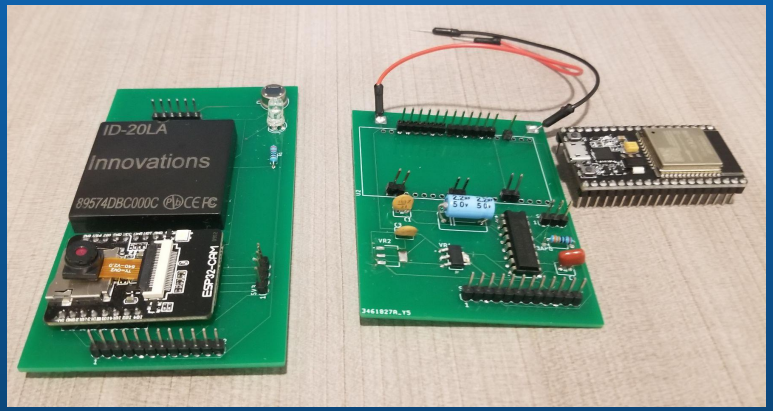


Total Power Consumption		Battery Life
Active	3.19 W	6.097 Months
Deep-Sleep	1.65 mW	



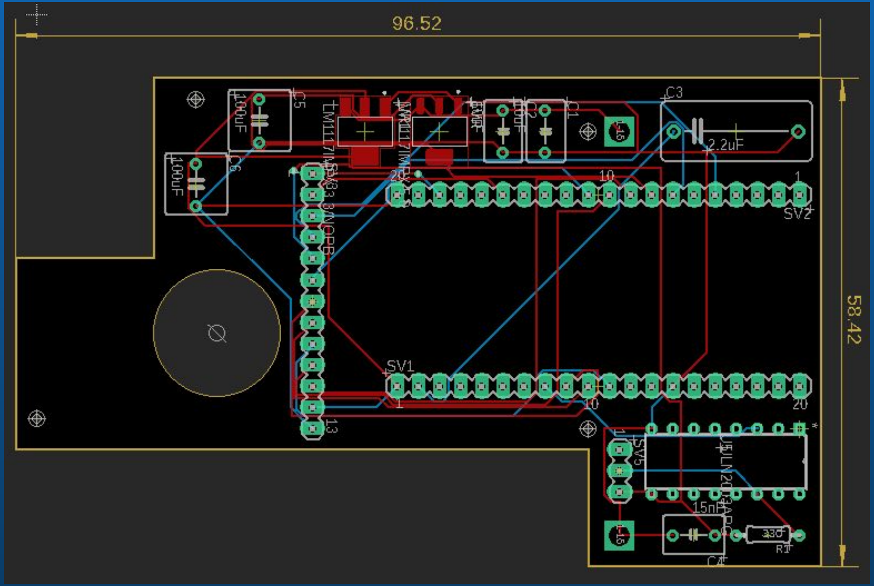
Changes From First Prototype

- New voltage regulators
- Fixed footprint for ESP32 Microcontroller
- Fixed Gesture Controller orientation
- Shape of PCB for main microcontroller
- Added easier access to reset button on ESP32-CAM

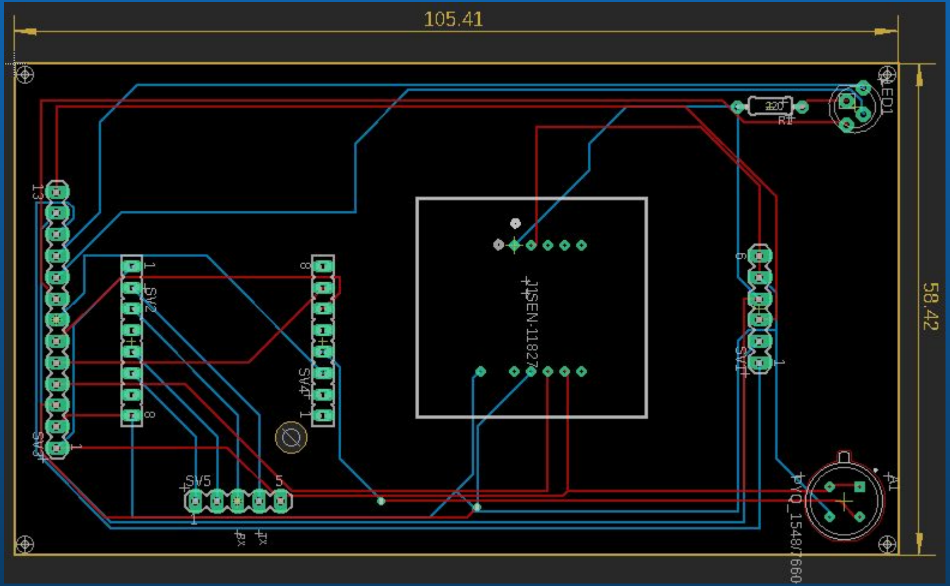


First Prototype of SOLAS system

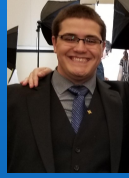
Final PCB Layouts



PCB for Main Microcontroller



PCB for RFID, camera, and sensors



Hardware Design Challenges

- RFID module uses non-standard pin spacing
- PIR motion sensor range and over-sensitivity
- 3.3 voltage regulator issues
- Camera WiFi issues with 1st generation PCB
- Developing the PCB to fit all the necessary components in a small enough footprint to fit the enclosures.
- Fitting a keyhole into the enclosure

Final SOLAS system

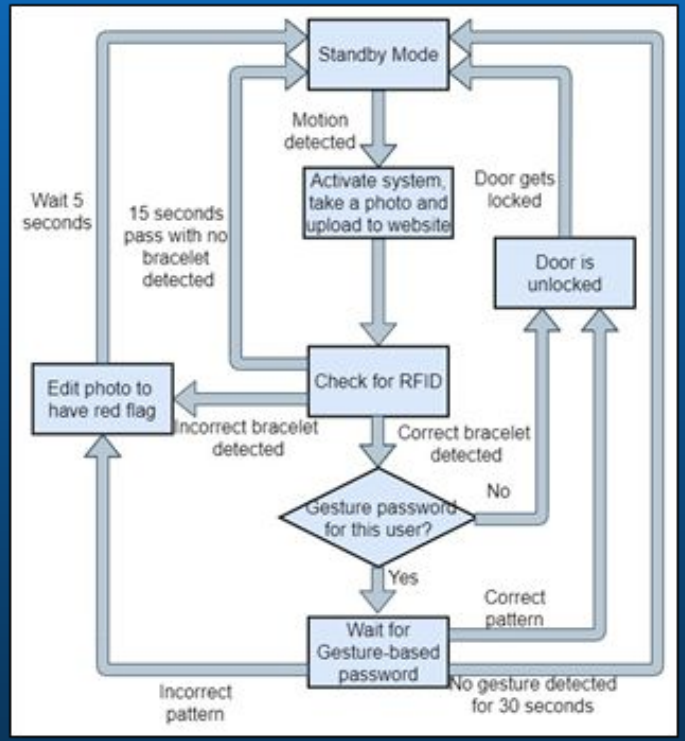
Back

Front

SOLAS
Software Design

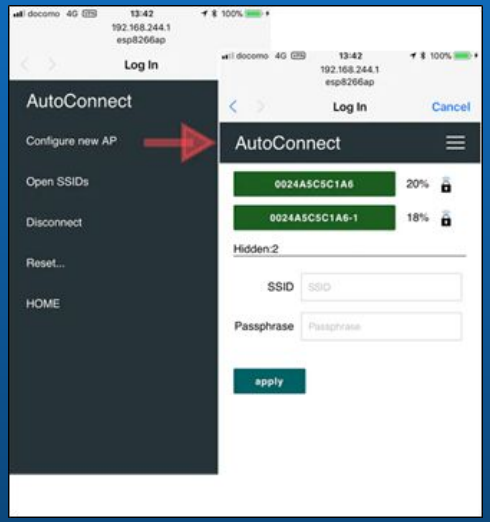
Software State Diagram

- State diagram used to help model desired behavior
- Use of interrupts from sensors to switch between states
- Implement design using Arduino IDE in the C language



Microcontroller Software Design: Wifi

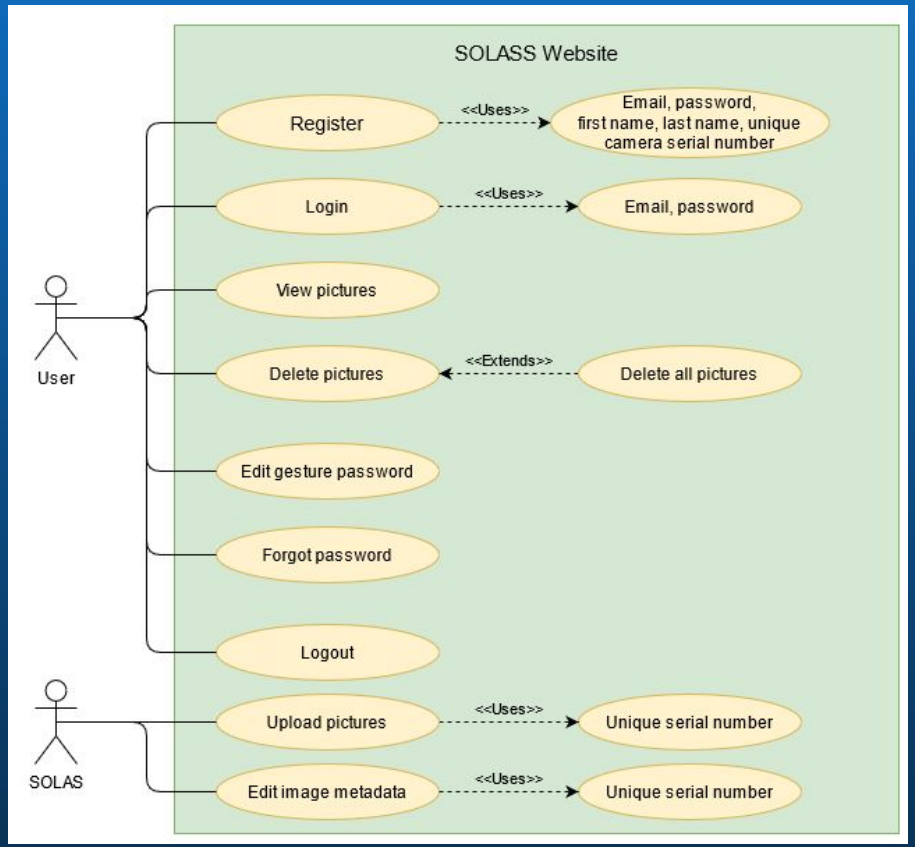
- AutoConnect used to connect the microcontroller to wifi
  - Allows auto-reconnection to same wifi without hard-coding credentials
  - Requires password to initially connect
  - Removes the necessity for user to download and use an app
- Images uploaded over this wifi connection to the website
  - Images uploaded with red flag in the case of incorrect password



Microcontroller Software Design

- RFID system calibrated by reading in ID sent back from RFID tag
  - A local database of all acceptable tags is input into the microcontroller
  - All further communication compares received ID to the stored IDs
- Camera and main board operate separately
  - Motion sensor wakes up camera to take the picture and upload it to website
  - Camera also wakes up Dev board which does RFID and gesture password processing
    - Dev board attaches additional message and flag to image data in website
  - Once Dev board finishes processing it puts whole system back to sleep

Website Use Case Diagram



Major libraries

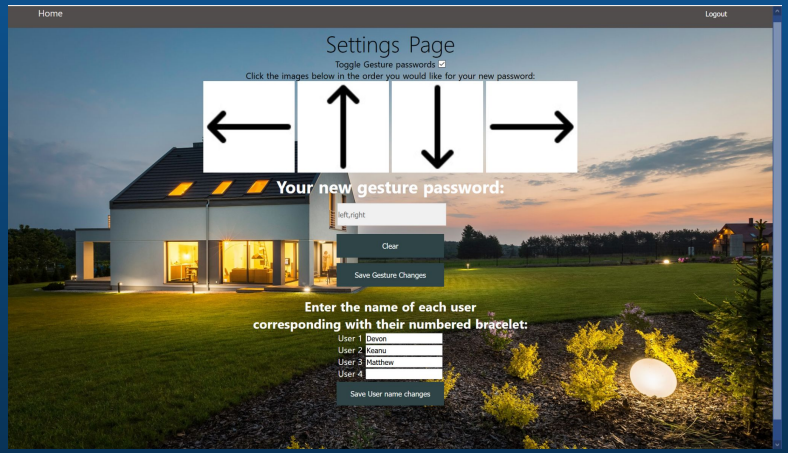
- Sendgrid
  - Provides API for sending emails to user accounts automatically
- Gridfs
  - Framework used in conjunction to mongoDB
  - Allows for easy upload and stream of images in mongoDB and browser
  - Allows attachment of “metadata” to each image to store information associated with it

Web Stack

- MongoDB
- Express.js
- Vue.js - with Nuxt.js
- Node.js

Web Application

- Deployed to heroku
- Simple login and register forms, with a home screen to display an activity log
- User registers with the camera's serial number, used to pair user accounts to cameras
- Settings page to change gesture password as well as associate user bracelets to names
- Forgot password feature utilizing user's email
- User receives email when redflag picture is uploaded



Software Design Challenges

- Website
  - User authentication and cookies
  - Deployment to Heroku
  - HTML/CSS issues
- Microcontroller software
  - Blue LED doesn’t correctly display current status
  - Syncing the main microcontroller with the camera microcontroller so multiple pictures are not taken when trying to unlock the system
  - Watchdog timer issues with the camera
  - Uploading images taken to user website/image timing
  - Wrong library for gesture controller
  - Http posts to backend

SOLAS Administrative Content

Group member contributions

Task	Matthew Guevara	Devon Anselmo	Keanu Zeng
• Microcontroller Connections	**Primary**		Secondary
• Circuit/PCB Design	**Primary**		
• RFID communication	**Primary**	Secondary	
• Camera programming		**Primary**	Secondary
• Gesture Controller	Secondary		**Primary**
• Website		Secondary	**Primary**
• Database		**Primary**	Secondary

Budget and Expenses

Item	Development Cost	Single Unit Cost
Anqueue bracelets	$9.90	$0
OrangeIOT door lock	$40.98	$20.49
ESP32cam + dev board x4	$42.95	$7.15
ESP32-WROOM x2	$21.98	$10.99
RFID tag	$7.50	$0
RFID module x2	$81.27	$34.95
SD card for camera	$14.15	$0
Resistors/capacitors	$15.87	~$1.50
PIR motion sensor x 4	$25.11	$1.56

Item	Development Cost	Single Unit Cost
Gesture controller x4	$36.41	$6.00
PCBs generation 1	$23.40	$0
Voltage regulators	$18.78	$1.65
Pin headers	$7.99	$0.13
PCBs generation 2	$24.30	$24.30
RFID bracelets	$5.89	$5.89
Heroku server	$25.09	$0
Enclosure box	$17.98	$8.99
Totals	$419.55	$123.60

Additional features implemented

- Website
  - Activity log instead of just images
  - Sends email when red flag is uploaded
  - Ability to associate user number with a name for activity log
- Microcontroller
  - Distinguish user numbered bracelets by RFID tag

Project results

- Camera is able to take pictures of surroundings
- RFID security allows only specified RFID tags
- Basic gestures read in, but didn't have time to implement more complex gestures
- Proximity sensor works but is too sensitive
- LED color changes relays software state to user
- Battery lasts only 6 months, not 12
- Able to mount on door, but had to physically modify door
- Website correctly displays activity log
    - Allows for gesture password change, as well as user/bracelet association
    - Able to edit the activity log to add information for each event

Possible Changes for Future SOLAS generations

- Higher quality camera
- 3d printed enclosure
- Use computer vision to read hand gestures instead of the current gesture controller hardware for access to more complex gestures
- Smartphone application
- Use just one microcontroller with camera sensor
- Better motion sensor technology
- Ability to automatically relock after a specified time has passed
- Use microcontroller chip rather than Development board on the PCB
- Allow each user to have their own gesture password

Thank You