Garage Door Security System

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Abstract

This project focuses on the design and build of a low cost system that monitors garage doors and transmits their state to a receiver unit placed at a convenient location inside the user's house. This provides the user with the ability to monitor their garage doors from the comfort of inside their home without having to go outside and look at the garage. The receiver unit includes a screen to display system information and LEDs to make it easy to view the garage door's status from a distance. The system has great enough range to place the receiver at any location within the house while providing an accurate status of the garage door. This project aims to increase home security by designing and building this simple, low cost system that suffices for the average household.

Chapter I: Introduction

Most modern houses have built-in garages that people use to store their belongings and park their cars. Oftentimes, garage doors accidentally get left open when people rush groceries in from the car or after they work outside in their yard. This poses a threat to the homeowner and leaves them vulnerable to the dangers of today's world such as theft and vandalism of their belongings in the garage.

Up to 15% of home burglaries start from a thief entering the house via a garage [12]. Nearly half of these burglars enter through an open garage, making it clear that one of the easiest home security tips suggests keeping the garage door closed at all times the homeowner doesn't need it open [13]. An open garage door gives thieves an easy target; they get a clear glimpse at the unsecured belongings in the garage, making it easier for them to choose a house to rob. It seems like a simple concept to keep the garage door closed, but it becomes easy to forget once inside the house and the homeowner gets sidetracked and never thinks about the garage again until the next time they go outside.

Current products like this exist on the market, such as the Craftsman Wireless Garage Door Monitor and the LiftMaster 829L Garage Door Monitor [25]-[26]. However, they have limited functionality and only work with specific garage door opener models [25]. Consumers also note that current systems lack an acceptable wireless communication range, making the device essentially useless to the homeowner, because they cannot place the device at a convenient location inside their homes [26]. Clearly, these fallbacks hinder the device's effectiveness and limit its ability to function as desired.

This project attempts to address these issues by creating a universal garage door monitoring device that the user can place anywhere within their home. The project provides the user with a simple monitoring system that enables them to act more security conscious, effectively increasing the safety and security of their home. The device consists of a transmitting unit in the garage that tracks the door's position, and a portable, wireless receiving device in the house that clearly displays the garage door's status.

Chapter II: Customer Needs, Requirements, and Specifications

Customer Needs Assessment

Customers that utilize this system consist of homeowners, forgetful elderly, people with disabilities that make it difficult for them to get up, and others such as store and shop owners who may benefit from having a garage door monitor. To determine the customer needs, we analyzed current products on the market to see what they offered. In addition, we looked at customer reviews for those products to get direct feedback from the targeted customers. After developing the basic customer needs, we researched further to understand what types of visual methods prove best for the user. The system needs to easily display the garage door's status without the customer having to get up [28]. Customers may have disabilities limiting their sight, so the system needs to accommodate this by using a combination of different visual stimulation [27]. The system requires simplified use and installation for the everyday user. The receiver unit inside the house needs to have enough range to work from anywhere inside the house so that the customer can place it at the most convenient location for them [26].

Requirements and Specifications

The Garage Door Security System serves as a device homeowners use to increase the security of their home [5]. The requirements for the device largely come from the customer needs. The compact design allows for a small and portable device, making it hassle-free to relocate in the house. Portability means it needs to operate from battery power, and it needs to have a strong wireless communication range [1]. Meeting this requirement proves difficult because some of the more common wireless communications, such as Bluetooth, do not offer a strong enough range. Customers have different needs in determining the garage door's status, so the device needs to have clear visual indicators [4]. Table I on the following page describes in detail these requirements and specifications.

TABLE I

GARAGE DOOR SECURITY SYSTEM REQUIREMENTS AND SPECIFICATIONS

Marketing Requirements	Engineering Specifications	Justification
1, 2, 4, 8	(1) The receiving device must operate on a 5V DC source.	DC power provides the best way to make the device portable and movable anywhere within the home, not limited to near an outlet.
2, 7	(2) The transmitting unit must operate on a 120V AC source.	Powering the transmitter from a wall outlet enables easier installation and eliminates the need for replacing batteries.
1, 2, 4, 8	(3) The receiving device must last for at least 90 days before replacing the batteries.	This provides the user with an adequate operating time before requiring maintenance.
5, 6	(4) The system provides expandability to monitor up to three (3) garage doors simultaneously.	Many houses have multiple garage doors, making it essential for the customer to have the ability to monitor all of their doors.
3, 6, 8	(5) The receiving device has three (3) visual indicators: an LCD screen to display system information, a green LED to indicate a closed door and a red LED to indicate an open door.	These indicators clearly provide system information such as door status and battery life, while decreasing system failure rate by using multiple visual methods.
1	(6) The dimensions of the receiving device must not exceed 4" x 3" x 2".	This size fits easily on a countertop or nightstand without obtrusively taking up all the space.
2	(7) The dimensions of the sending unit must not exceed 3" x 3" x 3".	This size allows easy installation in the garage, even in areas with minimal free space.
4, 8	(8) The receiving device and the sending unit utilize wireless communication with at least 100ft of range with transmission through walls.	Wireless communication provides the best user experience, enabling customers to place the device easily anywhere in the house.
8	(9) The receiving device has a switch for the user to control the power.	This allows the user to have control over how the device operates.
7	(10) The system costs no more than $100 per unit.	A cost per unit of more than $100 does not meet the goal of a low cost system, and does not provide the user with a competitive price point.
9	(11) The system has WPA2 wireless encryption.	Wireless encryption ensures the system provides secure operation for the homeowner.
10	(12) The device has a plastic enclosure capable of withstanding an impact of 50psi.	This provides the user with a reliable device, capable of surviving accidental drops.

Marketing Requirements

1. Small, portable monitoring unit
2. Easy to install
3. Clearly view the status of the garage door
4. Works wirelessly anywhere in the house
5. Capable of monitoring multiple garage doors
6. Improve security of home
7. Low cost
8. Easy to use
9. Secure
10. Durable

Table II below details expected key deliverable dates over the project's course. Each deliverable corresponds to its respective delivery date in EE 460, 461, and 462.

TABLE II
GARAGE DOOR SECURITY SYSTEM DELIVERABLES

Delivery Date	Deliverable Description
April 11, 2016	Design Review
May 22, 2016	EE 461 Demo
June 3, 2016	EE 461 Report
July 1, 2016	Progress Project Report
Nov. 11, 2016	EE 462 Demo
Feb. 15, 2016	ABET Sr. Project Analysis
Nov. 18. 2016	Sr. Project Expo Poster
Dec. 9, 2016	EE 462 Report

Chapter III: Functional Decomposition

Level Zero

Figure I and Table III below show the Level Zero overall system functionality. Figure I depicts the system's overall inputs and outputs at a very basic understanding. Table III gives more details and explains what each of the inputs and outputs mean [29]. It also contains a functionality description to tie all the inputs and outputs together.

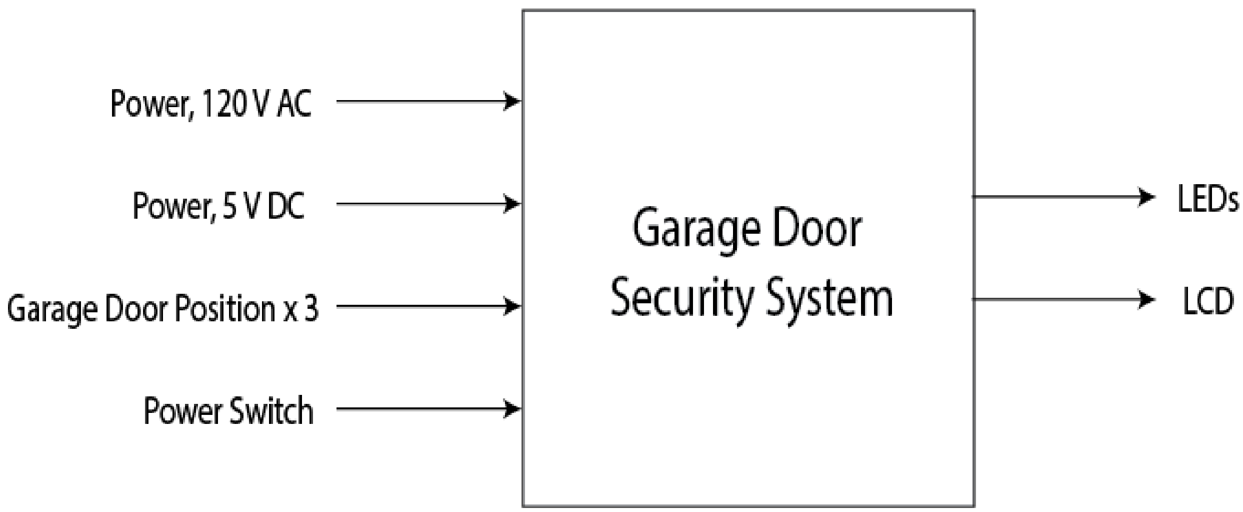

FIGURE I
GARAGE DOOR SECURITY SYSTEM LEVEL 0 BLOCK DIAGRAM

TABLE III
GARAGE DOOR SECURITY SYSTEM FUNCTIONALITY

Module	Garage Door Security System
Inputs	- Power: 120 V AC rms, 60 Hz and 5V DC - Garage Door Position Data - Power Switch
Outputs	- LEDs: Red and Green - LCD Screen
Functionality	- The Garage Door Security System module has 6 inputs including AC and DC power, three door positons, and a user switch for device power. With these inputs, the system determines the garage door's state and outputs its status to the LEDs and LCD.

Level One

Figure II, Table IV, and Table V correspond to the Level One decomposition for the Garage Door Security System. Figure II has two subsystems, the receiver and the transmitter, that make up the whole system. The only link between the two subsystems consists of a wireless connection that transmits the door position data from the transmitter to the receiver. Table IV and Table V breakdown and explain each of the inputs and outputs to the subsystems to give a better understanding of the system [29].

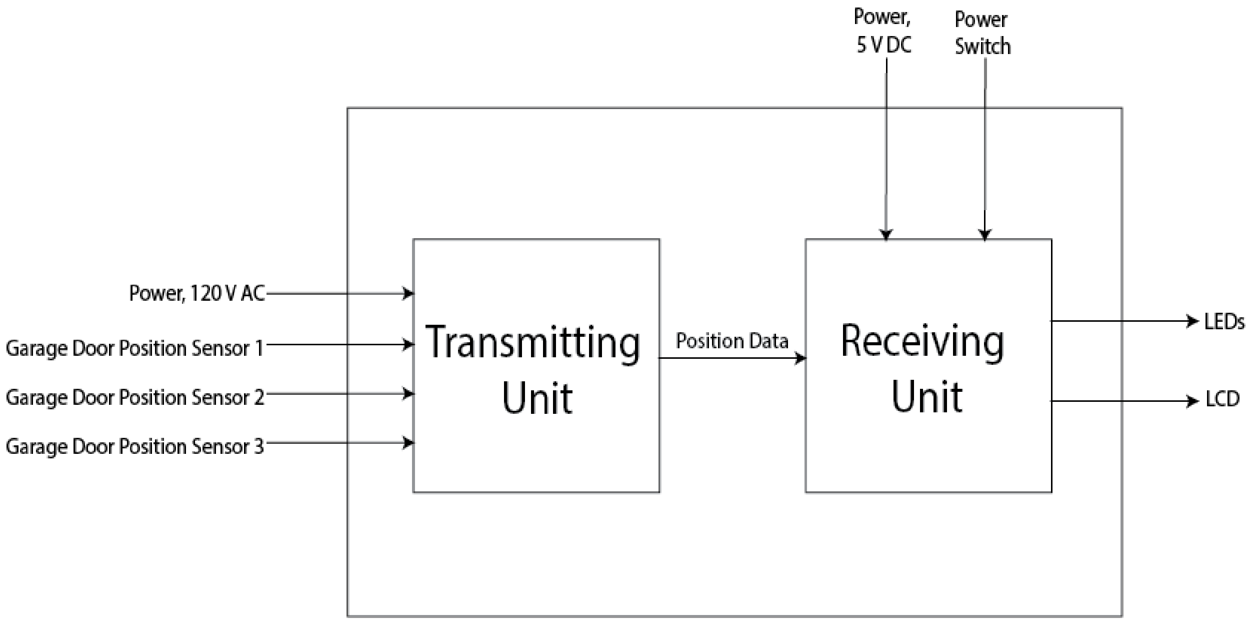

FIGURE II
GARAGE DOOR SECURITY SYSTEM LEVEL 1 BLOCK DIAGRAM

TABLE IV
RECEIVER MODULE FUNCTIONALITY

Module	Receiver
Inputs	- 5V DC - Sensor data signals - Power Switch
Outputs	- LEDs: Red and Green - LCD Screen
Functionality	- The Garage Door Security System receiver module has 3 inputs including DC power, the data from the sensor signal sent from the transmitter module, and a user control for device power. The system uses these inputs to determine the door's status and outputs the status to the LCD, LEDs, and audio device.

TABLE V

TRANSMITTER MODULE FUNCTIONALITY

Module	Transmitter
Inputs	- 120 V AC rms, 60Hz - Garage Door Position Sensor 1 - Garage Door Position Sensor 2 - Garage Door Position Sensor 3
Outputs	- Sensor data signal
Functionality	- The Garage Door Security System transmitter module has 4 inputs; AC power and the position of the monitored doors. The module analyzes the door position using a sensor and outputs the sensor data to the receiver module.

Chapter IV: Project Planning

The following pages contain Figure III, Figure IV, and Figure V, which correspond to Gantt Charts for EE 460, EE 461, and EE 462. The Gantt Charts show, in detail, specified tasks and their estimated duration. This tool helps to keep the project on track by ensuring goals and deadlines stay well documented [29].

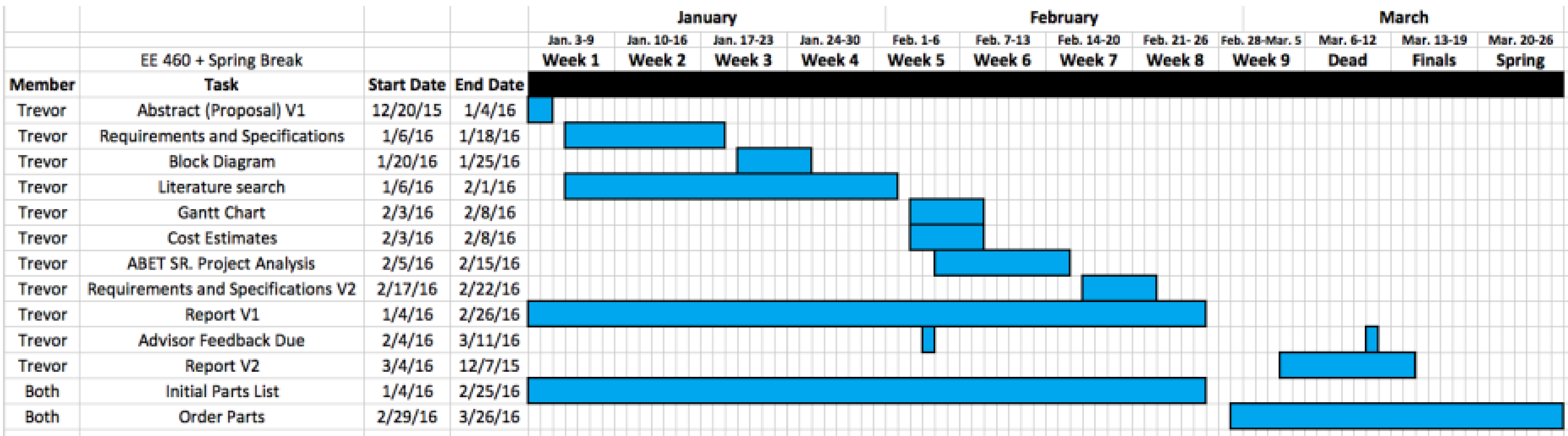

FIGURE III
GANTT CHART FOR EE 460 AND SPRING BREAK

	EE 461		
Member	**Task**	**Start Date**	**End Date**
Trevor	1: Design 1	3/27/16	4/27/16
Austin	A: Receiver Circuitry	3/28/16	4/9/16
Trevor	B: Transmitter Circuitry	3/28/16	4/9/16
Both	C: Microprocessor Programming	4/3/16	4/13/16
Both	D: Prototype 1	3/28/16	4/14/16
Trevor	I: Test 1	4/6/16	4/18/16
Trevor	II: Review Design 1	4/17/16	4/21/16
Austin	III: Improve Design 1	4/20/16	4/27/16
Austin	2: Design 2	4/26/16	5/27/16
Trevor	A: Order Parts 2	5/1/16	5/2/16
Trevor	B: Parts Shipping 2	5/1/16	5/15/16
Austin	C: Receiver Circuitry	5/12/16	5/18/16
Trevor	D: Transmitter Circuitry	5/12/16	5/18/16
Both	E: Mircroprocessor Programming	5/3/16	5/15/16
Both	F: Prototype 2	5/8/16	5/21/16
Austin	I: Test 2	5/15/16	5/25/16
Austin	II: Review Design 2	5/21/16	5/27/16
Trevor	EE 461 Demo	5/28/16	5/30/16
Trevor	EE 461 Report	3/27/16	6/3/16
Austin	Final Parts Order List	6/6/16	6/8/16
Austin	Final Parts Purchasing & Shipping	6/6/16	6/11/16
Trevor	Documentation	3/27/16	6/11/16

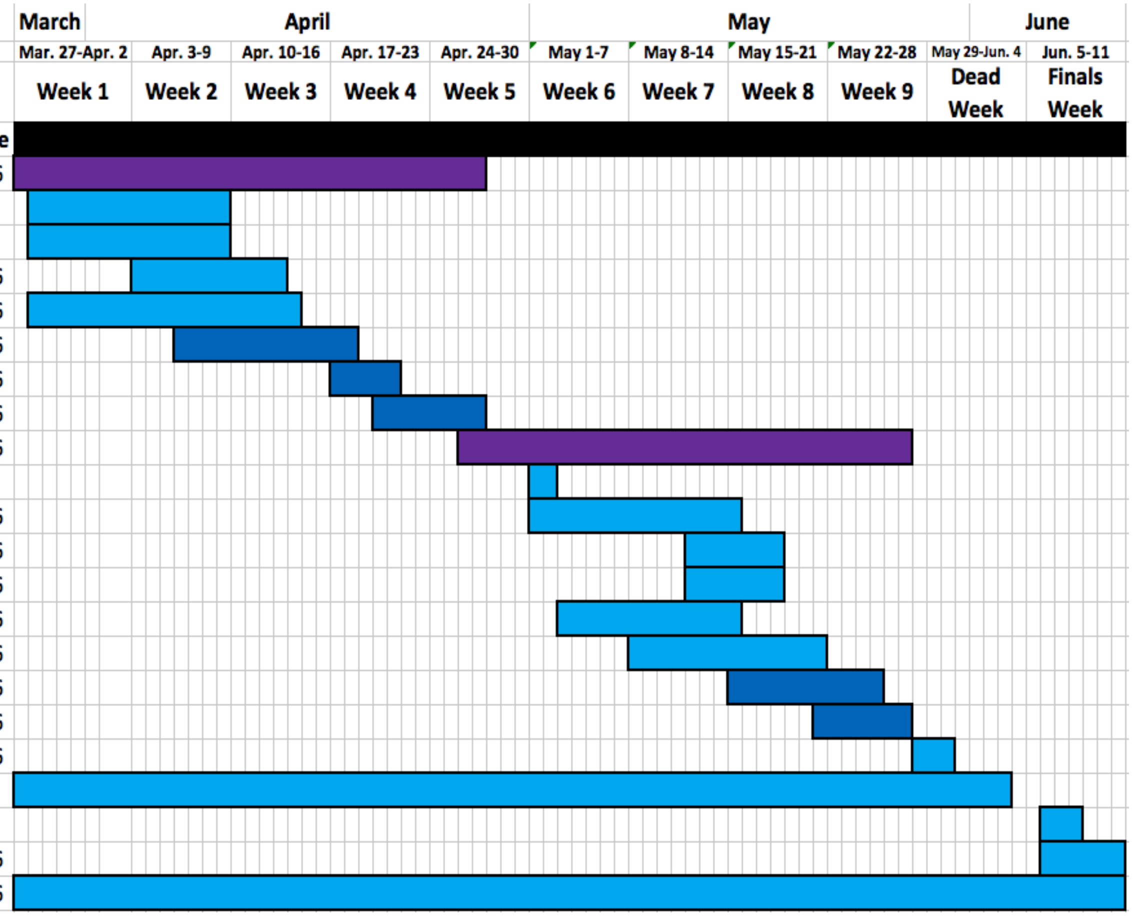

FIGURE IV
GANTT CHART FOR EE 461

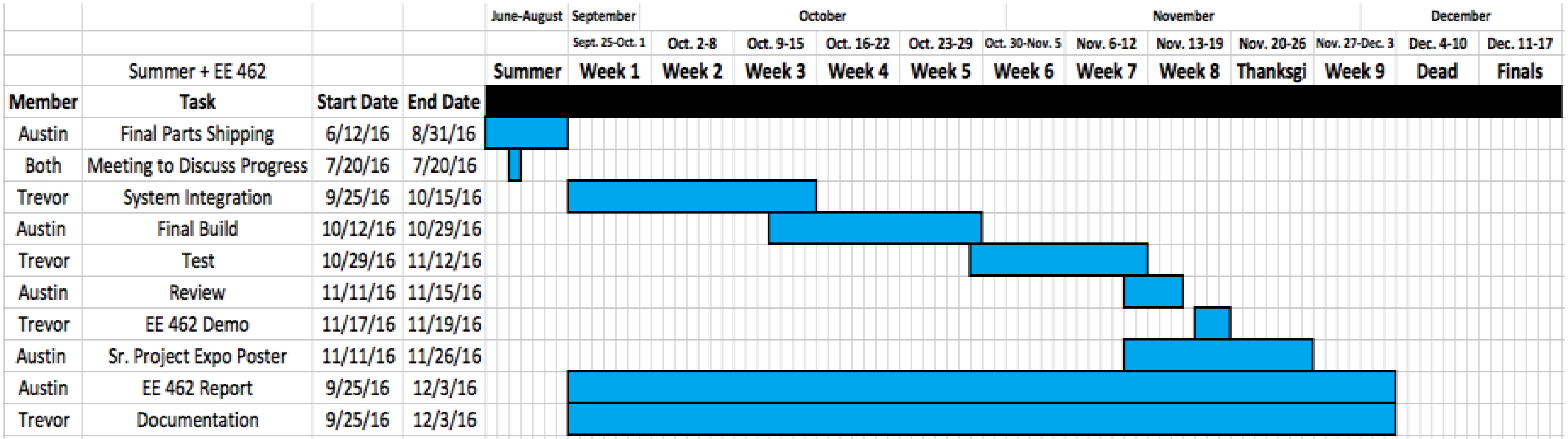

FIGURE V
GANTT CHART FOR SUMMER AND EE 462

TABLE VI
ESTIMATED PARTS AND LABOR COSTS

Parts	Optimistic	Typical	Pessimistic	PERT estimate
Sensors	$15	$25	$45	$26.66
Wi-Fi transmitter	$2	$5	$9	$5.17
Wi-Fi receiver	$2	$5	$9	$5.17
Microcontroller	$8	$10	$15	$10.50
LCD Screen	$6	$8	$10	$8
LEDs	$0.40	$0.70	$1.20	$0.73
Miscellaneous	$5	$10	$15	$10
Parts total	**$56.40**	**$63.70**	**$104.20**	**$69.23**
Labor				
Labor Costs (x$35 per hour)	$3,500 (100 hours)	$5,250 (150 hours)	$7,000 (200 hours)	$5,250 (150 hours)
Total	**$3,556.40**	**$5,313.70**	**$7,104.20**	**$5,319.23**

Table VI above represents the estimated costs associated with the Garage Door Security System. The parts and their prices listed may change, however these provide a good starting point for the project fundamentals. The labor costs come from a $35/hour rate. The Gantt Chart and the PERT estimate helped derive the total hours for each specific task [29]. Totaling them all up gives an estimated representation of labor costs. Adding the parts total and the labor total gives the estimated cumulative total for system design and development.

Chapter V: Project Design

Design Concept

The Garage Door Security System relies on hardware and software. The system utilizes two microcontrollers, one for the transmitter side and one for the receiver side. The transmitter side gathers data from up to three magnetic sensors that are easily mounted to most doors. The sensor data is sent to the receiver using Wi-Fi modules where the receiver interprets the data and alerts the user using an LCD display and two different color LEDs.

Hardware Design

<u>Transmitter</u>

Microcontroller

The microcontroller used for the transmitting side of the system was chosen to be an Arduino Mega. This seemed to be the best option because it uses the Atmega2560 microcontroller which is easily available and the IC can be purchased by itself without the need for the whole Arduino board. This enables us, in the future, to design a PCB with the Atmega chip on the PCB without having to use the big Arduino Development board. The Mega has a plethora of GPIO pins and additional hardware serial connections, should we choose to use hardware serial for the Wi-Fi modules. The microcontroller is used to read the input from the three garage door sensors and then combine them into a single signal to be sent to the Wi-Fi module via UART every 15 seconds.

Wi-Fi

Many forms of wireless transmission were considered including Bluetooth and standalone RF modules. The ESP8266 Wi-Fi module was chosen for use because it is a cheap but reliable option. Using Wi-Fi over the other options allows for easier future functionality and expandability such as having a phone app. Wi-Fi also enables the Garage Door Security System to work anywhere in the house, limited to the range of the user's home Wi-Fi network. The ESP is also Arduino compatible with many libraries and examples to help with implementation. The ESP module has 8 pins. VCC, GND, SHUTDOWN, RST, TX, RX, GPIO1, and GPIO2. For the purposes of our system, we only needed to use VCC, GND, SHUTDOWN, TX, and RX. The module runs on 3.3V, so a bi-directional logic level shifter was needed to go between the 5V logic level of the Arduino and the 3.3V of the ESP8266. The ESP8266 Wi-Fi module receives its data from the RX and TX pins of the Arduino. We communicate with the ESP8266 through AT Commands, which is a standard set of commands used for modems. The Arduino code sends these commands to the ESP8266 which we have configured to upload to a web server about every 15 seconds, which is fastest allowable update speed for the web server we are using.

Sensors

To determine the state of the garage doors, we choose magnetic proximity sensors that utilize a reed switch. The sensor consists of two pieces, one is a magnet that is mounted on the moving part of the door, and the other is the reed switch which is mounted somewhere stationary on the door frame and connected to the Arduino. When the two pieces line up with each other, the reed switch is activated and the circuit is closed. When the pieces are away from each other, the

circuit is open. The sensors have two wires to connect them. One wire simply goes to ground, and the other wire is connected to VCC through a pull-up resistor and connected to a pin on the Arduino. By connecting them in this way, we are able to determine whether the door is open or closed, and send that to the Wi-Fi module.

Power

The Garage Door Security System is designed to be easy to use by the consumer. To help keep this in mind, the Transmitting Unit is powered by plugging it in to the wall outlet and using a 12V AC-DC converter. The Arduino then uses this 12V DC source and its onboard Buck converter to lower the voltage down to the 5V needed. The ESP8266 runs on 3V rather than 5V, so an external voltage regulator is used to regulate the 5V down to 3V for the ESP. By powering the Transmitting Unit in this way, the consumer will not need to worry about replacing the batteries and the unit will remain working maintenance free once it is initially set up.

<u>Receiver</u>

Microcontroller

The microcontroller used in the receiver was chosen to be the Arduino Uno. The Arduino Uno is a development board based off the ATmega328P IC, which means at a future time, we could buy the IC separately and design a PCB to use this chip rather than needing to use the big development board and connect wires. The microcontroller on the receiver end is used to communicate with the ESP8266 and receive data of the current state of the garage doors from the web server. Once it receives the data from the Wi-Fi module, the microcontroller interprets the data and outputs it to the LCD and LEDs which are also connected to the microcontroller.

Wi-Fi

The Wi-Fi module used in the receiver is the same as the module used in the transmitter, the ESP8266. The hardware setup is also the same as it is in the transmitter. The differences between the Wi-Fi module in the transmitter and receiver are purely software differences with how we interact and communicate with them.

User Notification

The system uses two visual methods to notify the user if a door is open. The first method uses a green LED to indicate all doors are closed and a red LED to indicate one or more doors are open. This method provides an overview of the system at a quick glance. The LEDs also help those with poor eyesight determine if a door is open. The second method uses a 2004A LCD screen to specifically display the status of each door, either open or closed. The LCD displays the status of three separate doors as well as a receiver unit battery life indicator.

Power

The Garage Door Security System has a portable Receiving Unit that the consumer can place anywhere in their house to monitor the status of their garage doors. To make it portable and easy to move and place anywhere convenient, the Receiving Unit uses a rechargeable battery. The battery we chose for the system is a Lithium Ion 5V DC 2800 mAh rechargeable battery. This battery provides the system with enough current to run the Arduino, LCD, and ESP module without overdrawing the source. The biggest limiting factor we encountered was optimizing the

system for maximum battery life. The Arduino Uno running the Receiver Units code consumes roughly 50mA. The LCD consumes a rather small current, however with the backlight on the LCD enabled, the current consumption rises to nearly 60mA. The ESP8266 Wi-Fi module consumes the most current out of all the components in the Receiving Unit. When the module is sending a command, it peaks around 170mA. When it is receiving data, it peaks around 50mA. When it is idle connected to a Wi-Fi access point but not transmitting or receiving data, the module typically draws 30mA. When taking into consideration each of these current draws and how long the system is in each of these modes, the average current draw for the receiving unit is about 146mA. Given the battery we are using, this leads to a battery life of about 19 hours for the receiving unit before the system needs to be recharged. While this battery life is not the most ideal for the consumer, it works well enough to provide continued monitoring of the garage doors for testing purposes. Choosing a battery with a larger amp hour rating and optimizing the Arduino to run more efficiently would lead to an overall system with a better battery life.

Software Design

The Garage Door Security System is divided up into the two components discussed above, the transmitter and the receiver. Because of this, we utilize two microcontrollers which each have their own code running to perform their required tasks. The ESP8266 Wi-Fi modules are also capable of being flashed with different firmware, enabling you to run simple code directly on the module, however for this project, we needed the added functionality of the Arduinos with multiple GPIO pins.

Transmitter

The microcontroller for the transmitter is set up such that when the device is first plugged in and powered on, it initializes the GPIO pins to be inputs for our sensors to send their data to the Arduino. We then utilize Software Serial on the Arduino to communicate with the ESP8266 Wi-Fi module. Once the Software Serial is defined and running, we begin sending AT Commands to the ESP8266. The first command sent is a Reset command, which clears any previous Wi-Fi networks the module was connected to and gives a clean start. The code then sends a command to join the specific Wi-Fi network defined in our code using our SSID and Password. Once the module is connected to the Wi-Fi network, the next set of commands establish connection with the server we are using to store our data from the sensors. Once all of this initialization has occurred, the code enters the main loops where the Arduino is constantly pulling data from the sensors and storing it as the current state of each of the sensors. In the main loop of the code, we send a command to the ESP8266 about ever 15 seconds to upload the current state of the sensors to the web server. Every 15 seconds is the quickest time we can send data to the server without causing problems or getting errors returned to the module. Once the data is send to the ESP8266 to be uploaded to the web server, the main code runs again until the 15 seconds have elapsed and another round of data is sent.

Receiver

The microcontroller on the receiver is configured to do more work than the transmitter. When the receiver is first powered on, it initializes some GPIO pins as outputs to control the LEDs and the LCD screen used to notify the user of their garage doors status, and displays a message on the LCD that the system is initializing and to please wait. Just like on the transmitter, the Arduino is

used to send commands to the ESP8266, starting with the Reset command and then establishing connection with the Wi-Fi network. Once all the initialization is completed, the code enters the main loop where commands are sent to the ESP8266, asking it to pull data from the web server and store it into a variable in the code. Once the ESP8266 gets the data and stores it in the Arduino, the code parses the data and performs analysis on the raw data to determine the current state of each of the three doors. Based on the data, the LCD displays the status of each garage door, and either a green LED will illuminate if all the doors are closed, or a red LED will illuminate if any one or multiple doors are open. There are no limitations on how often we send commands to the ESP8266 to receive updated data, however the more frequently the commands are sent, the faster the battery will drain. So for the purpose of this project, we chose to have the receiver update every 15 seconds to match what the transmitter is doing. This leads to a worst case scenario of the receiver taking 30 seconds maximum to display the latest door status, depending on what step the code is in when the door's state changes.

Chapter VI: Testing

The Garage Door Security System consists of many parts and components that work together to complete the fully functional system. During development and testing, each component was isolated as much as possible and tested individually to ensure we could communicate and interface with it properly before introducing it to the system. Working with the Arduino Uno and the Arduino Mega was straightforward with little problems encounter that were directly related to the microcontrollers. The next component to test was the sensors. We tested the sensors by applying 5 volts to one of the wires and ground to the other, and viewing the output on the oscilloscope and measuring how far the magnet can to be from the Reid switch for it to read a high logic level. Once we had this information, we knew how to interface our sensors as well as how we would have to physically set them up to accomplish what we needed them to do. The last major component to test individually was the ESP8266 Wi-Fi module. This module proved fairly complicated to get set up and working how we wanted. Following the pinout on the datasheet, we connected all the pins and used the Arduino to allow us to talk to the ESP through the computer. We used the Serial Monitor of the Arduino IDE to talk to the ESP8266. To do this, we connected the RX of the Arduino to the RX of the ESP, and TX to TX, which is not the typical way you would wire them under typical application. Doing this allowed us to talk directly to the ESP by sending it AT Modem commands. Once we had the ESP set up and configured using the AT Commands, we integrated the module into our system to be interfaced from the Arduino. Everything seemed to be working, however it was not reliable and we were seeing very intermittent success with the modules After studying the datasheet and the pinout very thoroughly and through observation, we found that the ESP modules are very sensitive to any instabilities and changes in the voltage rails. To take care of this, we added capacitors directly across the VCC and Ground rails, which cleaned up the lines and solved some the intermittent problems we were having. However, we also found that the Arduino does not always provide enough current for the ESP when it is working at its max, which would cause it to stop working completely. To take care of this, we used an external power supply for the ESP8266 that is able to provide the required current when the module is transmitting.

Once each of the components were proven to be working individually, the system was put together and developed further into the full system. Table VII below shows the test cases of the system to ensure it meets the specifications of the design requirement.

TABLE VII

GARAGE DOOR SECURITY SYSTEM SPECIFICATIONS TEST

Engineering Specifications	Result	Test Description
1	Pass	5V source was applied to the receiver side and run for 1 day.
2	Pass	The transmitter side was connected to 120V AC using a power adapter and run for 1 day
3	Fail	The system was run for several days to test battery life.
4	Pass	The system was run with 1,2, and 3 doors connected looking at functionality.
5	Pass	Test cases with differing door statuses were used and the functionality of the visual indicators was evaluated.
6	Pass	The receiving unit was measured against the given dimensions. Although no enclosure exists the test is still relevant.
7	Pass	The transmitting unit was measured against the given dimensions. Although no enclosure exists the test is still relevant.
8	Pass	Each side of the system was moved to opposite ends of Wi-Fi router range and tested for functionality.
9	Pass	The power switch was operated to enable and disable power.
10	Pass	Component costs were added up and compared to the $100 limit.
11	Pass	The Wi-Fi modules used connect to a router which has the required encryption.
12	Not tested	No plastic enclosure exists for either side of the device.

Chapter VII: Conclusion and Future Work

The Garage Door Security System, in its current state, accomplishes the goals we set and functions as required. The system is able to connect to the user's home Wi-Fi network and send updates to a web server from the transmitter, and the receiver is able to connect to the Wi-Fi and get the updated information and display it wirelessly in the house. The transmitter is powered by a wall adapter so the user doesn't have to worry about replacing batteries, and the receiver is powered by batteries so that it can easily be moved throughout the house.

However, this system has a lot of room for improvements. Currently, it is a prototype and isn't packaged. A big improvement would be designing PCB's for the transmitter and receiver to clean up wiring and greatly reduce the size of the system. This hardware step is critical in order to make the system marketable and to continue the development.

Another area for future improvements is to reduce power consumption, particularly for the receiver. The receiver has a lot of current draw, the Arduino, a rather large backlit LCD display, LEDs, and a Wi-Fi module that draws a lot of current while transmitting and receiving data. The battery life is a huge limiting factor in the everyday use of this system and needs to be addressed to make the system more desirable.

The last major area for future work is the implementation of connecting the system to the Wi-Fi network. Currently, this is accomplished manually by entering the Wi-Fi credentials in the code. This only needs to be done once, however the system currently doesn't have a method for users to directly enter their Wi-Fi credentials into the system.

REFERENCES

[1] J. H. Green, *The Irwin Handbook of Telecommunications*, 5th ed. New York: McGraw-Hill, 2006.

This source provides useful information about radio frequency communication as well as other types of wireless communication. This can help me figure out and guide me in the right direction for a method of wireless communication. It shows its authority through its credible publisher, as well as its current 5th edition, suggesting it has gone through continual updates. The author also has written multiple books on telecommunication systems, showing his knowledge in the subject.

[2] K. Balasubramanian and A. Cellatoglu, "Analysis of Remote Control Techniques Employed in Home Automation and Security Systems," *Consumer Electronics, IEEE Transactions on*, vol. 55, no. 3, p. 1401-1407, Aug. 2009. [Online]. Available: IEEE Xplore, http://www.ieee.org. [Accessed January 21, 2016].

This journal article seems very relevant to my project because it talks about home automation and security and the methods that have shown success. It helps me try to use methods that have shown success in home automation, and stay away from those that have not seen as much success. The source has authoritative qualities because it comes from an IEEE published journal and the two authors have years of documented experience in the field.

[3] Parallax Inc. (2000, January 27). "433.92 MHz Transceiver" [Online]. Available: http://media.digikey.com/pdf/Data%20Sheets/Parallax%20PDFs/27986-988pdf.pdf [January 30, 2016].

This datasheet shows important information about an RF transceiver. This document provides me with knowledge that I can use to base my design decisions from. It has authority because it comes from a well known parts website, for the official documentation for this particular component.

[4] Garage door remote system with alert feature, by C. A. Redden. (2013, February 12). Patent US8373555 B1 [Online]. Available: http://www.google.com/patents/US8373555 [January 30, 2016].

This patent has similar aspects to the goals of my project. This makes it a useful tool for me to reference and get ideas to bring into my project. The patent shows credibility and authoritativeness based on the amount of citations it has received as well as its strong technical description, explaining its justification.

[5] J. Margulies, “Garage Door Openers: An Internet of Things Case Study,” *Security & Privacy, IEEE,* vol. 13, no. 4, p. 80-83, Aug. 2015. [Online]. Available: IEEE Xplore, http://www.ieee.org. [Accessed January 31, 2016].

This journal article talks about a remote garage door monitoring and opening device, which seems very relevant for me. It also goes into detail about how the garage door opener works and the security risks this involves. The article has credibility because it comes from a published IEEE journal undergoing peer review, as well as the author, a chief technology officer of a cyber security company.

[6] Sharp. (2006, December 1). “Distance Measuring Sensor Unit” [Online]. Available: http://www.sharp-world.com/products/device/lineup/data/pdf/datasheet/gp2y0a21yk_e.pdf [January 30, 2016].

This datasheet provides useful information on a possible device that I can use to determine the garage door’s position. Its credibility comes from a reputable manufacturer and it provides all the ratings and characteristics to determine if the device operates how I need.

[7] V. Chunduru and N. Subramanian, “View-based approach to constructing reliable Home Appliance Control System,” in *Proc. of the 2006 IEEE Region 5 Conference, 7-9 April, 2006, San Antonio, TX* [Online]. Available: IEEE Xplore, http://www.ieee.org. [January 30, 2016].

This conference proceeding has interesting characteristics because it discusses home automation and the positive impact it can have on the homeowner. This matches the overall goal of my project, to create a positive experience for the homeowner and allow them to feel safer in their home. This article comes from a published conference proceeding from an IEEE conference, written by a computer science professor who has spent years developing home automation and control systems.

[8] D. Chizhik and R. A. Valenzuela, “Radio Wave Diffusion Indoors and Throughput Scaling with Cell Density,” *Wireless Communications, IEEE Transactions on,* vol. 11, no. 9, p. 3284-3291, Sept. 2012. [Online]. Available: IEEE Xplore, http://www.ieee.org. [January 30, 2016].

This journal article explains how radio waves diffuse and lose strength as they travel through different media such as walls and air. This can prove useful to me because my device needs to transmit and receive through walls and work inside a house. The article has authoritative qualities based on the published journal, as well as the authors who wrote it. They have degrees in electrophysics and electrical engineering, with extensive expertise in wireless communications.

[9] Texas Instruments. (2013, May). “Mixed Signal Microcontroller” [Online]. Available: http://www.ti.com/lit/ds/symlink/msp430g2553.pdf [January 30, 2016].

This datasheet provides all the necessary information in order to understand and use the microcontroller. This helps to inform me of any technical limitations I may encounter in my project as I begin integrating the system with a microcontroller. The datasheet has authority

because the manufacturer provided it directly as the most current, updated version they have produced.

[10] R. S. Dilmaghani and H. Bobarshad, “Wireless Sensor Networks for Monitoring Physiological Signals of Multiple Patients,” *Biomedical Circuits and Systems, IEEE Transactions on*, vol. 5, no. 4, p. 347-356, July 2011. [Online]. Available: IEEE Xplore, http://www.ieee.org. [January 30, 2016].

This journal article expresses the convenience of using a microcontroller to wirelessly interact with biomedical sensor and send the data directly to the doctors. While not exactly related to my project, it has relevance in gaining an understanding of the implications of wirelessly interfacing sensors to communicate with a microcontroller. The source has credibility because of its publication in the IEEE journal, along with the authors who have their PhD’s in electrical engineering and communications engineering, with years of experience in the biomedical engineering field.

[11] D. O'Brien, “Audible Alarm Basics,” *Digikey*. [Online]. Available: https://www.digikey.com/web export/supplier content/mallorysonalert_458/pdf/mallorysonalert_audiblealarmbasics.pdf?redirected=1. [February 20, 2016].

[12] N. Gromicko and K. Shepard, “Burglar-Resistant Homes,” *InterNACHI*. [Online]. Available: https://www.nachi.org/burglar-resistant.htm. [February 21, 2016].

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[14] N. Lesson, “Left Open, Garages Will Draw Thieves,” *Sun Sentinel*, 2006. [Online]. Available at: http://articles.sun-sentinel.com/2006-06-25/community/0606230283_1_garage-opener-door-thieves. [February 21, 2016].

[15] J. Zander, “Performance of Optimum Transmitter Power Control in Cellular Radio Systems”, IEEE transaction on vehicular technology, Vol. 41, issue 1, pp 57-62, Nov 1991. [January 30, 2016].

[16] K. Vitkus et al, “Door ajar detection and recovery for a wireless door sensor” U.S. Patent 9 224 287, December 29, 2015. [January 30, 2016].

[17] Sharp, “Analog Output Type Distance Measuring Sensor,” GP2Y0A41SK0F datasheet, March 2007. [January 30, 2016].

[18] SK. Yong, “60 GHz channel characterizations and modeling” in *60 GHz technology for Gbps WLAN and WPAN*, john Wiley & Sons, 2010, ch 2, pp 17-61. [January 31, 2016].

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[24] Wenshing “Wireless Hi Sensitivity Receiver Module,” RWS-371 series datasheet, Feb. 1 2004 [Revised Dec. 28 2008]. [January 31, 2016].

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[26] “Craftsman Wireless Garage Door Monitor,” Amazon.com: Home Improvement. [Online]. Available: http://www.amazon.com/craftsman-wireless-garage-door-monitor/dp/b001reg43u. [February 22, 2016].

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Appendix A – Analysis of Senior Project Design

Project Title: Garage Door Security System
Students' Name: Trevor Lehr, Austin Williams **Students' Signature:**
Advisor's Name: Bridget Benson **Advisor's Initials:** **Date:**

1. **Summary of Functional Requirements**
The Garage Door Security System serves homeowners and allows them to make their home more secure [13]. The device monitors the garage door's position and transmits that data to a receiving device inside the user's home. The receiving device consists of a microcontroller used to process the door position data, an LCD screen, and LEDs. The receiving device turns on a red LED if the garage door gets left open and a green LED if the door remains closed, making it easy for elderly or disabled people to use [28]. The LCD displays detailed system information for the user to monitor.

2. **Primary Constraints**
A challenge faced with this project stems from the requirement of making a wireless transmitter and receiver with a long range to cover the whole house, 100ft [25]. This eliminated many possible wireless communication methods such as Bluetooth because they do not offer enough range. Bluetooth typically offers 10 meters of range in an unobstructed area [30]. Eliminating some options narrowed it down to using RF to transmit the garage door's position data to the receiver inside the house. See Chapter II for further explanation of project constraints.

3. **Economic**
The Garage Door Security System has multiple sources of economic impact. The product increases human capital as the product becomes more widely available and people adopt them in their homes. The product also increases financial capital by creating jobs for workers to build the device and for third party companies to ship and deliver the products. Most of the costs associated with the development of the project stem from the labor. The cost of parts becomes miniscule in comparison to the labor costs to develop and build the product [31]. The estimated cost for this project runs about $5,300, as described in Table VI. Due to the educational nature of this project, the labor costs do not actually get paid, and the students and the EE Department cover the cost of parts. As shown in Table VI, the estimated cost of component parts for the project totals about $70. Additional equipment costs consist of a computer used to research and program the microcontroller. A spectrum analyzer may also come in handy to determine the frequency at which the RF transmitter operates at, to implement a filter designed around the correct frequency [1]. If the project gets put into production, it would potentially earn $20 per unit sold. This profit would go to the designers, as well as a portion to the selling location. Once the product development and testing concludes, the next step aims at preparing for production. The device should not require any maintenance other than replacing the batteries, should they die. From the Gantt Charts depicted in Figures III-V, the estimated project development time totals about 18 weeks.

Minimal economic impacts occur unless the project enters mass production. The designers take the main impact of the project by contributing over 100 hours of work to the project and purchasing parts. A school fund can provide money for parts. The costs occur at the start of the project, peaking in the design-build-test phases of the project. Benefits occur at the end of the project in the form of senior project completion for the designers. Costs continue throughout the manufacturing process if the project enters mass production. The mass production process requires investors to start. Benefits, in the form of profit, begin after the first sale of 500 units and benefits grow with each unit sold. Refer to Figures III-V for the Gantt charts related to the project and Table VI for the preliminary cost estimates.

The homeowner also gets an economic benefit from using this product. An FBI study shows that an average home burglary results in about $1,725 in losses [36]. By simply using this product, homeowners reduce the likelihood of having their home broken into and falling victim to losing large amounts of money.

4. **If Manufactured on a Commercial Basis:**
During the first year of availability, an estimated shipment of 500-1,000 would seem reasonable. Each device would cost approximately $70 to manufacture, with a selling price of around $100 per device, the per device profit would come close to $30 [26]. If 800 devices get purchased in the first year, this equates to bringing in $24,000; subtracting the $5,300 for development, this still leaves over $18,000 in profit for the first year. It costs the user about $5-$10 every 3 months to replace the batteries to use the device.

5. **Environmental**
The Garage Door Security System has some minimal effects on the environment. Using the device requires batteries, which if improperly disposed, proves detrimental to the environment [33]. The biggest negative impact on the environment comes from shipping the product to houses and to the stores by burning fossil fuels. This project directly uses natural resources such as silicon and other materials in the manufacturing process of the devices. Indirectly, the project requires the burning of fossil fuels. Once the product reaches the hands of the user, it requires batteries and electricity to operate. Some of this electricity may come from renewable sources such as solar or wind power.

This project uses electrical components that contain minerals such as silicon, uses power often generated by burning fossil fuels, and uses batteries containing more minerals such as lithium. The impact on minerals occurs at the start of the project by purchasing these components. The impact on fossil fuels starts at the build phase of the project and continues throughout the device’s lifetime; the greatest impact occurs when the device receives constant use. The project has minimal impacts on the environment unless the project gets mass produced. The project does not cause a measurable effect on the environment if all parties involved in the project, including potential customers, adhere to proper disposal rules regarding electrical components. Large scale production of the device does potentially harm landfills, mineral deposits, and power sources, including the ecosystem surrounding those areas. Species in these ecosystem face loss of territory as

the human sites grow in size. The project can lead to less missing pets which reduces the number of lost pets in animal shelters, freeing up space for more animals in need.

6. **Manufacturability**

The biggest issue foreseen with manufacturing the product stems from making sure the receiver and transmitter work seamlessly and reliably enough to work at an extended range without problems [1]. If these components get manufactured poorly, the device becomes useless because the poor link established between the receiving and transmitting units would not allow the device to display any status info [8].

Manufacturing the device on a small scale has limited complexity. Creating the housing involves 3D printing, a long and potentially costly process. Manufacturing on a large scale provides more revenue and resources to improve the 3D printing process, but correctly programming the microcontroller of each unit becomes an issue. Loading the code by hand can take several minutes for just one unit; this becomes the longest step for large scale manufacturing. Using robots to load the code provides a faster solution but requires more investment in the manufacturing process.

7. **Sustainability**

Maintaining the device should not pose any real issues except for possible damage inflicted by users dropping the receiving unit, so the design should account for this and allow the device to withstand the trauma. The device uses batteries, which may not represent the most sustainable use of resources depending on how the user chooses to purchase the batteries. Choosing rechargeable batteries provides a much more sustainable option compared to one time use batteries [35]. The device has potential upgradeability to include a built-in Lithium-Ion battery that would reduce damage to the environment by using single use batteries.

8. **Ethical**

The use of the Garage Door Security System proves the homeowners' psychological egoism. The homeowner acts in his or her own self-interest by purchasing and using this product in order to help keep their family safe, as well as protecting their personal belongings. The device creates autonomy for the user by allowing him or her to use the device to their benefit, and stop using the device if they no longer see the need to use it. Beneficence develops one user at a time. As more and more people begin to use the device, homes become more secure and neighborhoods become more safe with less crime happening. The more people that use the product, the safer the community gets, because thieves have less targets in that specific area and therefore likely avoid the area.

Ethical principlism contains four parts: autonomy, non-maleficence, beneficence, and justice [29]. The consumer does not have to purchase the device and the designers do not have to work on this project. The designers must work on a project but not this project. The project does not harm the user or those around the user if used as intended. Harm can occur if a person uses the device to observe a house by intercepting the transmission signal or installing a monitor of their own. The project can facilitate many nefarious activities along these lines; stalking, theft, and even murder. The project helps forgetful

people who accidentally leave their doors open, ensuring security, pet safety, and the safety of small children. The project benefits the designers by providing experience working with the whole design process. All potential customers have access to the project but some economically struggling customers lack the funds to purchase the device. All purchasers experience the same benefits. The designers benefit more from a successful project but carry more risk if the project fails; the designers can't graduate from Cal Poly. Design of the product follows the IEEE Code of Ethics by completing adequate research to ensure a fully functional and operational device that the user should not have to tinker with to get things working properly [32]. The project's main goal of increasing security of the home by improving technical competence throughout the general public and encouraging them to make use of technology shows great ethical responsibility. The project has no large safety or welfare concerns. Section 9 of this analysis details the health and safety concerns of this project in accordance with section 1 of the IEEE Code of Ethics. The project aims to assist customers in securing their homes and avoids harming others if used as intended. The previous paragraph detailed the potential harms from unintended uses of the project. The project teaches the designers how to employ technology appropriately and shows the designers how to identify potential consequences of technology. Peer and advisor feedback identifies many of the errors in the project allowing the designers to quickly and effectively correct errors. The project occurs at the end of the Cal Poly EE curriculum ensuring that the designers possess the qualifications to undertake the tasks involved in this project.

9. Health and Safety

This project has minimal health and safety concerns regarding the use of the product. The transmitter module runs from 120VAC power, meaning to build this module, the designers risk a potentially harmful electrical shock [34]. Installing the transmitter unit carries the same risk. Electrical shock can occur with any of the components in the device, but much less dangerous than a shock from 120VAC. Manufacturing this product may present safety concerns, so precaution measures need to surround the manufacturing process from beginning to end. Using this product benefits the homeowners by increasing their safety inside their homes. By monitoring their garage door and keeping it closed, homeowners decrease the likelihood of thieves targeting them.

10. Social and Political

This project primarily impacts homeowners by making their home more secure and making them feel safer inside their homes [12]. The direct stakeholders for this product consist of the homeowners. Indirect stakeholders include manufacturers such as Texas Instruments, who benefit from having their parts used in the device. Other stakeholders include electronics stores where they sell the devices, as well as shipping companies who deliver the devices to customers. The project benefits each of these stakeholders by providing them with a monetary gain whenever someone purchases one of the products. Stakeholders do not necessarily benefit equally from this project. Homeowners benefit the most, because the overall goal of developing the product aims to benefit the homeowner. The next biggest stakeholder for the product consists of the manufacturer of components used. The component manufacturer benefits greatly because they get continued business over the lifetime of the product.

The direct stakeholders include the designers, Austin Williams and Trevor Lehr. A successful project benefits the designers by completing the last major milestone before graduating. The project also benefits the designers by providing valuable design cycle experience. The project harms the designers by reducing the amount of time they have for other classes, projects, and activities. Indirect stakeholders include Professors Braun and Benson, as well as the Cal Poly EE department. The project benefits the EE department by helping the department keep its ABET accreditation. The professors benefit by earning money to teach classes related to the project and advise the project. The direct stakeholders pay more than the indirect stakeholders in the form of time put towards the project. Both groups of stakeholders benefit but the direct stakeholders benefit more by completing their senior project and earning a bachelors degree.

11. Development

This project allowed us to further our knowledge of many electrical engineering concepts, and get our hands dirty in some new areas such as Radio Frequency (RF). The project uses RF for the sensor data sent wirelessly to the receiver inside the house where the signal gets processed by a microcontroller. We also learned how to make different types of filters that we haven't seen before and have common uses at frequencies in the hundreds of megahertz range [3]. Performing a literature search enabled us to expand our knowledge on various electrical engineering concepts that we have not had previous exposure to. See Literature Search References.

Appendix B – Hardware Schematics

Receiver

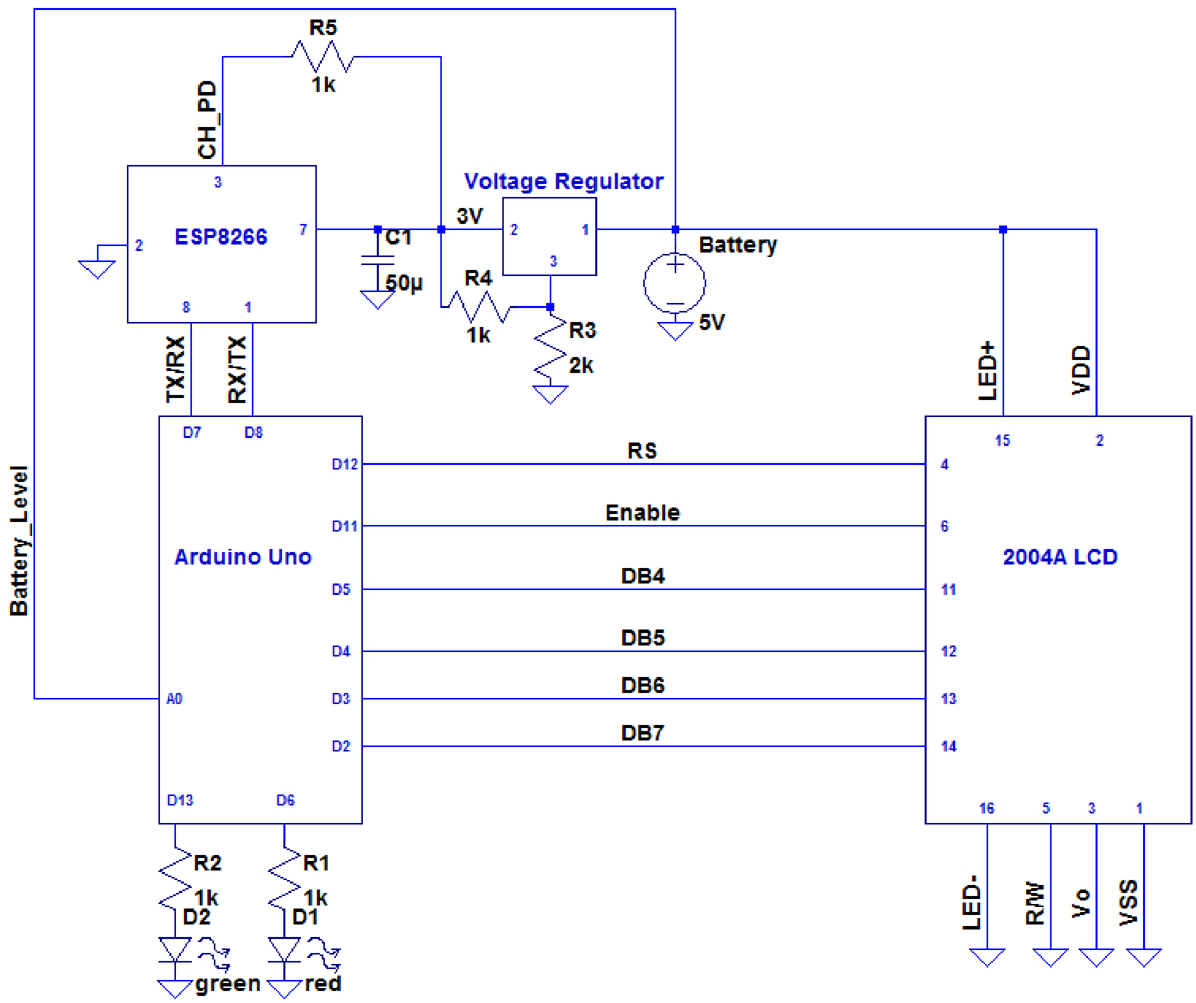

FIGURE VI
GARAGE DOOR SECURITY SYSTEM RECEIVER SCHEMATIC

Transmitter

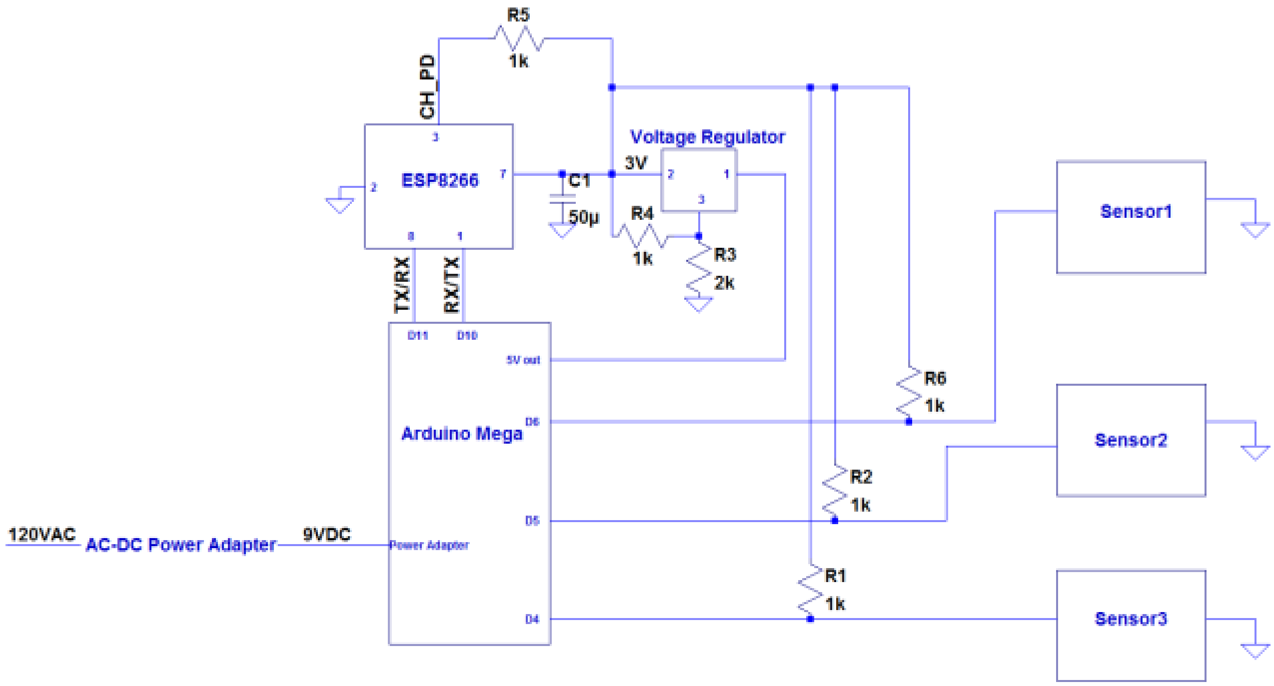

FIGURE VII
GARAGE DOOR SECURITY SYSTEM TRANSMITTER SCHEMATIC

Appendix C – Software Flowchart

Receiver

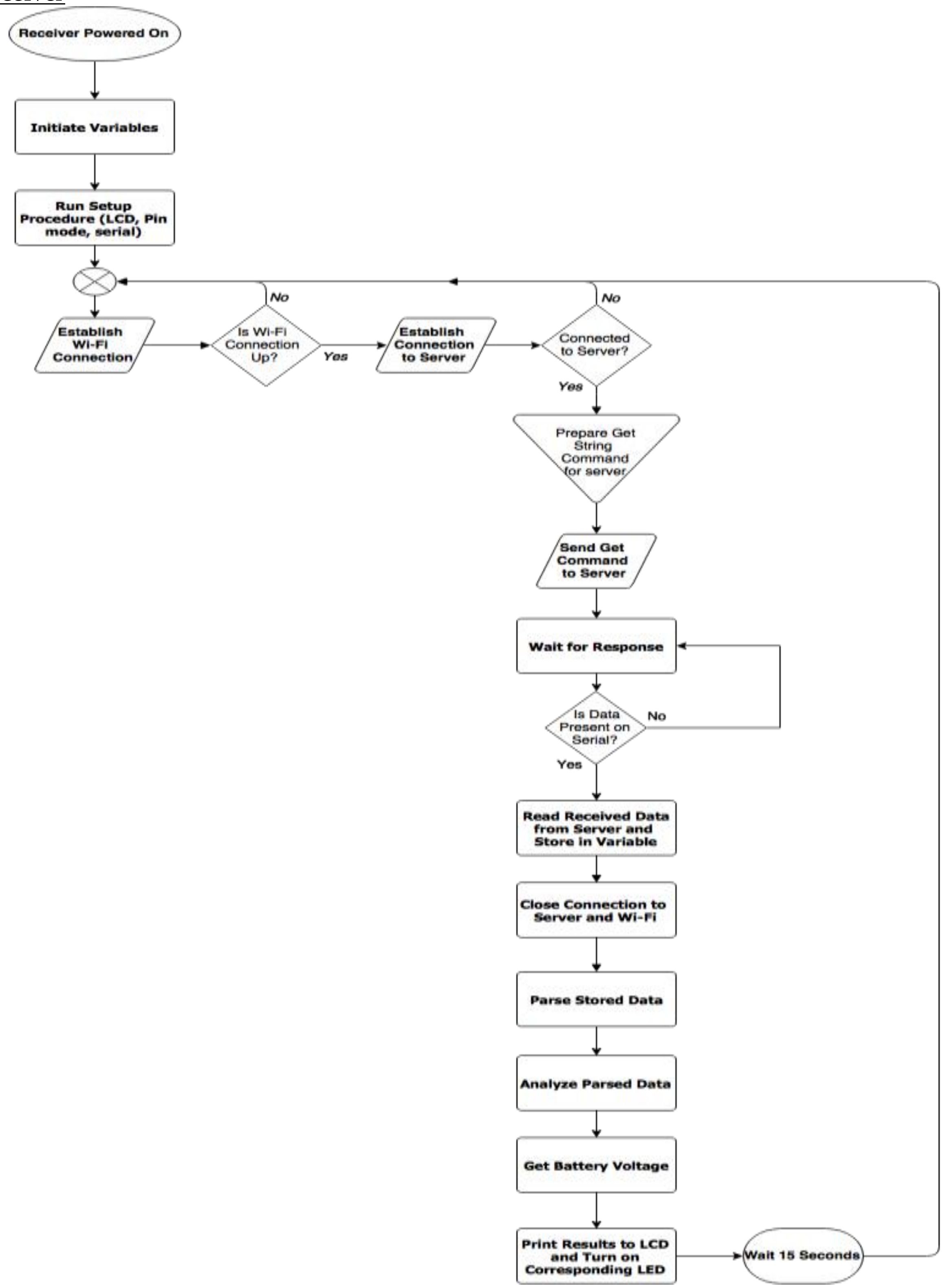

FIGURE VIII

GARAGE DOOR SECURITY SYSTEM RECEIVER SOFTWARE FLOWCHART

Transmitter

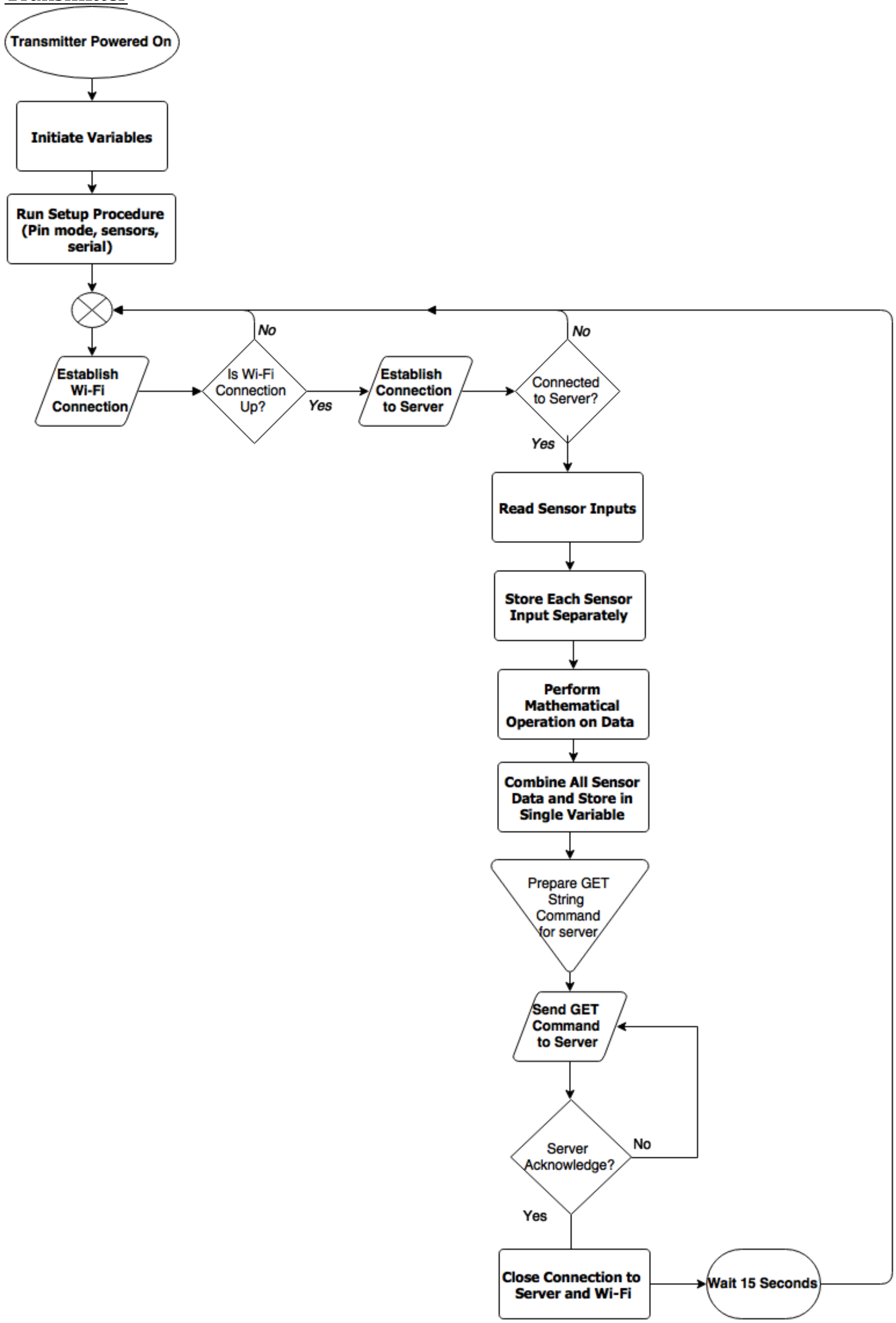

FIGURE IX
GARAGE DOOR SECURITY SYSTEM TRANSMITTER SOFTWARE FLOWCHART

Appendix D – Software Code

Transmitter

```
// Include some basic libraries needed for system to work
#include <SoftwareSerial.h>
#include <stdlib.h>
#include <math.h>

// Declare door sensors and assign GPIO Pins
int sensor1=6;
int sensor2=5;
int sensor3=4;

// Variables used to store state of each sensor
int sensor1State=0;
int sensor2State=0;
int sensor3State=0;

int val1=0;
int val2=0;
int val3=0;

int stat=0;

// ThingSpeak.com API for Garage Door Channel
String apiKey = "RWC8XCDQIALFFO3U";

// connect 10 to TX of esp8266
// connect 11 to RX of esp8266
SoftwareSerial ser(10, 11);  // RX, TX

// This runs once to configure ports and enable serial communication

void setup() {

  // Initialize the sensor pins as inputs
  pinMode(sensor1,INPUT);
  pinMode(sensor2,INPUT);
  pinMode(sensor3,INPUT);


  // Enable serial debug
  Serial.begin(9600);

  // Enable software serial
  ser.begin(9600);

  // Reset ESP8266 upon startup
  ser.println("AT+RST");
}
```

```
// Main Code
void loop() {

  // Reading the state of sensors
  sensor1State = digitalRead(sensor1);
  sensor2State = digitalRead(sensor2);
  sensor3State = digitalRead(sensor3);

  // Creates a multiplier for each sensor to be unique
  val1=sensor1State;
  val2=2*sensor2State;
  val3=4*sensor3State;

  // Variable to store the data/state of all sensors
  stat = val1 + val2 + val3;

  // Convert the sensor states into a string
  String state1=String(stat);

  // TCP connection to the ThingSpeak server
  String cmd = "AT+CIPSTART=\"TCP\",\"";      // String to send AT command
  cmd += "184.106.153.149";                   // api.thingspeak.com IP
  cmd += "\",80";                             // HTML port 80
  ser.println(cmd);             //Sends the AT Command via software serial
  Serial.println(cmd);          //Prints AT Command to serial monitor debug

  if(ser.find("Error")){        // If serial finds error message esp8266
    Serial.println("AT+CIPSTART error");  // Print error for debugging
    return;
  }

  // Prepare GET string for ThingSpeak
  String getStr = "GET /update?api_key=";
  getStr += apiKey;
  getStr +="&field1=";
  getStr += String(state1);

  getStr += "\r\n\r\n";

  // Find and send length of getStr command
  cmd = "AT+CIPSEND=";
  cmd += String(getStr.length());
  ser.println(cmd);
  Serial.println(cmd);

  if(ser.find(">")){
    ser.print(getStr);
    Serial.print(getStr);
  }
  else{
    ser.println("AT+CIPCLOSE");
    // alert user
    Serial.println("AT+CIPCLOSE");
```

```
  }

  // ThingSpeak needs 15 sec delay between updates (minimum)
  delay(16000);
}
```

Receiver

```
// Include common libraries needed for the system
#include <SoftwareSerial.h>
#include <stdlib.h>
#include <LiquidCrystal.h>

char inChar;            // Variable to hold data from serial
byte index=0;
int Green = 13;         // GPIO Pin for Green LED
int Red = 6;            // GPIO Pin for Red LED
int Batt = A0;          // GPIO Pin for Battery Voltage
double Battery = 0.00;  // Variable to store voltage
double BattVolt = 0.00;

// Connect 7 to TX of esp8266
// Connect 8 to RX of esp8266
SoftwareSerial ser(7, 8);  // RX, TX

// Declare the LCD
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

// This runs once to configure ports and enable serial communication

void setup() {

    // Sets the GPIO pins to either input/output
    pinMode(Green, OUTPUT);
    pinMode(Red, OUTPUT);
    pinMode(Batt, INPUT);

    // Set up the LCD's number of columns and rows:
    lcd.begin(20, 4);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Garage Door Monitor");
    lcd.setCursor(0,1);
    lcd.print("Initializing...");
    lcd.setCursor(0,2);
    lcd.print("Please Wait");

    // Enable serial debug
    Serial.begin(9600);

    // Enable software serial
    ser.begin(9600);
```

```
// Reset ESP8266 upon startup
ser.println("AT+RST");

delay(6000);
}


// Main Code
void loop() {

  // TCP connection to the ThingSpeak server
  String cmd = "AT+CIPSTART=\"TCP\",\"";   // String to send the AT CMD
  cmd += "184.106.153.149";                // api.thingspeak.com
  cmd += "\",80";
  ser.println(cmd);                        // Sends the AT Command
  Serial.println(cmd);                     // Prints the AT CMD to debug

  if(ser.find("Error")){                   // If error from esp8266
    Serial.println("AT+CIPSTART error");   // Print error for debugging
    return;
  }

  // Prepare GET string for ThingSpeak
  String getStr = "GEThttp://api.thingspeak.com/channels/179137/fields/1
  /last";

  getStr += "\r\n\r\n";

  // Find and send length of getStr command
  cmd = "AT+CIPSEND=";
  cmd += String(getStr.length());
  ser.println(cmd);
  Serial.println(cmd);

  delay(700);

  if(ser.find(">")){
    ser.print(getStr);
    Serial.print(getStr);

   delay(700);

  }
  else{
    ser.println("AT+CIPCLOSE");
    // alert user
    Serial.println("AT+CIPCLOSE");
 }
  String content = "";
  char character;
    while(ser.available())
    {
  content = ser.readStringUntil('\n');
  //content.concat(character);
```

```
    /*if (index < 19)
      {
        inChar = ser.read();
        inData[index] = inChar;
        index++;
        inData[index] = '\0';
      }*/
  }
  if (content !=""){
    Serial.println(content + "hi");
    Serial.println(content.substring(7,8));

    if (content.substring(7,8) == "0"){
      Serial.println("Door 1 Closed");
      Serial.println("Door 2 Closed");
      Serial.println("Door 3 Closed");

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Door 1: Closed");
      lcd.setCursor(0,1);
      lcd.print("Door 2: Closed");
      lcd.setCursor(0,2);
      lcd.print("Door 3: Closed");

      digitalWrite(Red, LOW);
      digitalWrite(Green, HIGH);}

      else if (content.substring(7,8) == "1"){
      Serial.println("Door 1 Open  ");
      Serial.println("Door 2 Closed");
      Serial.println("Door 3 Closed");

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Door 1: Open  ");
      lcd.setCursor(0,1);
      lcd.print("Door 2: Closed");
      lcd.setCursor(0,2);
      lcd.print("Door 3: Closed");

      digitalWrite(Red, HIGH);
      digitalWrite(Green, LOW);}

      else if (content.substring(7,8) == "2"){
      Serial.println("Door 1 Closed");
      Serial.println("Door 2 Open  ");
      Serial.println("Door 3 Closed");

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Door 1: Closed");
      lcd.setCursor(0,1);
      lcd.print("Door 2: Open  ");
```

```
lcd.setCursor(0,2);
lcd.print("Door 3: Closed");

digitalWrite(Red, HIGH);
digitalWrite(Green, LOW);}

else if (content.substring(7,8) == "3"){
Serial.println("Door 1 Open  ");
Serial.println("Door 2 Open  ");
Serial.println("Door 3 Closed");

lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Door 1: Open  ");
lcd.setCursor(0,1);
lcd.print("Door 2: Open  ");
lcd.setCursor(0,2);
lcd.print("Door 3: Closed");

digitalWrite(Red, HIGH);
digitalWrite(Green, LOW);}

else if (content.substring(7,8) == "4"){
Serial.println("Door 1 Closed");
Serial.println("Door 2 Closed");
Serial.println("Door 3 Open");

lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Door 1: Closed");
lcd.setCursor(0,1);
lcd.print("Door 2: Closed");
lcd.setCursor(0,2);
lcd.print("Door 3: Open  ");

digitalWrite(Red, HIGH);
digitalWrite(Green, LOW);}

else if (content.substring(7,8) == "5"){
Serial.println("Door 1 Open");
Serial.println("Door 2 Closed");
Serial.println("Door 3 Open");

lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Door 1: Open  ");
lcd.setCursor(0,1);
lcd.print("Door 2: Closed");
lcd.setCursor(0,2);
lcd.print("Door 3: Open  ");

digitalWrite(Red, HIGH);
digitalWrite(Green, LOW);}
```

```
      else if (content.substring(7,8) == "6"){
      Serial.println("Door 1 Closed");
      Serial.println("Door 2 Open");
      Serial.println("Door 3 Open");

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Door 1: Closed");
      lcd.setCursor(0,1);
      lcd.print("Door 2: Open  ");
      lcd.setCursor(0,2);
      lcd.print("Door 3: Open  ");

      digitalWrite(Red, HIGH);
      digitalWrite(Green, LOW);}

      else if (content.substring(7,8) == "7"){
      Serial.println("Door 1 Open");
      Serial.println("Door 2 Open");
      Serial.println("Door 3 Open");

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Door 1: Open  ");
      lcd.setCursor(0,1);
      lcd.print("Door 2: Open  ");
      lcd.setCursor(0,2);
      lcd.print("Door 3: Open  ");

      digitalWrite(Red, HIGH);
      digitalWrite(Green, LOW);}
  }
      Battery = analogRead(Batt);
      BattVolt = Battery * (5.0/1023.0);
      lcd.setCursor(0, 3);
      lcd.print("Battery Level ");
      lcd.print(BattVolt);
      lcd.print("V");

  //Serial.println(inData);

  // ThingSpeak needs 15 sec delay between updates (minimum)
  delay(16000);
}
```