UCF Senior Design I
Smart Mirror

Department of Electrical Engineering and Computer Science

University of Central Florida

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Senior Design I Final Research Document

Group 8

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1 Executive Summary

The document at hand describes the motivation, research, design and prototyping completed for the Senior Design 1 Semester at the University of Central Florida. The following will go into very detailed and rigorous amounts of information concerning the development of the Smart Mirror project of which Group 8 decided to take on as their project for two semesters. Four to five years of learning different areas of the Electrical and Computer Engineering field boils down to two semesters of a laborious project that inevitable will work flawlessly at the end of the second semester of work. The Smart Mirror system that is to be developed by this team of four is a project that has been seen on the internet before. However, the goal of this last course at the University of Central Florida is to challenge a team of creating something unique that folks have never seen before. This team has added some new and exciting features to the Smart Mirror that have not been seen before. By doing so, the team is able to fully demonstrate their abilities to cooperatively work as a team and come up with new and innovative ideas for this project as well as those encountered in their future careers.

The Smart Mirror is designed to be a technological addition into the lives of a wide range of users by providing a unique experience while viewing their appearance. Through the use of a one-way mirror, a display mounted on the rear surface will allow for select content to be seen through the mirror by the user, while the rest of the surface appears as a conventional mirror's reflective surface.

This mirror will be outfitted with electrical and computing components to display functions such as the time, weather, and social media feeds in an unobtrusive manner. Rather than designing a passive system which does not accept any input, the mirror will obtain sensor data from both the outside world and the user to determine the state in which it should currently exist.

Power savings methods will be implemented to detect when a user is no longer present and shut down unnecessary systems such as the LCD display. When a user approaches the mirror, the system will wake to display data on the screen, as well as utilize facial recognition to attempt to log in to that specific user's social media account and mirror settings.

While the user is in front of the mirror, a gesture sensor will accept input from the user to swipe through different feeds. Additionally, light levels will be monitored such that periods of low ambient lighting will result in LED assistance from strips mounted on the front of the frame. This not only serves the purpose of allowing the user to better view their appearance, but also creates a better environment to obtain images for the facial recognition system.

While similar products currently exist from single party developers, the aim of this project is to improve upon the work which has been completed to create a better experience for the end user. Through the addition of the aforementioned facial detection, power management, and user input, our group is striving to create a more complete platform that can also be further developed upon by electronic hobbyists in the future in an open source methodology.

2 Introduction

The following document provides an in depth look at the design and testing stage of the University of Central Florida's Senior Design final project for Group 8. Over the course of the semester, our group has faced real-world engineering decisions with relation to implementation, financial, technical, and time constraints. The goal of this final design course is to showcase the engineering knowledge that UCF has offered in its curriculum over the four years of attendance in a method that is similar to what will be experienced in a full-time job environment. While numerous classes have prepared students for working in groups and solving problems both together and separately, this course demands high levels of effort to fully complete the development of a finished product. Apart from graduating with soft skills such as working in a small team, the course also intends to allow students to delve deeper within their areas of technical interest to better understand the principles and concepts that will be expected from within the industry.

With that being said, students have the ability to choose what interests them most in the project and run with it. Using the resources provided to us by the University of Central Florida, the students can research their respective area of interest and develop new and innovative solutions to problems in the project. Even the simplest of ideas within projects can create problems that no student has ever been exposed to. This kind of technical practice prepares an individual for the complex and technical difficulties that may appear during ones' career.

As the following document is designed to be an intermediary step in the complete process, the finished product is currently under development. Come the end of Spring of 2017, the Smart Mirror project will be a completely developed system ready for showcase to the engineers and professors at the University of Central Florida, as well as current students and industry experts.

3 Project Description

This section will describe the project in its entirety. It will explain the motivations the team had for pursing the project, as well as any goals hoped to achieve by the members. This section will also outline the specifications the team has set for this project. The specifications sections will then go into more detail on each aspect of the project and the goals that should be met. Lastly, a house of quality diagram will be included to visually show the tradeoffs expected in this project.

3.1 Project Motivation and Goals

The motivation behind this project was building a device that is interesting to the team. We wanted to design something that excited us, and that we would want to use. Because our team is two electrical engineers and two computer engineers, not one area of interest was focused on. We wanted to learn more in our respective fields from this project, including designing hardware circuits and also computer vision. There was a large interest in the group for computer vision software, which lead to the addition of the facial recognition software.

While the Smart Mirror is a DIY project that already exists, we saw an opportunity to make it better. This device was interesting to us from the start, but the additions we thought of adding such as facial recognition and gesture control are what drove us to pursue this project. On the electrical engineering side, this would allow us to design our own circuits, including a power supply circuit and supporting circuits for various sensors and a microcontroller. It will give us the chance to learn more about the process of searching for specific components and parts needed to fulfill certain requirements.

On the software side, improvements are being implemented to both the existing open source framework as well as adding support through additional modules. By adding the software support for the additional subsystems, the final product will implement additional features outside those which are currently released. Motivations for adding the additional software were fueled by the desire to practice the engineering related concepts which have been taught throughout the past four years in higher education. Between concepts learned through various internships in the corporate engineering environment, to specialized technical elective courses outlining additional details in the field, practicing these select skills to fully realize a full system’s prototype will collectively reinforce the key skills required by the industry.

As each team member approaches graduation, leaving lasting impressions on the faculty and guests of the senior design showcase will assist in developing an extensive network of industry professionals. By selecting a project which highlights both computer and electrical engineering within the college, it is believed that the impression left based on the technology used in this project will be a positive one. By developing this network, potential full time engineering positions may be obtainable and solidified further down the career paths of each contributing team member.

The team saw an opportunity to improve an existing idea. The idea of a Magic Mirror had been shown with date, time, compliments and facial overlays. The team had not seen it implemented previously with multiple users or facial recognition. This would be a great

exercise in adding to an existing architecture, debugging, and new implementation. Also, it allows for an opportunity to learn about different architectures, languages and critical thinking techniques. These are all vital characteristics of being a developer – regardless of field. Very often, an engineer will be asked to take an existing idea and improve upon it. This means the engineer must put themselves in the same mindset of the previous developers and use the existing tools to improve the architecture. This exercise will allow the team to use these skills and improve upon them.

Overall, the motivations for completing such a project can be summed up as a desire to enhance a currently underdeveloped product with the team's own implementations and solutions, while showcasing the engineering skills each team member has obtained while in attendance at the University of Central Florida.

3.2 Objectives

The main objective of the Smart Mirror project is to design and retrofit a mirror with supplemental technology which will provide the user with relevant information during day to day life. Meeting this objective will entail creating a complete system to meet the project specifications in a manner which also remains user friendly. By implementing various features which have yet to be implemented on commercial smart mirrors, the final product will be a culmination of subsystems working in unison to provide a unique experience and addition to the lives of potential proponents.

The project's secondary objective entails implementing face recognition software to detect and identify the user. This will allow personalized information to be provided on screen based on the current person using the mirror by utilizing preconfigured credentials to retrieve information from social media news feeds.

The third objective is to implement power saving technology into the Smart Mirror in an effort to make it as efficient as possible. While other relevant projects have strived for practicality when designing similar products, this team is determined to create one that is both practical and efficient. Thus, making it a marketable product by making it appealing in more than just one way.

The final objective is to create a system which responds to user input. Rather than implementing a passive system, the project will utilize various sensors to respond to the environment. User presence detection, adaptive lighting control, and gesture interpretation will be designed into the system to create the next level of available smart mirror features.

3.3 Requirement Specifications

The following requirement specifications outline details for various components and subsystems which are to be implemented in the final design. By first creating a list of specifications, the team was able to properly compare and contrast various products existing on the market before making final decisions. Understanding the role that each component played within both the subsystem and the system as a whole allowed for a culmination of key requirements to properly ensure that the project requirements could be met. Additionally, compatibility among devices is an important consideration further solidifying the necessity of developing strong requirement specifications early in the design stage.

3.3.1 Project Specifications

The following product specifications define the requirements to be implemented in the Smart Mirror. The specifications defined using the word "*shall*" are hard requirements that team will meet by the end of the second semester of the Senior Design course. The requirements that use the word "*should*" are a stretch goal set forth by the team. All efforts will be made to accommodate these goals, but is it not expected from our advisor that these need to be met. With that being said, you can still see in the following requirements for the project that most utilize the word "*shall*" meaning there are a lot of features that the Smart Mirror will have for the completed design.

The following product specifications define the requirements to be implemented in the Smart Mirror.

- The Smart Mirror *shall* be within the boundaries of 22x22x5 inches
- The Smart Mirror *shall* not exceed 10lbs
- The Smart Mirror *shall* allow the user to view their appearance
- The Smart Mirror *shall* be powered via a single cord
- The Smart Mirror *shall* connect to a user's Wi-Fi
- The Smart Mirror *shall* display the following information:
    - Current Time
    - Current Date
    - Weather Forecast
    - News Feed
- The Smart Mirror *shall* enter a power saving mode when no user is detected after 2 minutes
- The Smart Mirror *shall* wake and power on the display when a user is detected
- The Smart Mirror *shall* utilize facial recognition software to:
- Determine the user
- Show data applicable to their account
- The Smart Mirror *should* allow a user to scroll through their news feed

3.3.2 Microcomputer Specifications

- The Microcomputer *shall* be network compatible
- The Microcomputer *shall* support graphic outputs to support LCD displays
- The Microcomputer *shall* be capable of handling multiple, simultaneous process
- The Microcomputer *shall* support serial communication with the selected microcontroller
- The Microcomputer *shall* interface with a camera to obtain user images

3.3.3 Microcontroller Specifications

- The Microcontroller *shall* be compatible with the Arduino bootloader and support the brand's programming
- The Microcontroller *shall* support serial communication abilities via UART and I2C
- The Microcontroller *shall* be powered by 5VDC or less

3.3.4 Camera Specifications

- The camera *shall* be capable of capturing images with adequate resolution for facial recognition
- The camera *shall* be compatible for use with the microcomputer
- The camera *shall* have a small footprint and size with relation to the mirror

3.3.5 Lighting Specifications

- The LEDs *shall* require a voltage no greater than 12VDC
- The LEDs *shall* include the capability to dim, whether natively supported or by external circuitry
- The LEDs *shall* output white light and not rely on RGB combinations to appear white
- The LEDs *shall* output light levels capable of lighting a user's face from one to two feet away

3.3.6 Power Specifications

- The power system *shall* accept an input of 12V DC
- The power system *shall* provide a 5V rail for the microcomputer, microcontroller, and sensors
- The power system *shall* provide a 3.3V rail for the logic level converter between the microcomputer and microcontroller.
- The power system *shall* utilize power efficient devices to reduce energy waste.
- The power system *shall* consume less power while under less load.

3.3.7 Presence Sensor

- The presence sensor *shall* interface with the microcontroller via serial communication
- The presence sensor *shall* detect the distance of a user within zero and two feet
- The presence sensor *shall* be powered with no greater than 5 VDC
- The presence sensor *shall* be capable of mounting on the frame
- The presence sensor *should* support multiple functionalities

3.4 House of Quality Analysis

The House of Quality is a unique tool used to visualize how the product or service will relate to the consumer. It contains market desires, customer desires, relationships between the two and sometimes more. The main aspect of this tool is to show the correlations between these wants and requirements from the customer, market and provider. These correlations can help give the producer of a good or service a good idea of how their product could be designed or delivered.The House of Quality for the Smart Mirror is shown below in Figure 1.

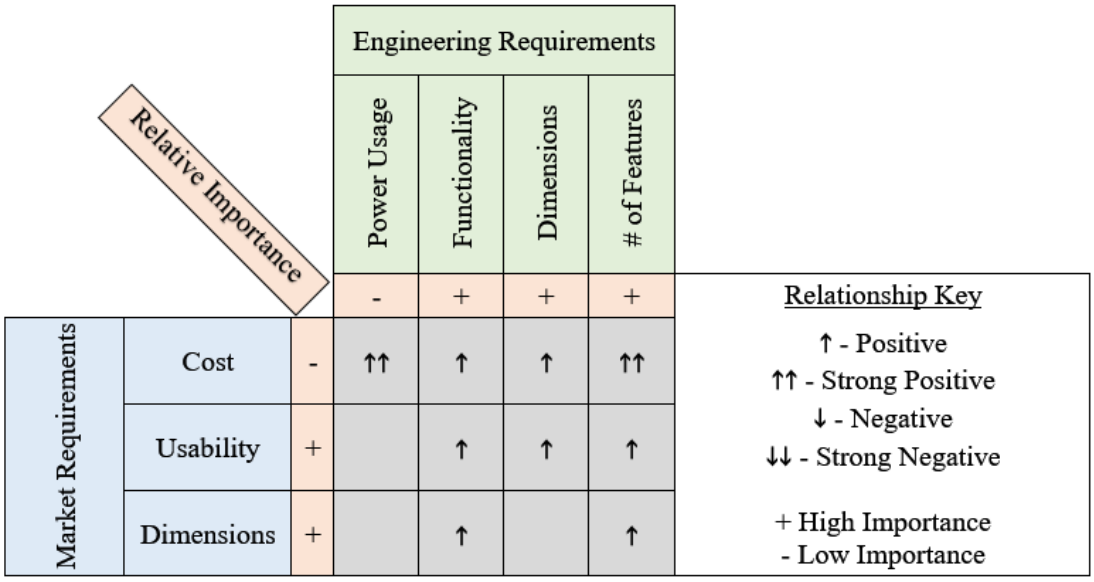


Figure 1 – House of Quality

One of the most important Market requirements is the cost of the product. This is one of the driving factors when it comes to designing a successful product. If the product is very expensive, it should contain a significant amount of quality such that it is still appealing to the customer. If the product is cheap, then the required effort and materials may not have been put into the product and this alone would make it unappealing to any customer and some competitors may view it as an advantage to their product/company. The cost to build the Smart Mirror is estimated to be around $600, but the development and build will most likely not come to that amount since the estimates for components are high.

This Usability of the product will also impact the market and engineering requirements. The higher the usability of the product or device, the better chance it will be successful on the market as well as profitable to the company producing it. For the Smart Mirror specifically, another important market requirement is the dimensions of the product. For this to be a successful product on the market, the mirror cannot be too large that it would not fit in someone's house. It would also likely drive the cost of the product through the roof! Too small of a mirror and the user would not even be able to seem themselves let alone the information that is to be displayed on the mirror.

When brainstorming the design for this Smart Mirror, four key engineering requirements were taken into consideration. The first one being power usage. Being that this is a device that would likely stay plugged in at all times or even have a hard-wire installation it needs to have some sort of power saving technology. This is obviously going to increase the cost. One of the specifications set forth by the team is to have the Smart Mirror pull less than 4 amps of current at any point in time.

The next engineering requirement on the chart is functionality. This one might be the most important one when it comes to the engineering requirements and relating them to the market requirements. If the functionality of the Smart Mirror is substantially above its' competitors it will do well on the market. Of course, functionality will increase the usability, cost and most likely the dimensions.

Dimensions is on both the engineering and market requirements. When designing the product, the size needs to watched carefully. It is easy to say there will be enough room for any certain component. However, in the end there may not end up being enough room. So, monitoring the dimensions of the Smart Mirror will directly influence the cost and usability of the device. The Smart Mirror that is explained throughout the remainder of the document has a dimension restriction of 22x22x5 inches.

The number of features that the Smart Mirror will have is one of the engineering requirements made to give the device a unique aspect to it. Adding the one-of-a-kind facial recognition is among many of the features on the Smart Mirror. This was something that definitely increased the cost of the product, but also increased the usability of it which appeals to consumers quite nicely.

4 Research

Before beginning such an involved project, research is required in order to build up a good background and understanding of what is needed. Research done by each engineer will be determined on what parts of the project they are responsible for or interested in. For the electrical engineers this consists of all hardware components, as well as design techniques. The computer engineers researched various techniques for communication, facial recognition, and the architecture that will ferry messages between the hardware and the Internet. Time was also taken to look into devices are products that already exist that are similar to ours. This is an important aspect not only to generate ideas for our own mirror, but also to make sure our device is different from the others and provides benefits that they cannot.

4.1 Existing Technologies

When designing any project, it is important to keep in mind any similar existing products. The Smart Mirror is not an original concept. A popular DIY version exists as well as a few consumer products. The following section will look at a few of these existing devices and how they influence our design.

4.1.1 Magic Mirror

The Magic Mirror is a DIY project designed by Michael Teeuw. This design was the main influence of our Smart Mirror. The Magic Mirror allows users to view the weather in their area, their calendar, the local news, and provide a compliment. The mirror works by having a display monitor display information behind a two-way mirror. The two-way mirror allows the information (white text) to be seen from the other side, while still reflecting the user's appearance. Teeuw designed a webpage that would constantly update with all the information to be displayed. The webpage is a simple design, white text on a black background, in order to be seen through the mirror. A Raspberry Pi is used in connection with the display monitor to show the webpage. In order to power the project, Teeuw found a monitor with USB ports and used that to power the Raspberry Pi. The biggest influences of the Magic Mirror on this project are the mirror design and the open source software. The use of a two-way mirror with a display monitor behind was adopted, but rather than use a monitor the same size of the mirror, one just big enough to display information will be used. The open source software Teeuw has provided will also be used as a base line for the Smart Mirror software, with additions being added to it.

Figure 2 - Teeuw's DIY Magic Mirror

4.1.2 Toshiba's Multi Display in Black Mirror

Toshiba showed a smart mirror concept at CES 2014 that they called "Multi Display in Black Mirror". They had two versions, one for the bathroom and one for the kitchen. The bathroom version allows the user to view daily information such as the local weather and fitness information pertaining to the user. The kitchen version allowed the user to create recipes or view ones already stored on the database and assist in the cooking process. The most interesting function of this product was the ability to use gestures to interact with the mirror, similar to the Xbox Kinect. This is to be implemented in the Smart Mirror as a way of navigating panes of information.

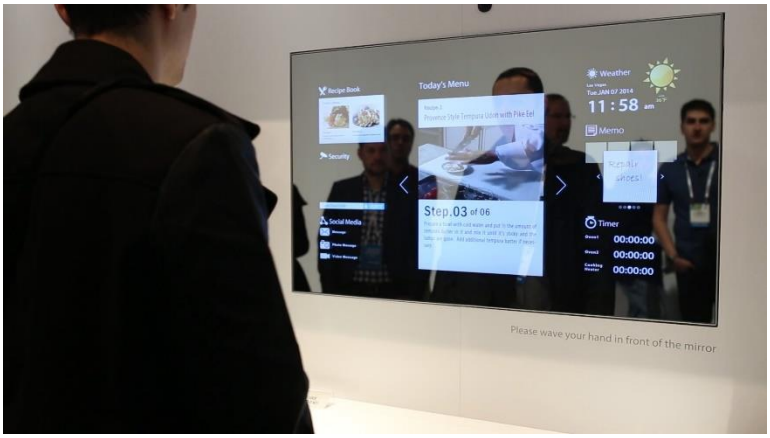


Figure 3 - Toshiba's Multi Display in Black Mirror

4.1.3 Samsung's ML55E

Samsung has their own smart mirror geared towards being used in hair and beauty salons. The ML55E has the typical features of smart mirrors like time and weather but also includes some additional features. Through a phone app, the display can be customized to

show information such as advertisements and promotions for the salon. A key feature of this particular display that is relevant to our project is the use of a proximity sensor. When a customer is not sitting in front of the mirror, the display takes up the whole mirror, making the advertisements readable for customers who are in the waiting area. Once a customer is sat in front of the mirror, it becomes more like a mirror, and all display graphics are moved to the sides of the screen. This project plans to use a proximity sensor as well. The proximity sensor will be used to determine when the user is in front of the mirror, but unlike the ML55E, the mirror will not be displaying anything while not in use. This is to make the mirror fit into common home décor while not in use.

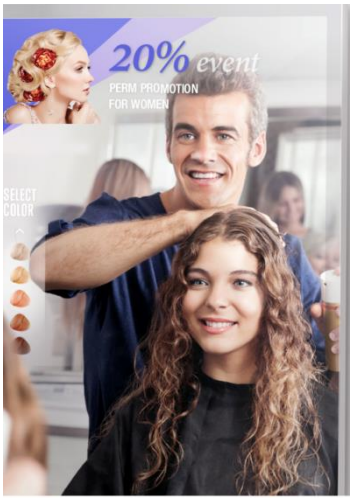


Figure 4 - Samsung's ML55E

4.1.4 Panasonic's Smart Mirror

Panasonic debuted their version of the smart mirror at CEATEC in Japan. Their version has a slightly different spin than all the other mirrors researched. The mirror was designed to be used in beauty and make up store. The main drawing feature of the mirror is the ability to tell you what is wrong with you face. It can point out flaws such as redness, wrinkly skin, and pores. The mirror can then recommend beauty products that the store carries that can be used to hide these blemishes. The camera does this by taking a picture and analyzing it. There is also a version of Panasonic's smart mirror that will give you a makeover by showing what certain projects will look like on your face. Our project will also feature the use of a camera in order to recognize what users are in front of the mirror.

Figure 5 - Panasonic's Smart Mirror Display

4.2 Relevant Technologies

The following research section highlights the relevant technologies and engineering related concepts which may be utilized within the development and implementation of the Smart Mirror. While an explanation of each technology is present, initial decisions regarding the different implementations may also be found, playing a part later in component selection. By first researching and understanding the existing technology which can be utilized in the system, the team has been able to make educated decisions with respect to technical concepts and options available.

4.2.1 TTL Serial Logic Levels

When working with embedded devices which must communicate with one another over a physical connection, considering the voltage logic level at which they operate is crucial. As a computing device, calculations are completed by both driving transistors in the circuit to a high voltage and pulling them low to ground, representing the 0 and 1 bits. One differentiating factor between devices is the transistor-transistor logic (TTL) voltage ranges which are used to differentiate the value of the bit.

If logic levels were implemented where 0 bits are represented by only 0v, and 1 bit are represented by only Vcc, numerous false readings and false transmissions would occur on the transistor level. Due to imperfections in circuitry and outside noise interfering with the system, it cannot be guaranteed that the voltage levels will be accurate in such a precise sense. Instead, an acceptable level of voltage ranges must be defined in which the device will accept a 0 bit as existing within a predefined range around the 0v ground. Similarly, an acceptable range for the 1 bit must be established as a range around Vcc.

4.2.2 I2C

The I2C communication protocol is a popular technology due to its robust nature of acknowledgments between a master and slave devices. The protocol relies on just two wires for communicating with up to ~112 devices. Two signal wires, SCL and SDA, are used for communication. The two signal wires are considered to be open drain since pull up resistors are used to pull the signal high when the devices are not communicating, and the devices will pull the signal low during communication. During design, a master device must be selected as the device which initiates all communication between itself and the slave devices.

With I2C communication, every device is designated as a Master or a Slave. In most implementations, a system will consist of a single master device which drives the SCL clock line and initiates all communication with slave devices. Slave devices act as responders to the requests being made by the master device. Each slave is assigned a specific address so that the master is capable of selecting the device it wished to communicate with. Since only a single master device exists within the system, conflicts between devices cannot exist due to the nature that slave devices are unable to initiate transfers of data.

When a master device requests data from a slave device, a specific pattern of bit sequences must be adhered to. The data can be divided into 8-bit sequences of request and response between the master and slave. To begin, the master must transmit a start sequence along the SCL and SDA communication lines. The start sequence is defined by holding the SCL

clock line high while the SDA data line is allowed to change from high to pulled low. As will be addressed in the future, this is significantly different than the data transmission stage where the SDA line must remain constant during a high clock cycle.

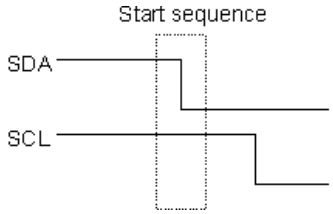


Figure 6 - To begin communication, the master device must issue the start sequence (Reprinted with permission from Robot Electronics)

Following the start sequence, the master device will transmit a 7 bit sequence containing the address of the slave device in which it will be requesting communication with followed by a read/write bit. Due to the 7 bit addressing sequence, there are 128 possible addresses, but I2C reserves certain addresses for specific functions, decreasing the number of possible devices to 112 as previously mentioned. The 7 bit address is sent with the most significant byte first, ending with the least significant byte. The final byte of the first 8 bit sequence is the read/write bit, indicating the operation the master wishes to conduct on the slave.

Following the first 8 bit sequence addressing the device the master wished to communicate with, the master device will relinquish control of the SDA data line for use by the slave device. The slave device sends an acknowledgement to the master by pulling the SDA line low, as a way of stating that it has received the message and is prepared for the next stage. In the case that the acknowledgement bit is not sent, the master device must decide how to proceed with the operation.

The master device will continue to pulse the SCL clock line at a regular interval while data is transmitted over the SDA until a stop bit is transmitted. The stop bit is the opposite operation of the start bit, where SDA must be allowed to return to high from being pulled low by the device during a point in time where the SCL clock line is high.

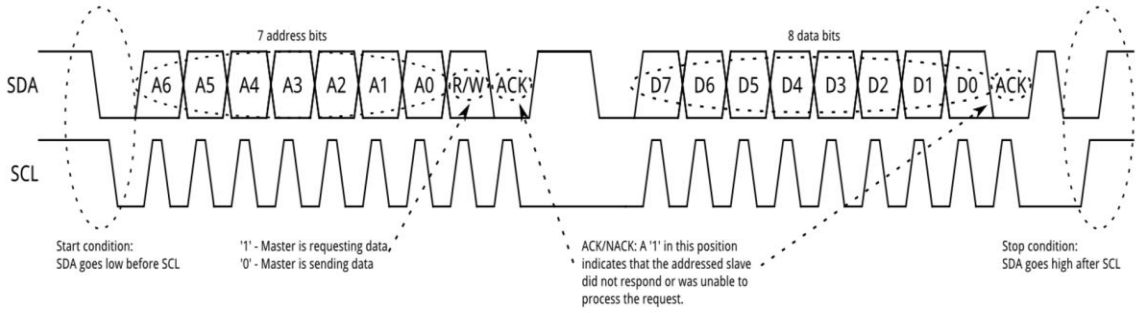


Figure 7 - A full picture of the SDA and SCL communication lines during typical master-slave data request and transfer (Reprinted with permission from Sparkfun)

4.2.3 UART

UART Serial Communication, is a peer-to-peer asynchronous protocol in which two devices communicate using two signal lines. The universal asynchronous receive/transmit

protocol is an intermediate serial stage used to connect the parallel interfaces of two devices. This is completed by shifting out a bit sequence from a register and transmitting the data bit by bit across the signal lines, where the receiving device will shift in the data bit by bit at the same rate as transmission. In short, the parallel data is converted to serial data by the transmitter, and serial data is converted to parallel data by the receiver. Unlike I2C, a device can act as both a receiver and a transmitter in the same system and is not assigned a set role.

Key concepts in understanding the UART communication method lie in first recognizing that the protocol is asynchronous. Asynchronous communication is defined as the transmission of data intermittently between two devices rather than a continuous data stream with an external clock governing the transfer. In this design, the devices are permitted to complete internal processor operations and query the UART buffer when the data is desired, rather than yielding the current operation to service the communication. The following discussion explains in detail the concepts used in UART communication and the differences between this communication protocol and I2C.

The two lines used for communication are the TX transmit and the RX receive data lines. Unlike I2C, a clock line is not required. Within each device's UART exists a clock generator to keep the proper timing baud rate for reads and writes to the signal lines. Typical baud rates are 9600 bits per second, but are capable of reaching up to 115200 bits per second if such speeds are required for the application.

UART data is transmitted in the form of packets between the transmitter and receiver. Similar to the I2C method, a 1-bit start signal is used to signify the beginning of transmission by the transmitting device pulling the TX line low during a clock cycle. Following the start bit, the data bits are then transferred, typically 8 bits followed by a parity bit. Following the parity bit, a stop bit sequence of at least two clock cycles is used to signify the end of transmission.

Parity bits are used by the receiver to check for errors during transmission that may have been incorrectly changed along the path from the transmitter to receiver. UART utilizes a parity bit based on the count of bits that were set to high. The transmitting device is aware of the count of high bits in the data frame it is transmitting and sets the parity bit to 0 if there is an even number of 1 bit and sets the parity bit to 1 if there is an odd number of 1 bit. The receiver compares the parity bit to the information it received and if there is a mismatch between the data, it can conclude that a bit must have been corrupted during transmission. The system will then handle the error, possibly by requesting a retransmission.

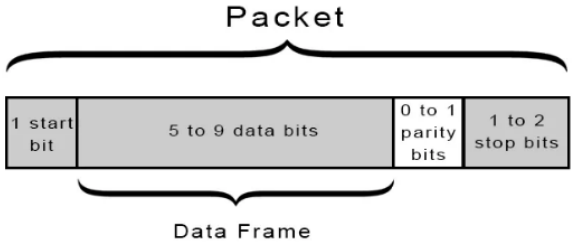


Figure 8 - UART data is transmitted in the form of packets rather than a constant bit stream as in I2C (Reprinted with permission from Circuit Basics)

Select advantages of this method include no clock signal line required, a parity bit is used to check errors, and that the protocol is well documented for use between microcontroller units. Disadvantages include limited data frame size, and the lack of support for connections between multiple devices. For this project's implementation, the disadvantages hold little weight as multiple connections are not required, and the ATmega and Raspberry Pi are capable of holding stable clocks and therefore stable baud rates.

4.2.4 Pulse Width Modulation

Pulse Width Modulation (PWM) is a digital, modulated, square waveform typically utilized in control circuitry and implemented in a wide variety of applications. For example, it can be used to control servos, analog circuits, or dim LEDs.

PWM signals take the shape of a square waveform with alternating values of high and low voltages. Based on the clock cycle time of the microcontroller, a duty cycle can be used to describe the amount of time the signal is kept high compared to the overall cycle time of the signal. Based on the selected duty cycle and the high voltage level, it is possible to calculate the average voltage output by the system by simply multiplying the duty cycle percentage value times the high voltage level.

In the application of the project, a PWM signal will drive a MOSFET circuit to dim the LEDs on and off, rather than simply applying a high or low signal. Using this method, the user will not be startled or blinded by sudden bright lights illuminating the space, but allowed to adapt to the changing levels as the voltage applied to the LEDs gradually increases.

4.2.5 Power Supply

When designing any project one must decide on what type of power supply will be used to power the device. There are multiple ways a device can be powered including by battery, AC to DC power supplies, and via USB. All three of these options are viable for most projects, so selecting one would depend on one's project requirements including mobility, power requirements, and need of a constant voltage. Research was done on these three power sources to determine which option was the best fit for the Smart Mirror.

Table 1 gives a quick look at the benefits and drawbacks to these types of power supplies.

Table 1 - Pros and Cons of Various Power Supplies

	Battery Powered	**AC to DC Power Supply**	**USB**
Mobile	Yes	No	Depends on device connected to
Wired	No	Yes	Yes
Need to be Charged	Yes	No	No
Size	Depends on battery size	Larger	Small/Medium
Cost	Depends on battery	Higher	Lower

Power that is supplied by batteries allows a project to be mobile. Without the need to be connected to AC supply like a wall outlet, a device can be used wirelessly and is not restricted by location. There are many different battery technologies that can be used and one would need to consider the power requirements of their project and select a battery with the proper capacity. Capacity is given in amperes per hour, so the capacity of a battery tells you how many amps the battery can supply for an hour while fully charged. If a battery power supply is chosen, then the size and weight of the battery must be considered. If a device is meant to be mobile a heavier battery might not be ideal. A downside to batteries is the need to recharge. If it is essential that a device be constantly operating, batteries are not the appropriate supply.

A second form of power supply is via USB. This option is highly recommended for devices that work in tandem with a laptop, computer, or other electronic device. The USB connection is simple and easy to implement in a project. For projects that talk with computers or other devices through USB, powering through USB as well is an obvious choice as it reduces the amount of cables needed for the project. This method is not useful for devices that do not operate alongside a computer.

A third option for the power supply that was researched is an AC to DC power supply. These devices are commonly used by computers and laptops to convert the AC power that is supplied by a wall outlet into DC power in order to power or charge the device. This technology is useful as the supply outputs a regulated DC voltage and current, which you can design your project around. This style of power supply comes in the form of a wall adapter with the AC to DC converter either at the point of contact with the outlet, or further down the cable in the form of a power brick. These converters are commonly found and should be chosen based on the voltage and current requirements for the project. Because the adapters are so commonly found, they tend to be very budget friendly options. The disadvantage of this form of power supply is the need to be connected to an outlet. This restricts the mobility of the device and also adds a wire to the device, eliminating wireless capabilities.

If an AC to DC power supply were to be used, the type of connection would need to be decided as well. The first type of connection researched is a DC barrel connector. This common connection is typically found in inexpensive electronics. The male side of the connecter is usually found on the end of a wire and the female side mounted to the device PCB. The female connector has at least two pins with an optional third that can be used to detect when a male plug is inserted. The other two pins are commonly named the “tip” and “sleeve”. There are three variables to consider when selecting a barrel connector. The sleeve diameter, the pin diameter (which is dependent on the sleeve diameter), and the polarity. The polarity refers to the voltage of the tip compared to the sleeve. Positive polarity is the common type, but negative could also be used.

Another option researched is the Molex connector. The name “Molex” comes from the company that originally designed the connector, but has become the general term for all similar connectors. This connection has multiple pins and is rated for high current as each pin can supply up to 11A per pin. This feature makes Molex connectors common in high power projects. The female connector is actually found on the cable and the male side on

the board. The pins of the male side fit very tightly into the female side in order to keep devices from losing power. The more the plug is detached, the looser the hold gets on the pins, making this not a good option for devices that frequently change connections.

JST connector was another technology that got its name from the company that first designed it. This connection is small (2mm) and takes up very little PCB space. It is also durable and hard to disconnect which leads to less power failures. However, because of the difficulty in disconnecting, if it were to be unplugged, it could likely damage the pins or connectors. JST connectors come in a variety of packages, and can have varying number of pins.

4.2.6 Unregulated Versus Regulated Power Supplies

All types of power supplies can be divided into 2 categories, either regulated or unregulated. The portion of the power supplies that is either regulated or not is the voltage. Unregulated power supplies allow for the voltage to fluctuate based on the load current, where the regulated versions keep a constant output voltage. Research was done on both forms of power supply to determine the best option for this project.

The unregulated power supplies are the simpler of the two types. As the name suggests, they do not require a switching or linear regulator. Instead of providing a constant voltage, these power supplies provide constant power. This means that as the load current increases or decreases, the voltage does the opposite in order to maintain power. This means the voltage listed on the device is only applicable for load currents equal to the max current rating. If the current goes up, the voltage will decrease, and vice versa. These changes in output voltage are named ripple voltage, and can cause noise on the output signal. For devices with load currents close to that which the supply is rated for the noise is very little. And in cases where the load current differs it is possible to use capacitors to filter the signal. For devices that can be negatively affected by noise, this type of power supply is not recommended. If noise is not a concern however, this is a viable option due to its low cost and availability.

The main difference between the unregulated and regulated power supplies is the use of a voltage regulator, either switching or linear. This means that no matter the load current, the voltage will remain constant, providing lots of reliability. This is not the case however if the current rating is exceeded. The switching regulated power supplies are often power efficient, but that comes at a cost. Both versions of the regulated power supply are more expensive than the unregulated, the switching supply more so than the linear.

When selecting which supply is to be used in a project a few parameters should be considered in order to make the best decision. First, it should be determined if the device being supplied has strict power requirements. If the device must operate at a specific voltage, but the load current frequently fluctuates, an unregulated power supply is a poor choice as the voltage would change. Cost, size, and mobility are also factors to considered. The regulated power supply is at advantage in size and mobility due to it being smaller, but is also more expensive. For devices which will not be moved, much, unregulated can be a good choice that saves some money.

4.2.7 Voltage Regulators

A power supply needs to be able to power all components of a project, which often calls for providing differing voltages base on component requirements. The input voltage of the power supply must be either stepped up or down in order to meet these requirements. There are two common types of components used to regulate voltage: the switching regulator and the linear regulator. Research was done on both devices to determine the best fit for this project.

Switching regulators are the more complex way to regulate your voltage, but depending on the project can be more efficient. A switching regulator has the capability to step down, step up, or inverse an input voltage. The regulator takes small portions of energy from the input voltage source and moves them to the output a little bit at a time. As the name suggests, a switch is used in tandem of a controller to determine the rate at which the energy is transferred. This method of moving portions of energy, little bits at a time, makes them more efficient for high power devices. When the regulator is switched off, no power is lost. While the regulator is on, little power is lost since it is only moving a portion of the input energy. There are some drawbacks to switching regulators though. First off, due to the switching at high frequencies, there can be a lot of noise found on the signal. Switching regulators also need high input voltages in order to supply enough current to operate. The complexity and cost of implementing a switching regulator are also some of the drawbacks.

Linear regulators can be the answer to many of the drawbacks of a switching regulator. They have a simple design and require very little in terms of supporting circuit, usually just a couple of capacitors. Because of the simple design, linear regulators are most times cheaper than their counterparts, and have more options in terms of output voltage and current. The disadvantage to linear regulators is their efficiency at high power. Because they function by dissipating heat, they essentially waste power. If the difference between the input and output voltage is small, then they are often very efficient. However, as that difference grows, they waste lots of power, and in these cases a heat sink should be considered to reduce lost and protect the device.

When one is deciding between a linear or switching regulator the variables to consider are power efficiency, capabilities, noise, supporting circuit, size, and cost. These factors are broken down for each device in Table 2.

Table 2 - Differences of Linear and Switching Regulators

	Linear Regulator	Switching Regulator
Power Efficiency	Depends on input voltage. Low for high voltage differences, High for small differences	High efficiency
Capabilities	Only step down	Step down, step up, and inverse
Noise	Low	More noise due to higher frequency
Supporting Circuit	Simple: usually only bypass capacitors	Complex: could require inductor, diodes, and filter caps
Size	Small, unless a heat sink is required	Medium, smaller than linear with heat sink
Cost	low	Medium to high

4.2.8 Logic Level Converter

When a project has multiple devices that communicate with each other, the possible issue of the devices using different voltages. In the case of the Smart Mirror, the ATmega is a 5 volt device and the Raspberry Pi a 3.3 volt device that talk to each other using I2C communication. A logic level converter fixes this issue. Logic level converters (LLCs) are simple circuits with just three components: two pull down resistors and one N-channel MOSFET. References voltages from the system must also be supplied to the circuit. Figure, which is from Phillips Application Note AN97055, shows the circuit diagram of two connections using an LLC.

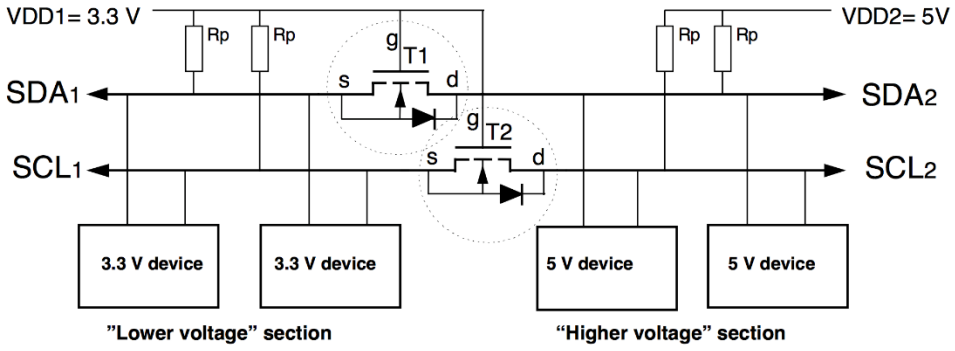


Figure 9 - Two LLC Circuits (Permission Pending from Phillips Semiconductors)

When the 3.3 volts device sends a signal the source becomes “low” while the gate stays at 3.3 volts. This causes the MOSFET to enter conducting phase, which allows the 3.3 volt device to bring the “higher voltage” section down to low. This brings the voltage level on both sides to the same level, allowing the devices to communicate. When the 5 volt device

sends a signal, the voltage on the source side of the MOSFET is pulled down via the diode in the MOSFET. This causes the MOSFET to enter conducting phase that pulls the voltage on the source side further down to low. With both voltages low, the devices can communicate.

It is possible to use the same circuit for different voltages such as 2 and 10 volts. The only restriction is that the lower of the two voltages be on the source side, and the higher voltage on the drain side of the MOSFET. There also needs to be a connection between the gate and the lower reference voltage.

4.2.9 Facial Recognition

For the human brain, facial recognition is a simple task that can be accomplished instantly. However, with computers, a machine learning approach must be used to recognize and identify various faces. The overall process can be divided into four main steps which can be implemented and tested separately during development.

The first step in facial recognition requires obtaining an image and locating the face. This first step can be completed using various algorithms which rely on the same general principle. Initial setup for face detection algorithms rely on obtaining a greyscale image to simplify operations. In the early 2000's, the Viola-Jones methodology was a popular method which relied on iterating common masks over the input image to first detect regions of the face, such as the bridge of the nose or cheeks, which were common among every face. The algorithm would then create an integral image to simplify operations in the future, train classifier through the use of the Adaboost training methodology (to be later explained), and finally using a series of cascading classifiers to determine if the input image does or does not contain a face.

Alternative to the Viola-Jones face detection methodology is a more recent method called Histogram of Oriented Gradients, HOG, developed in 2005. As previously mentioned, this method also relies on an input greyscale image so that the gradients may be calculated and compared. By iterating through each pixel and making a comparison to its neighboring pixels, a gradient magnitude and direction can be calculated. The magnitude directions are typically divided into 8 sectors of 45 degrees each. The HOG methodology points the magnitude direction in the direction of decreasing intensity, or increasing darkness. Using the magnitude directions removes the dependency on the brightness of the image, so as long as the main features of the face are visible, they will be detectable in both low light and bright light situations. Since storing each pixel gradient is unnecessary to accurately identify a face, pixels are groups into blocks of 16x16 and assigned the dominant magnitude direction. By comparing this final magnitude image to known patters of training images, identifying the location of the face within the image becomes trivial.

The second step in facial recognition requires face landmark estimation to account for the fact that the user's face will not be perfectly aligned, and then transform the image to be as centered as possible. By identifying key features along the chin, eyebrows, etc., the main features can be rescaled and translated to the center. This creates a baseline standard image which can be used to compare against other faces.

The third step requires encoding the faces to a neural network based on the second step's output of main facial features. By operating in sets of three, the algorithm will compare the image of a known person against a second image of the as well as a separate person. The

neural network is built by ensuring that there is a difference between each person's face identifiers and embedding the measurements for each face. Each person is mapped to a unique set of 128 numbers which can then be compared to the input image in step four.

The final step of facial recognition is simply comparing the input image against the known set of trained classifiers. Once the network has been trained with the correct values as described in step three, the final step will quickly calculate the classifiers for the input image, compare against the populated network, and return the identity of the face.

Feasibility of neural network implementations on microcomputers will be investigated to determine if processing specifications are up to par. In many instances where microcomputer facial recognition is implemented, database training is performed using an outside computer source with a high spec GPU where computed training results are then transferred to the microcomputer for reference only.

Alternative methods to neural network implementations include the use of face databases to compare an input image to each reference image within a database based on specific traits. OpenCV includes libraries which analyze such traits. Eigenfaces, Fisherfaces, and histogram patterns can be used to detect and compare face images and are further discussed in Section 7.4.

5 Related Standards and Realistic Design Constraints

The following sections describe various standards and constraints associated with this project. It is important to keep standards in mind during the design process in order for our project to be up to industry par. It is also pertinent to understand the constraints involved so that the process can go smoothly with no sudden surprises.

5.1 Related Standards and Impact

There are a multitude of standards that must be abided by in the process of designing a project, and many constraints that must be recognized and worked with. Our group took the time to research a few of the standards that directly impact our project and they can be seen in the Standards section below. We recognized what kind of constraints may arise from the project based on the nature of the required components and operation of the various subsystems.

Within the corporate engineering environment, numerous standards must be applied to the new technology and devices developed by the engineering and technical employees. By abiding with the set of standardized rules, product safety, compatibility, consistency, and repeatability are enforced for these products. As a precursor to industry development, it is crucial to understand the research process required to develop a new product compliant with the established legal standards.

5.1.1 USB 2.0

Universal Serial Bus (USB) is the standard that details the cables, connections and communication protocols for a bus that can be used for communication and/or power supply between electronic devices. The Raspberry Pi is powered using a Micro USB cable so this standard is relevant to the project. For this project the USB Power Delivery section of the standard is most applicable. This standard offers some useful features in regards to the power delivery capabilities of USB. It can deliver up to 100W, power flow is bi-directional, optimizes the flow of power, and can also be used in low power situations. The most useful feature for this project is the optimized flow of power. This means that only the power needed to run a device is sent through the cable. When the mirror is not in use, the Raspberry Pi will draw less power is less of the devices connected to it will be using energy. Once the mirror is in use, the Pi will need more power drawn for the power supply.

5.1.2 RS232

RS232 is the standard set by Electronic Industries Association (EIA) that relates to serial communication transmission of data. The standard defines signal characteristics such as voltage levels, timing, slew rate, signaling rate, short circuit reactions, and cabling standards. This standard is applicable to the project as the ATmega328 microcontroller and Raspberry Pi microcomputer will communicate with each other via serial communication. The selected components, to be later discussed, implement the RS232 standard natively through the UART embedded modules.

5.1.3 IEEE 802.11 (Wi-Fi)

802.11 is the standard set by IEEE regarding the use of Wi-Fi. The standard allows the transmission of signals over the 2.4 GHz ISM band in the US. This standard allows all

devices, regardless of manufacturer, to communicate with each other wirelessly. This project will use a Raspberry Pi that has a Wi-Fi chip, so this standard is applicable. We will use the Wi-Fi connection to connect to the local network to obtain data from multiple sources for display on the mirror. Adherence to this standard has been met through association as the manufacturers of the Raspberry Pi have developed the board with a 802.11 compliant chip. Specific implementations of the standard will not require design from the ground up and are reliant on the certified compliance of the device when it was released to the market.

5.1.4 IEC 60269

IEC 60260 is the engineering standard that applies to the use of fuses to protect a circuit. The volume that is applicable to the project is "IEC 60269-5 – Guidance for the Application of Low Voltage Fuses". This section explains how to apply fuses to your circuits in order to protect your electronic equipment or electrical devices. This is the first time the engineers in the team have designed a power distribution system so a fuse will help to ensure protection in case there is a fault in the design. When the PCB is designed, circuit protection will be kept in mind, and a fuse will most likely be used in this way.

5.2 Realistic Design Constraints

When taking on any project, one must always consider the constraints involved. These are what will limit the project in ways that typically cannot be controlled. Due to the nature and setting of this project many constraints arise. The following sections will discuss these constraints in detail.

5.2.1 Economic and Time Constraints

The economic and time constraints are two of the strictest involved with this project. At the beginning of the semester the team met to decide on an appropriate budget by listing all known needed components and their estimated price. The totals came out to approximately $700. Due to the fact that the project is to be financed by the four members of the team, with no outside sponsors, it is pertinent that the budget is followed. This constraint will be considered when selecting specific parts, and the pros and cons of more expensive components will be evaluated before a decision is made. Time constraints of a project typically involve relevancy or strict deadlines that need to be met. Our project is constrained by the former, as it must be completed in the time frame of Senior Design's two semesters. This gives about eight months of time to complete the project, not including the time that must be taken to maintain good standings in other classes and to fulfill work and internship commitments. This short time frame is shorter than a typical product development timeline, which means the group must work efficiently and diligently.

5.2.2 Environmental, Social, and Political Constraints

There are no environmental constraints involved in this project due to the device being used indoors. There are also no political constraints involved. Social constraints arise from the presentation of social media and information related to users. The device will display information associated with the user interacting with it, but it should not show information about other users of the Smart Mirror for privacy reasons.

5.2.3 Ethical, Health, and Safety Constraints

The ethical constraints of this project relate to privacy issues. The device has the ability to display information about a user including their social media feed, calendar of their events and appointments, and will store images of the user for facial recognition functionality. To maintain user privacy, this information should only be displayed when that user is interacting with the mirror. No other user should have the ability to access that data. Health and Safety constraints pertain to the use of electronics. There should be no exposed components that could cause and harm to the user.

5.2.4 Manufacturability and Sustainability Constraints

The manufacturability constraints of the project involve the limited access to resources and machinery. Material must be budget friendly and the project is assembled by hand, not machine, so precision is not guaranteed. As for sustainability constraints, the device should be easily repaired with replacement parts if needed.

6 Project Hardware

These next sections will be related to the hardware components of the project. The first part will explain all the hardware subsystems that make up the project. The next sections describe the process of searching for, comparing, and selecting components required for this project. The last sections will also explain the testing done with each component in order to ensure it is suitable for the needs of the project.

6.1 Subsystem Overview

The Smart Mirror has been divided into five main subsystems divided by functionality and purpose. As shown in Figure 10, multiple separate components are used to contribute towards the goals of the system and provide a complete functioning project.

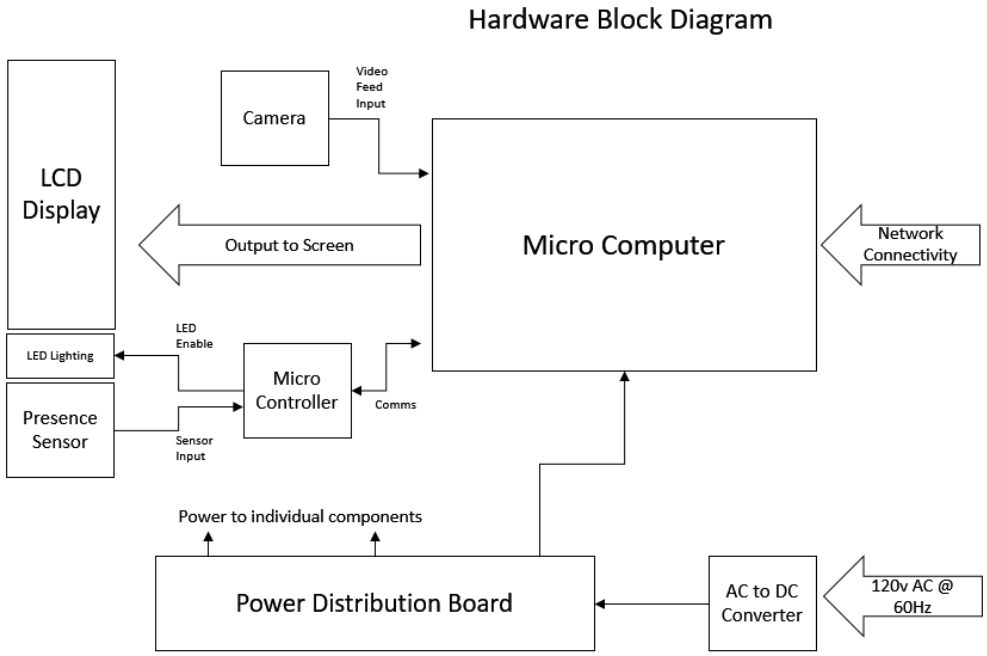


Figure 10 - The hardware block diagram illustrates each of the main components of the Smart Mirror including inputs and outputs.

The overall system has been separated into the five following subsystems: Power Distribution, Operational Software, LED Lighting Control, Sensor Input, and Serial Communication.

The power distribution subsystem will be responsible for providing the correct power to all other subsystems. The components of the subsystems all require various voltage and current levels, so the power circuit must be able to supply multiple voltage rails and handle a specific load current. This will require the use of voltage regulators to maintain constant power rails. A 12V, 5V, and 3.3V rail will need to be provided. In the following sections, work was done to determine whether switching or linear regulators were most suitable for each rail. By using multiple voltage rails, the subsystem will also meet the requirement of having only one power cord going into the Smart Mirror.

Another aspect of the power distribution system will determine the types of connection used to provide the power to each component that needs it. Devices that will be mounted on the PCB can be connected using traces, but many of the modules in this project are separate from the PCB board. The various kinds of connections will be compared, and the most suitable for each module selected and tested.

The operational software subsystem consists of the programs running on both the microcomputer and microcontroller. The ATmega microcontroller software continuously runs to obtain sensor data and control LED output while the Raspberry Pi microcomputer processes the network data inputs to create a visual output on the display for the user.

The serial communication subsystem ensures that the previous subsystem, the operational software, is capable of communicating via UART between the microcomputer and microcontroller. With both devices aware of the status of the system, the devices can operate in an efficient manner and avoid continuous computations when no user is present.

The LED lighting control subsystem consists of the interactions between the photocell, ATmega, and the LED control circuitry. Based on the sensor readings from the photocell, the ATmega will determine the optimal light setting pulse width modulation to provide to the control circuitry for the conditions at that specific period of time.

The sensor input subsystem categorizes the interaction between the microcontroller and the presence sensor used to determine if a user is present in from of the mirror. By preprocessing the gestures and sending the

The following sections outline the selection of components comparison for each subsystem. Additionally, tests for each of the subsystems, including individual components, are used to verify the functionality performs as expected.

The final hardware implementation will combine all subsystems into the same finished product enclosure. Figure 11 addresses the component placement within the mirror frame. On the exterior of the frame, the LEDs will be mounted vertically along the right and left perimeter to illuminate the users face. The photocell light level sensor circuitry will exist at the top of the frame to obtain light level readings of the current environment the mirror is placed in. The camera module, which will be used for face detection and recognition, will be placed at the center top of the frame where the best vantage point of the user will be available. The gesture sensor, used to detect the presence of a user, will be placed at the bottom of the assembly for ease of reach as well as ensuring the infrared light is capable of detecting the user mid mass.

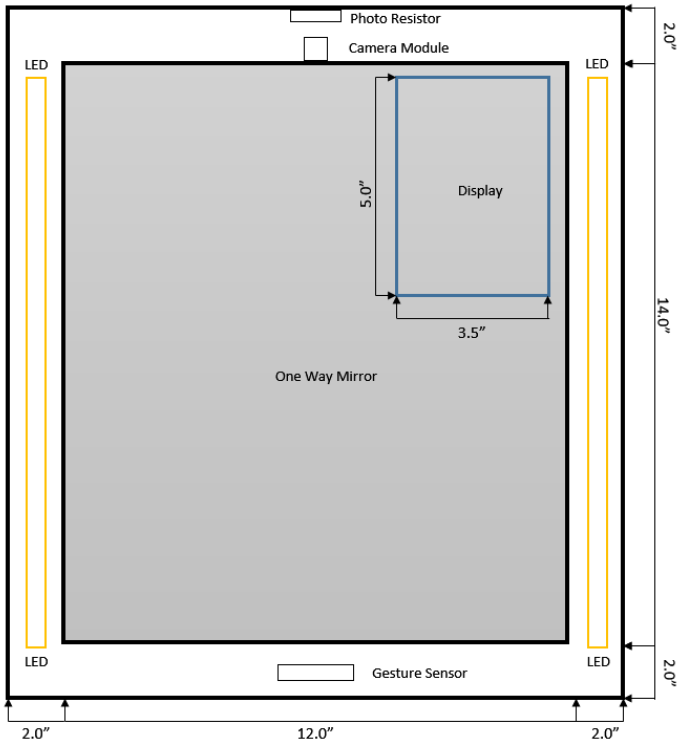


Figure 11 - The Smart Mirror schematic layout defines component location and dimension

6.2 Part Selection Summary

The following part selection summary is used to describe the comparison between multiple potential components for use within the Smart Mirror. By considering each of the components which are currently available on the market today which meet the requirement specifications, individual comparisons permit a complete understanding of the products available, including the cost, functionality, limitations, and inter-compatibility between each of the devices.

6.2.1 Power Supply

When selecting components for the Smart Mirror power supply there were a few requirements that were kept in mind. Because the mirror is to be mounted to a wall, the supply of power is to come from a wall outlet using an AC to DC converter. The output needed to be 12 volts in order to supply appropriate voltage for the LEDs subsystem. For the other subsystems, 5 and 3.3 voltage is required. To deliver these various voltages to the Smart Mirror voltage regulators needed to be selected in order to create the necessary power rails. Table 3 shows the voltage requirements of the project components.

Table 3 - Voltage Requirements of Components

Component	Voltage
ATmega328	1.8-5.5 V
Raspberry Pi 3	5 V
LED Strips	12 V
Gesture Sensor	5 V
LLC Circuit	3.3 V, 5 V

6.2.1.1 Five Volt Regulator

Two voltage regulators are needed for this project, one regulator to supply 5 V and one to supply 3.3 V. The 12 V needed for the LED subsystem can be pulled from the input voltage so no regulator is needed for that rail.

The 5 volts rail is the most demanding. It will supply power to the Raspberry Pi, ATmega328 chip, the gesture sensor, and the logic level converter circuit. When deciding on which regulator to used various components were considered, both linear and switching. The components considered were TI's LM2596 switching regulator and TPS6213 switching regulator, as well as STMicroelectronics' L78S05 linear regulator. When choosing a regulator, the following parameters were considered: input voltage, output voltage, output current, efficiency, number of supporting components, the unit price, and availability. The comparison between these three regulators can be seen in Table 4.

Table 4 - Comparing 5V Regulators

Parameter	LM2598	TPS6213	L78S05
V_{in}	4.5V - 40V	3V - 17V	10V – 35V
V_{out}	5V	5V	5V
I_{out}	3A	3A	2A
Efficiency (At 12 V)	80%	~85%	~42%
Number of Supporting Components	4	6	2
Price	$5.72	$2.74	$0.68

When deciding on a regulator, the biggest parameter to take in consideration is the efficiency. The values for the LM2598's and TPS6213's efficiency were taken from the datasheet. For the linear regulator the following equations were used for the calculations.

$$Efficiency = \frac{Output\ Voltage}{Input\ Voltage}$$

$$Output\ Voltage = Input\ Voltage\ \times\ Output\ Current$$

$$Input\ Voltage = Output\ Voltage\ \times\ Output\ Current$$

As seen in the table the switching regulators are about double as efficient as the linear regulator. For this reason, the linear regulator was not chosen. Choosing between the other two switching regulators required further investigation as their efficiencies were within 5% of each other. One difference is the input voltage requirements. The LM2598 works at a large range of 4.5V – 40V, whereas the TPS6213 has a smaller range of 3V – 17V. The project is to operate at 12V, which is close to the upper limit of the TPS6213. If the input voltage was to spike, the component could be damaged and cause malfunction in the project. Also, the power for the project comes from an AC/DC wall adapter. It is possible a user could use an adapter with a higher output voltage. The high input voltage limit of the LM2598 reduces this risk.

The other factors researched were the number of supporting components required and the price. There are more supporting components required for the TPS6213 as compared to the LM2598. This increases circuit complexity for the power supply circuit as well as more space on the PCB. The prices for the regulators are $2.74 for the TPS6213 and almost double, $5.72, for the LM2596. After taking all these factors into consideration the LM2596 was chosen as the best component for this project. The main reason for this decision was the simplicity of the component and supporting circuit compared to the TPS6213. Even though the efficiency is less, 80% is still very good and the component appears to be worth the price.

6.2.1.2 3 Volt Regulator

The logic level converter circuit requires 3.3V along with the 5V as a reference in order to allow the ATmega328 and Raspberry Pi to talk. A few options were researched with similar parameters to those of the 5V regulators. Because the LLC circuit draws such little current, the efficiency is not a big factor. This comparison can be seen in the Table 5.

Table 5 - Comparing 3.3V Regulator

Parameter	TLV1117	MCP1700	TPS61097
V_{in}	4.7V - 15V	0V – 6V	0.9V – 5.5V
V_{out}	3.3V	3.3V	3.3V
I_{out}	800mA	250mA	200mA
Number of Supporting Components	4	2	3
Price	$0.62	$0.37	$2.26

As previously stated, power efficiency is not a big factor for this regulator because the load current is very small, and the difference between the input and output voltage is also small.

So with that in mind TI's TPS61097 was out of consideration. The two linear regulators, TI's TLV1117 and Microchip's MCP1700 are very similar with just a few differences. The MCP1700 was chosen for this project due to its simplicity and price. The circuit only involves two bypass capacitors, whereas the TLV1117 requires 3 capacitors and a diode. The MCP1700 is also half the price of the TLV1117

6.2.1.3 Power Supply Connection to Raspberry Pi

In order to operate the Raspberry pi, as well as the display monitor, 5V and 2A need to be supplied to the microcomputer. There are two ways to power the Raspberry Pi, through the Micro USB port, or directly through the GPIO. Table 6 shows the pros and cons of each method.

Table 6 - Raspberry Pi Power Connections

Parameter	Micro USB	GPIO
Circuit Protection	Yes	No
Number of Cables	1	2
Estimated Price	~$8.20	~$0.36

Based on Table 6, the Micro USB connection type was chosen. The major motivation for this decision was the circuit protection the Micro USB port of the Raspberry Pi provides in the form of a fuse and a TVS diode. Because this is the group's first attempt at designing a power supply, this avoids the risk of damaging the Raspberry Pi. Though the price is much higher due to the cost of USB cables, the benefits were deemed worth the cost. Micro USB male to Micro USB male cables are not vastly manufactured, so a USB 2.0 to Micro USB cable was purchased along with a USB to Micro USB adapter to connect the PCB and the Raspberry Pi. It should be noted that the USB connection is only used for power, not data will be transferred along these lines.

The type of connection port, which would be on the PCB, would also need to be selected. USB connectors and ports come in a variety of styles. In order to save space, a Micro USB port was selected. Not only is Micro USB smaller than USB A, it is also cheaper due to the need for less material. The only drawback to using a Micro USB connector is the cable that would be needed. Micro USB to Micro USB cables are not readily available. However, the group already owned a Micro USB to USB A cable, as well as a USB A female to Micro USB male adapter. These two parts combined form the cable needed in order to power the Raspberry Pi. Care should be taken during testing to ensure that no power is lost over this cable created. If necessary, the two parts can be spliced together to form a better connection.

6.2.1.4 Power Input Connector

The power supply circuit needed a connector for the AC to DC converter to provide the input voltage of the circuit. There are a few different options available for DC connectors. The first is the coaxial power connector. This is the most common type of connector and is typically used to connect cables to power supplies. The plug on the cable is only one pin, which is inserted into a "barrel". There are many different sizes, with the most common

being a 5.5mm outside diameter. This type of connection can be connected and disconnected without much difficulty.

The next type of connection is a Molex connector, which is typically found in computer applications. These connectors have either 3 or 4 pins and have a tighter connection, using spring metal sockets.

The last type of connector considered was a JST connector. JST is the company that produces these connecters, as well as many other types of connections. They feature two pins, VCC and ground. Like the Molex connector, the connection is very strong and often difficult to disconnect.

The coaxial power connector was selected as the best option for the project. The ability to easily disconnect the power cable from the mirror allows for it to easily be moved and carried. The JST connectors would not be suitable, as the more the user disconnects and reconnects the cable, the more likely the connection is to become damaged. The coaxial connector is also more readily available, meaning it is easier to repair or find a replacement for should it sustain any damage.

6.2.1.5 AC to DC converter

An AC to DC wall plug converter is needed in order to provide input power to the power supply circuit. There were a few requirements needed from this component. The output needs to be 12V fixed in order to provide enough voltage for the LED circuit. The provided current also needed larger than 3A to meet the needs of the LED circuit and power supply circuit. The other stipulation was the output side of the cable needed to be a DC coaxial power plug in order to be compatible with the input port selected for the power supply circuit.

The benefit of using an AC to DC power supply is they are very common and can be found in most hardware stores. This allows us to save money by avoiding shipping costs for an already expensive component. The hardware store offered a variety of AC to DC converters ranging from 1.8V to 15V. Each of the different voltage outputs also had a variety of different current ratings. There were three options available with 12V output and a comparison can be seen in Table 7.

Table 7 - Comparison of AC to DC converters

	Option 1	**Option 2**	**Option 3**
Output Voltage	12V	12V	12V
Output Current	2.8A	4.58A	9A
Connector	Coaxial power Plug	Coaxial power Plug	2-Pin Connector
Length	2 ft.	6 ft.	6 ft.
Cost	$16.62	$17.95	$23.95

Option 2 was selected as the best AC to DC converter for this project. It fits all the needed parameters and is moderately priced. Option 1 does not provide enough current and at only 2 ft. it would limit the placement of the mirror in a home. Option 3 almost meets the

parameters except the connector was not correct. A coaxial power plug could be spliced onto it, but the output is more than needed for this project and it was also the most expensive option. For these reasons Option 2 was chosen. Upon purchase, the hardware store provided, free of charge, the cable that connects from the wall outlet to the AC to DC converter. This cable is also 6 feet giving the mirror the capabilities to be mounted within 12 feet of any wall outlet.

6.2.1.6 Switching Regulator Supporting Circuit

The 5V regulator selected is a switching regulator, which means a more complex supporting circuit is necessary for operation. The LM2596 5V Switching Regulator selected requires two capacitors, a diode, and an inductor for typical operation. This section will describe the process of selecting which variation of each component needed was selected based on the recommended components section of the datasheet for the LM2596.

The first capacitor needed is the input capacitor, C_{in}. This capacitor is needed to avoid significant voltage transients at the input from affecting the switching regulator operation. This capacitor needs to be either aluminum or tantalum, with a low ESR. The most important parameters as listed by the datasheet are the voltage rating and the RMS current rating. The voltage rating of the capacitor must be 1.5 times larger than the input voltage, and the RMS current rating 0.5 times the DC load current. The input voltage will be 12V so the voltage rating needs to be at least 18V, and with a 3A max load current the RMS current rating needs to be at least 1.5A. 18V rated capacitors are not manufactured, so the next highest, 25V, is chosen. Based on Figure 23 of the datasheet, the value of the capacitor must be 680uF due to the high load current.

The output capacitor is necessary in order to filter the output signal of the regulator, as well as stabilize the feedback loop. An electrolytic capacitor with low ESR is preferred. The most important parameters are the ESR value (the most important), ripple current rating, voltage rating, and capacitance The LM2596 provides a tool for selecting the correct capacitor with a low enough ESR, needing only the load current and max input voltage. For this project the max input voltage would be 15V and the load current 3A. With those parameters selected the tool provided two possible capacitors for best operation, Panasonic's HFQ series and Nichicon's PL series. Both capacitors are 330uF and have a voltage rating of 35V. The Panasonic HFQ, however, is discontinued. Being the only option left, the Nichicon PL series capacitor was selected. It should be noted Nichicon changed the naming from PL to PM. The specifications for this 330uF capacitor include a voltage rating of 35V, an impedance of 60mOhm, and ripple current of 810mA.

The LM2596 also requires a diode, as most switching regulators do. The purpose of the diode is to provide a path to ground for the current of the inductor while the switching regulator is "off". The diode must be fast due to the high switching frequencies, so the datasheet suggests a Schottky diode. The reverse recovery time should be at most 50ns. Using the diode selection tool provided by the datasheet, the 1N5823 diode was selected. This diode has a current rating of 5A and a voltage rating of 20V.

The last component that needed to be selected for the switching regulator supporting circuit is the inductor. Figure 12 is taken from the LM2596 datasheet and shows how to select the appropriate regulator. To use this tool, you select your input voltage and output load current. Where those two parameter lines intersect shows which inductor identifier is the

best option. With an input voltage of 12V and load current of 3A, the intercept is in the L40 block. L40 in Table 1 of the datasheet gives possible options for inductor. The options listed were researched and compared in the datasheet. Pulse Engineering's PE-54040 was selected with the specifications of 33uH and 3.5A current rating.

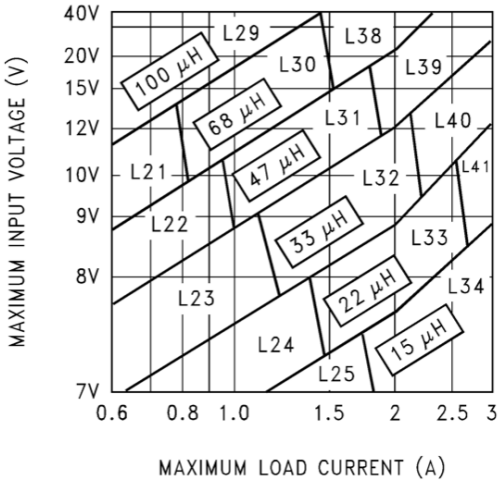


Figure 12 - Inductor Selection Tool from LM2596 Datasheet

6.2.1.7 3V Linear Regulator Supporting Circuit

The supporting circuit for the MCP1700 3V regulator is simpler than that needed for the switching regulator previously discussed. Typical application for the MCP1700 only requires two capacitors, which is standard for linear regulators. It is not absolutely necessary for these capacitors in the circuit, but for optimal operation, they are recommended.

The datasheet for the MCP1700 was referenced when choosing the appropriate capacitors. The capacitor on the input is needed in order to stabilize the circuit. This regulator is only to supply a reference voltage to the logic level converter, meaning it draws very minimal current. The data sheet says for current less than 100mA, so a 1uF ceramic capacitor is sufficient.

The output capacitor is beneficial for improving output signal stability. In applications in which the output current is no more than 250mA, a 1uF capacitor is sufficient. The datasheet allows for ceramic, tantalum, or aluminum electrolytic capacitors to be used. An aluminum electrolytic capacitor of 1uF was selected for this circuit.

6.2.2 Microcomputer Selection

Based on the desired specifications, options for the main controller board were narrowed down to three specific options. As defined in the project specifications, considerations towards the features offered by each of the following devices were used to determine the microcomputer board that would be best equipped for use within the Smart Mirror.

Initial considerations for a network enabled microcomputer led to the Arduino YUN, however this device did not meet key requirements for final selection considerations. The Arduino YUN is a microcontroller board built around an ATmega32u4 and Atheros processor supporting an embedded Linux distribution. With twenty separate I/O pins, this board would permit all of the necessary peripherals to connect and communicate, as well

as permit future expansion for any later add-ons. Additionally, the Arduino Yun supports network connectivity through both Wi-Fi and Ethernet connections, so it is capable of meeting the wireless capability requirements. While many of the hardware requirements are met by the Arduino YUN, this board fails to meet the desired graphic support for LCD screens. In order to properly display information to the user, the project requires an interface between microcomputer and display without large supporting hardware to render the graphics. For this reason, finding other System-On-a-Chip options was required to adequately meet the requirements of the project.

6.2.2.1 TI Beaglebone Black

The TI Beaglebone Black is a Linux based microcontroller manufactured using Texas Instrument's Cortex A8 Arm Processor. The board is equipped with the 1GHz processor running at a faster clock rate compared to that of the Arduino Yun and Raspberry Pi, and also includes 4GB of flash storage on board.

The Beaglebone Black's specifications are oriented towards robotic applications which focus on quickly processing inputs from various subsystems, analyzing the data, and creating decisions on what action to complete. Additionally, the 65 I/O pins available on the Beaglebone Black would be an excess abundance in comparison to the relatively few I/O pins required for the Smart Mirror

Although the Beaglebone has a powerful processor, the two areas for which the board will not be selected for the project include the lack of Wi-Fi and dedicated graphics support. The Beaglebone does support network connectivity through the use of an Ethernet port, however, as a requirement, the project will need to be wireless. The Beaglebone is capable of configuration with a wireless USB adapter, however, with past experience using the device, the connection can be unreliable and highly dependent on outside factors such as the chipset used within the USB adapter as well as the wireless router the device attempts to connect to. To alleviate the wireless connection issues, a board which natively supports wireless capabilities will hold much greater value.

The Beaglebone Black Wireless was not considered in this part selection. Due to the fact that the device was new to the market, lacked a user base to contribute to and request support, and the reliability of the Wi-Fi communication was largely untested, it was decided that considering alternative options was a reasonable decision. When developing a system, the reliability of each individual device is incredibly important, and since the computer board is not simply an extra peripheral whose failure would result in a non-functional system, options were comparted where operating characteristics and reliability were well established.

6.2.2.2 Raspberry Pi Models 2 and 3B

The Raspberry Pi, similar to the Beaglebone Black, is a Linux based microcomputer capable of running multiple distributions of embedded Linux releases. The Raspberry Pi holds many strengths with regards to the wireless capabilities, graphics support, hardware support, and processing power in comparison to the Beaglebone Black.

The dedicated graphics processing unit, a Broadcom VideoCore IV, is used to separate graphics processing from the system-on-a-chip processing. This approach frees the main processor to handle other tasks while the graphic output is handled by the dedicated chip. Graphic connections are not limited to using only the HDMI port on the board. The Pi also

supports a DSI (Display Serial Interface) using a zero insertion force socket for use with a wide range of supported displays.

The Raspberry Pi is a clear choice over the other options, however all of the features are not ideal. Power for the Raspberry Pi should be provided via the micro USB port and routed through the onboard voltage regulation circuit rather than directly providing power via header pins. In the schematic design and layouts, a USB power header will need to be included to work around this less-than-ideal operational requirement, unless such modifications are used to ensure a steady power supply will overload the board.

Table 8 – Microcomputer Considerations

Property \ Device	**TI Beaglebone Black**	**RPi Model 2**	**RPi Model 3B**
Price	$60.00	$35.00	$35.00
Processor	AM3358 ARM Cortex A8 @ 1GHz	ARM Cortex-A7 @ 900MHz	LPDDR2 ARM Cortex A53 @ 1.2GHz
Memory	512MB DDR3	1GB @ 400MHz	1GB @ 400MHz
Storage	4GB eMMC Built-In	MicroSD Expandable (Max 64GB)	MicroSD Expandable (Max 64GB)
Graphics	PowerVR SGX530	Dedicated VideoCore IV Graphics Chip	Dedicated VideoCore IV Graphics Chip
Networking	Ethernet + USB Wi-Fi Dongle	10/ 100mb Ethernet RJ45 + USB Wi-Fi Dongle	10/ 100mb Ethernet RJ45 + USB Wi-Fi Dongle + Bluetooth
GPIO PIN	46	40	40
USB Port	1	4	4
Power	300-600mA @ 5V	300-600mA @ 5V	300-600mA @ 5V
Power Supply	microUSB + GPIO	microUSB + GPIO	microUSB + GPIO
Logic Level	3.3v	3.3v	3.3v
Software	Debian, Ubuntu, Android	Raspbian, Occidentalis	Raspbian, Occidentalis

6.2.3 MicroSD Card Selection

The Raspberry Pi does not feature an onboard flash memory chip to store the operating system image and supporting data. This puts the responsibility of selecting a micro SD card to act as the storage device for the system on the engineer. The designer must unzip and install a system image file to the card from a personal computer, insert the device into the Pi, and from there the Pi is capable of reading the image, booting, and running. Without properly configuring, or by completely excluding the SD card, the Pi will fail to boot and pose no useful purpose.

In other applications, such as digital cameras, data is typically written to an SD card in consecutive order such that each storage block within the card is equally written to over the lifespan of the device. However, during operation in the Raspberry Pi, specific blocks may be grouped, assigned, and serve different purposes within the operating system. Where certain storage blocks may only be written to during the creation and installation of the system image, other storage blocks may be frequently written to and updated, such as where the operating systems stores user editable files. As a storage block degrades, the time required to read and write to that block will increase until it eventually fails.

Wear leveling refers to the process of redistributing the read/write load across the entire device such that the overall lifespan of the device is maximized with regards to the functionality of the storage blocks. In the case of the Raspberry Pi, an 8GB SD card is the minimum required storage size to hold the operating system image. However, if larger cards are selected such as 16GB or 32GB, the wear leveling process can allow the read and writes to be distributed across a larger storage footprint, effectively providing not only additional storage space for various files and media, but also increase the longevity of the device in high read/write applications. In this project, it can be estimated that a fairly average number of storage accesses will be used to run the operating system, and since the device will not be acting as a network based media file storage system as it is assigned in certain cases, wear leveling must be considered in a reasonable manner.

Additional configurations within the Raspberry Pi can be made to further ensure the longevity of the storage device. By disabling swapping, the SD card will no longer be used as an extension of RAM, therefore the read/writes will be decreased during normal operation. Journaling is a method which keeps track of changes before they are written to memory. By disabling journaling, the risk of losing data during a power failure is more prevalent, however in everyday use should pose no risk. By disabling the access time save feature of files, we will no longer save the time that each file was last read. The access time will be saved for files which are written to, but disabling this feature will stop saving it during file reads. Finally, by saving highly access directories in RAM, we can continually update the directory and push changes at less frequent intervals to the card.

Aspects of the project will be consistently rewriting data in the computer vision and network data retrieval for display, so wear leveling must be taken into account, but the limiting agent for the longevity of the system will most likely exist as a separate component if the proper considerations are taken into account in advance. Since SD cards do not notify the user of failed data operations and return no I/O error, advanced planning can save extensive debugging later in development.

Potential SD card options were selected based on the current on-hand card options and operational recommendations based from the eLinux reference table outlining Raspberry Pi compatible SD cards. Each of the following cards listed in Table 9 have been verified to work with the Pi and the selected Linux release.

Table 9 - MicroSD Card comparison for Raspberry Pi operating image

	SanDisk SDSQXNE-016G-GN6MA	**Samsung MMAGR08GUDCA-DB**	**Sony SR-16UYA**
Price	$8.95	$6.00	$15.00
Size	16GB	8GB	16GB
Transfer Speed	Up to 90MB/s	Up to 24MB/s	Up to 40MB/s

For final implementation, the SanDisk SDSQXNE-016G-GN6MA will be used to run the image. This cards offers a low cost ratio with respect to the available storage and transfer rates in comparison with other models available on the market. During initial first semester testing of the Raspberry Pi, the smaller 8GB Samsung model will be used to limit the overall number of read/write accesses to the SanDisk since numerous developmental changes will be continuously being made. Once the final implementation of the operational image has been established with the development card, the image will be installed to the larger capacity release card where performance statistics will be expected to increase. Naturally, proper care will be taken to test the final card in stages throughout development to limit any unforeseen compatibility issues.

6.2.4 Presence Sensor Selection

An ultrasonic method of detecting the user was determined to be a non-ideal approach. In order to obtain data readings from the sensor, a minimum of 2 lines are required: Trigger and Echo. The sensor requires a trigger signal be sent at regular intervals to emit a high frequency sound pulse, and the Echo signal provides the microcontroller with a voltage representing the distance calculated from the time between the propagation of the pulse and the detection after reflection. Such data readings require constant polling of the sensor by the microcontroller. The additional continuous computation results in the microcontroller requiring additional power during periods of no operation while a user is not present.

A passive infrared motion sensor was an additional consideration for detecting users within the immediate vicinity. Typical applications for sensors such as these include motion activated outdoor lights or security systems. This PIR sensor's sensing capabilities range up to 20 feet with adjustable sensitivity and time delays between detection signal outputs. Similar to the other sensors, it favors 5V but can be modified to accept 3V power supply inputs. Although the relatively long range of the sensor may seem to be a favorable option to implement, typical use cases of the mirror will range within one to two feet, so activating features for users in excessive distances would prove illegitimate. This sensor was also decided against due to the lack of multi-purpose use in comparison to the ZX Sensor.

Table 10 – Presence Sensor Considerations

	Ultrasonic Sensor HC-SR04	Passive IR Motion Sensor	ZX Distance Gesture Sensor
Price	$15.00	$10.00	$25.00
Communication	Analog Value Output	Analog Value Output	I2C Serial
Range	0-13 feet	0-20 feet	0-24 inches
Data Types	Distance Only	High/Low Signal for Presence Detection	Distance, Right + Left + Up Swipes, X Hover Position

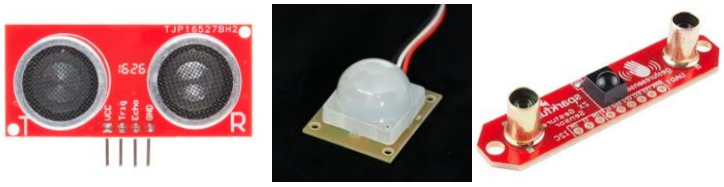


Figure 13 - Presence Sensor Considerations. Pictured from left to right, Ultrasonic HC-SR04, PIR Module, ZX Gesture Sensor (Reprinted with permission from Sparkfun)

6.2.5 Camera Selection

As a requirement, the mirror will be capable of loading user-specific data to the output display through the use of facial recognition. In order to recognize the user, a camera will be used to feed images to the Raspberry Pi for further processing. The quality, size, and price of the camera have played a role in the selection process

6.2.5.1 Logitech C920 Webcam

The Logitech C920 Webcam is a high definition webcam commonly used in embedded platforms for facial recognition and video streaming. Equipped with H264 encoding, the data stream can be compressed for transmission and allow for a high quality video at high frame rates on the receiving end. Such compression methods put less demand on the computing system since the camera is handling compression methods rather than the OS. While the devices boast high specs and has been commonly used for real-time systems, in the application of this smart mirror, the high price, large footprint, and heavy weight all limit the feasibility of implementing the device.

6.2.5.2 HP Webcam 2100

The HP Webcam 2100 is an entry level webcam intended for conventional PC use. Developed in the mid 2000's the specifications for the device lack up-to-date performance in comparison with the other options. This webcam was considered due to the lost cost and USB interface in the event that USB data transfer of images was desired for later testing. Image formats for the device lack in comparison to the more up to date options available on the market and image/video capture resolutions and pixel formats exist at the minimum threshold desired for face image capturing. The webcam is supported by embedded Linux

distributions and would be capable of running with the selected microcomputer, albeit with a less than spectacular quality.

6.2.5.3 Camera Module v2 for RPi

The Raspberry Pi Camera Board is a camera module developed specifically for use with the Raspberry Pi. At 8 megapixels, this camera will be capable of providing adequately sharp images of the user's face for further image processing. Since it is developed for use specifically with the Raspberry Pi, the board is natively supported with the Raspian releases of embedded Linux.

This camera module features high specifications for such a small package that is roughly the size of a quarter. While other options may feature better quality images, the small size of this module lends itself well to creating a compact mirror assembly.

Table 11 – Camera Considerations

Property \ Device	**Camera Module v2 for RPI**	**HP Webcam-2100**	**Logitech C920**
Price	$30.00	$30.00	$98.00
Size	25x25x9 mm	2.5x2.5x2.5 inches	3x7.5x8 inches
Weight	3 grams	30 grams	450 grams
Resolution	8 Megapixel	8 Megapixel	15 Megapixel
Sensor	Sony IMX219	1.3MP CMOS	Proprietary
Horizontal FOV	53.5 degrees	52 degrees	78 degrees
Vertical FOV	41.41 degrees	40 degrees	43 degrees
Image Formats	JPEG, RAW, GIF, BMP, PNG, YUV420, RGB888	JPG, BMP, PNG	JPEG, JPG, BMP, IMG, TIF, PSD, GIF, PNG
Video Capture	1080p30, 720p60, 640x480p60/90	640x480p60	1080p60,720p
Linux Integration	V4L2 Driver	V4L2 Driver	V4L2 Driver
Front LED	No	Yes	Yes
Physical Interface	Camera Serial Interface via Ribbon Cable	Universal Serial Bus 2.0	Universal Serial Bus 3.0

Figure 14 - Camera considerations included both webcam and board device models. Pictured from left to right, Logitech C920, HP 2100, Camera Module v2

6.2.6 Display/Monitor Selection

The Smart Mirror will need a display or monitor of some sort to be able to show the information gathered for the user on the mirror itself. Even though it is one of the simpler components to the project, a significant amount of time and effort was put forth to make sure the display selected would be compatible for our application. Also, it also needed to fit the specifications set forth at the inception of the project. The remainder of this section goes through the various specifications of different options that were looked into for the selection of the display for the Smart Mirror.

6.2.6.1 7-inch Touchscreen Display

The first option considered was the "7-inch Touchscreen Display for Raspberry Pi" from Adafruit. One of the first downsides noted in the title of this option is that fact that it is a touchscreen display. Since the display is mounted behind the mirror itself, the touchscreen feature included with this display will be unusable. However, this seems one of the only disadvantages to this display. The cost is comparable to the other options mentioned in this section as shown in TABLE XX. The "7-inch Touchscreen Display for Raspberry Pi" is a little smaller than the mirror but it would still be large enough to display the information that is to be displayed on the Smart Mirror. The text and figures will also be able to be seen clearly and legibly from the distance the Smart Mirror is to be intended to be used.

6.2.6.2 Secondhand Computer Monitor

The next option considered for the Smart Mirror display was to go to a local computer recycling shop. The local shop closest to UCF is "Orlando Computer desktop recycling and disposal". This is one of the lower cost options. Since the displays at this location are used from various companies and IT departments, it is also possible to have some defects and/or malfunctions for our display. This is just one of the downsides of this particular option. However, one of the advantages to selecting this route is that if the display were to malfunction or have a defect it would again be relatively cheap to replace the display on the Smart Mirror with a 'new' used monitor. In regards to shipping time, this was a likely option as well since the monitor would be able to be picked up the same day. It would also be helpful to know exactly the ports that the monitor is equipped with. The way the monitor will interface will be very important when it comes to piecing all of the subsystems together.

6.2.6.3 13.3-Inch 1080p LED Widescreen HDTV

The final option considered was to purchase a display directly off of the internet. Preferably a vendor with an excellent track record, especially when it comes to shipping and the quality of the product. Also keeping costs in mind, this solution could cost significantly more than the rest. One of the options looked at was the "SuperSonic 13.3-Inch 1080p LED Widescreen HDTV" from SuperSonic with the order being filled by Amazon. This particular monitor has an HDMI port to be able to interface with the Raspberry Pi 3. The power to the monitor is another specification that was closely monitored while choosing the display. The fact that most monitors available on the internet require a separate power source and cable could potentially be an issue when making the final decision.

Finally, from the options explained in the above portion of this section, it was fairly simple to come to an efficient and sensible choice. That is, the "7-inch Touchscreen for Raspberry Pi" from Adafruit. This solution offers the best quality, cost and size for the application at

hand. The other possible routes that could have been taken for this would have been too expensive or too poor of quality. One of the specifications also states that the Smart Mirror should be powered by one single cable. The "7-inch Touchscreen for Raspberry Pi" also fulfills this requirement by receiving its power and display information through one single cable connected to the Raspberry Pi. This completely eliminates the need to power the display from a 120V outlet or any other external power source. While the other options all required external power supplies.

Table 12 – Display Considerations

	7-inch Touchscreen for Raspberry Pi	Orlando Computer desktop recycling and disposal	SuperSonic 13.3-Inch 1080p LED Widescreen HDTV
Cost:	$$	$	$$$
Size:	7-inch	Varies	13.3-inch
Power Source:	Raspberry Pi	External	External
Display Connection:	DSI	HDMI/VGA	HDMI
LCD or LED:	LCD	LCD	LED

6.2.7 LED Lighting Selection

Various types of LED strips were considered in an effort to obtain a product that would not only be cost efficient but also meet the needs of the facial recognition feature without consuming a significant amount of power. Table 12 shows a brief comparison of the options considered for the different types of LED strips looked at.

6.2.7.1 DotStar Digital LED Strip

The first option considered for the LED strip was the DotStar Digital LED Strip from Adafruit. This LED strip requires a digital input signal. This is due to the fact that this kind of LED strip has individual drivers for each of the RGB LEDs on the strip. These are used to control each of the colors within the individual LED. The RGB type is an LED that can output a variety of different colors by combining red, green, and blue light together. This was considered as one of the options for the project in an effort to provide a pleasing aesthetic feature to the Smart Mirror. It could also provide the user with a unique experience with different color mood lighting.

The consideration of have a digital LED strip on the Smart Mirror opened up more issues regarding functionality and cost. Yes, it would be very nice to the customer to have a cool ambient light when walking into the room. However, it would also cost the producer of this product more money and resources to do so. Not to mention, the functionality of the Smart Mirror could be potentially hindered if certain colors of mood lighting from the LEDs were not sufficient enough to illuminate the users face for accurate and reliable facial recognition. These are just some of the drawbacks when looking into this type of LED strip for the Smart Mirror.

6.2.7.2 Standard Density (30 LEDs/m) LED Flex Strips

The next option reflected upon for this project was the "Standard Density (30 LEDs/m) LED Flex Strips" from LED Supply. Since these LEDs are only comprised of a simple white surface mount LED, there is no need for them to be driven by a driver to control different colors. A simply PWM/analog signal can be used to modulate the power to the entire LED strip.

Only two connections on the LED strip are needed to operate the strip to its maximum potential. Whereas, on digital strips, there are normally 3 or 4 connections needed to operate the LED strip to its maximum potential. Since the LEDs can be driven with an analog signal, a MOSFET can be used to switch the LED on and off with a low current 'high' signal coming from a microcontroller. One of the only downsides to this option is the lower brightness level it provides, even at full power. This LED strip only offers about 300 lumens of light, where the next option described below provides double that amount of light!

6.2.7.3 Cool White LED Weatherproof Flexi-Strip 60 LED

The final option researched was the "Cool White LED Weatherproof Flexi-Strip 60 LED", which can also be found from Adafruit. This is an analog solution and can be very easily implemented into the PCB design of the Smart Mirror. As explained in option 2, it is much easier to interface with the analog type of LED strips. A single MOSFET can be utilized in conjunction with a PWM/analog signal coming from the microcontroller to turn the LEDs on or off, or even dim them. Minimal parts and wiring would be needed to run this LED strip.

As mentioned in the option 2 description above, this LED strip is much brighter than the rest of the options. This provides the Smart Mirror with the ability to provide enough light to the users face in order for the camera to accurately and quickly recognize the user.

Table 13 – LED Strip Considerations

	Adafruit DotStar Digital LED Strip - White 60 LED	Standard Density (30 LEDs/M) LED Flex Strips	Cool White LED Weatherproof Flexi-Strip 60 LED
Color of LEDs	RGB	White	White
Brightness (Lumens per meter)	~419	~300	~600
Analog or Digital	Digital	Analog	Analog
Max Current Draw (Amperes)	~60m (per RGB LED)	~20m (per white LED)	~20m (per white LED)
Waterproof?	Yes	Yes	Yes

No other types of lighting were chosen or even considered for this application. Strips were chosen over any other type of lighting for a few simple reasons. The first reason being, that LED strips are very low profile. Whereas, other alternatives are much bulkier and could be

unattractive to a consumer. The low profile aspect makes it very easy to mount to any area of the Smart Mirror without it significantly affecting aesthetics. Another reason this type of lighting was chosen, was the fact that they generally have very low power consumption specifications compared to other lighting options. This is essential in creating a product that customers would find value in owning/using.

When deciding between analog and digital LED strips, there were a few more pieces to look further into other than those stated in the option descriptions above. The first being that analog LEDs are a relatively cheap solution compared to digital LEDs. The analog LEDs are also much more simple and easy to implement when it comes to software. The code will be much more condensed and quicker. Another feature that digital LEDs provide is the ability to create a chain reaction of lighting. This is when the first LED turns on and the rest turn on, one after the other all the way down the LED strip. This is not entirely necessary for this application since the LED strips themselves will be relatively short and the effect would not be worth the cost.

Ultimately, the LED strip chosen for this project was the third option, the "Cool White LED Weatherproof Flexi-Strip 60 LED" from Adafruit. This analog strip is only a single color and would be plenty bright enough for use in conjunction with the facial recognition feature of the Smart Mirror.

6.2.8 Photocell Selection

The photo-cell is used in conjunction with the LEDs that are mounted to the front of the mirror's frame. The feature that was added by including this photo-cell into the design is essential to proper functionality of the Smart Mirror.

Even though it is one of the smallest components, this remains one of the most important pieces of the facial recognition system. To guarantee that this feature will work one hundred percent of the time, there needs to be a sufficient amount of light. If the face of the user is not bright enough, the program will have a hard time determining if this is a user whose information has been pre-loaded into the system. Therefore, the system will not log them into their accounts and no information will be displayed on the Smart Mirror rendering it to just a plain mirror.

To fix this potential issue, it was decided that a photo-cell should be included in the design to detect for different lighting scenarios. This way, there will always be enough light illuminating the users face to make sure that the system works quick and efficiently. Since there is not a whole lot of variations when it comes to photocells and their characteristics, only three different kinds were considered.

6.2.8.1 GL5528

The GL5528 from Sparkfun has a medium value compared to the other options for dark resistance. This value specifies the value of the device when it is exposed to total darkness. The power dissipation of this particular component is acceptable for the needs of the project. The higher the better, but this will not be a component where a lot of current will be used so 100 MW/°C for power dissipation should be more than enough if this component is decided to be the one used. The last detail looked into for the photocells is the Spectral Application Range. This is the range of which the photocell can detect changes in visible light. The greater this value is, the more accurate of a device it will be.

6.2.8.2 PDV-P8001

The PDV-P8001 from Digikey is one which was not considered as heavily as the other two options. This is due to the fact that the dark resistance value was much lower than the team had hoped. Chances are that the device would still work with the system, but we want to be sure that there is the absolute correct signal is being sent to the microcontroller to properly illuminate the users face. This option as similar power dissipation values as the previous. The spectral application range is slightly smaller than the other options on the table, moving this device even further down on the list to be chosen.

6.2.8.3 NSL-5532

The final option considered is the NSL-5532 from Digikey. This option was heavily weighed against the first. The dark resistance value would ensure that proper values are being sent to the microcontroller. The power dissipation is higher than the other options on the table at a whopping 125 MW/ °C. Lastly, the spectral application range is the highest of all the devices making it a solid candidate for being chosen for the project. Table 14 illustrates a comparison between the options considered.

Table 14 – Photocell Data Comparisons

	Option 1:	**Option 2:**	**Option 3:**
Part Number	GL5528	PDV-P8001	NSL-5532
Dark Resistance	1.0 MΩ	0.2 MΩ	11.0 MΩ
Power Dissipation	100MW/ °C	100MW/ °C	125MW/ °C
Spectral Application Range	540nm	520nm	550nm
Cost	$1.50	$2.22	$1.41

To summarize this part selection, the team chose option 1, the GL5528 from Sparkfun. Even though this might not have been the heftiest option compared to the others, it will be more than sufficient for the application at hand. Option 2 was not very suitable for the Smart Mirror application because of the possibility of false signals being sent to the microcontroller when accurate readings are absolutely necessary for facial recognition. Also option 2 was much more expensive than the other options. Option 3 was not chosen for the simple reason that it was seen as a device that would likely be overkill for the application it is intended for. The pricing was good, but it was also more convenient to purchase from Sparkfun at the time to combine shipping costs with other products which were purchased from the same online vendor.

6.2.9 Clock Configuration Selection

The following sections will discuss different setups that the ATmega328 can use in order to produce a clock frequency acceptable for use in various applications and scenarios. Some of the topics discussed are; clock speed, power consumption, noise and other interference, and the ability to retain stability in noisy environments. Another key aspect which may be subtler than the rest is the ability to retain stability with voltage and

temperature fluctuations. All these characteristics need to be taken into account when designing the clock for the system.

6.2.9.1 Internal Clock Configuration

The ATmega328 contains an internal RC clock that is capable of producing a clock frequency of up to 8.0 MHz. This is one of the simpler and power efficient solutions when choosing a clock to run off of for the microcontroller. The nature of the clock is one that does not require any external components. The amplifier located on the inside of the microcontroller along with resistors and capacitors takes care of the full production of the frequency generation. Using other bit settings within the programming of the ATmega, one could also divide the clock frequency and use the smaller frequencies for different types of applications. One of the downsides to using the internal clock is that it is much more susceptible to noise and could potentially be unstable. The reasons these issues could arise is due to voltage fluctuations and temperature variations to the microcontroller as it is being powered and utilized. However, most of these issues could be resolved if the programmer takes some time to calibrate the internal clock to be able to use it to its full potential.

6.2.9.2 External Clock Configurations

The best solution to a stable and reliable clock is one that is external to the microcontroller. This will eliminate the need for extra programming for calibration of the internal clock. The external clock is will provide the microcontroller with the most stable and precise clock frequency output. While the possibility of external noise and interference is always still a possibility, it is significantly less than the internal clock. Since we are able to move the clock to a place on the PCB where it is not prone to noise and interference. The external clock has a couple of different types of configurations regarding power consumptions and frequency ranges.

The ATmega328 has the capability of running at a maximum frequency of 20.0 MHz. However, a safe speed to run the microcontroller at is 16 MHz. This is the same speed that this microcontroller is run at when used on other boards and applications.

The first type of configuration considered was the “Low Power Crystal Oscillator”. This configuration is one that is very susceptible to interference from other nearby devices. The PCB which will be used for the Smart Mirror will also contain the power supply circuit on the same board. However, the components for the power supply circuit will be separated from the logic components providing the PCB with the least amount of noise possible to the logic areas. Even with this said, there will always be noise produced from electronic devices and to keep the microcontroller running smoothly this may not be the best solution for producing a clock frequency. One of the pros to taking this route would be the lower power consumption rate. This setup has a reduced voltage swing on the output of the internal amplifier used to provide feedback. This feedback is used to stabilize the clock frequencies.

The next type of configuration, which is the one chosen for the Smart Mirror application is the “Full Swing Crystal Oscillator”. While, this is a solution which may not be the most efficient when it comes to the aspect of power. It is one which has the most amount of protection from noise and interference from other nearby devices. As mentioned above, the power supply is one of the noisiest environments on the PCB and special precautions must be taken to ensure stability of the entire system designed on the PCB.

The bottom line to this discussion is that the system needs a stable, noise protected, and fast clock to provide for the needs of the Smart Mirror system. The clock is one of the more important pieces of the logic system considering it is responsible for making sure data can be communicated correctly between all devices. One of the most important communications routes is that of the data which is being transmitted and received from the Raspberry Pi 3 to the ATmega microcontroller. UART serial communication along with I2C communication will be utilized in this system. While I2C does not require a very fast clock to communicate efficiently, UART does. If the clocks are not fast enough which are being utilized on both ends of communication for UART, then the information will be corrupted and will not be well received or transmitted. This will ultimately create issues with the overall system and certain features will begin working incorrectly. For these reasons, one of the highest clock frequency productions methods was chosen.

Figure 15 shows a simple sketch of what the clock setup will look like. The capacitor values are specified by the manufacturer of the crystal used. Both values in most cases should be equivalent.

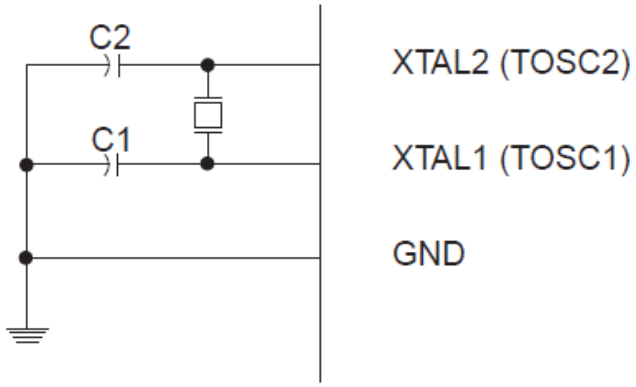


Figure 15 – ATmega External 16MHz Clock Circuit

6.3 Subsystem Tests

After the parts for the subsystems are selected, they needed to be tested to ensure they would meet the requirements of each subsystem and behave as expected upon purchase. The parts were individually tested first, and then the subsystems were prototyped and individually tested. Once the subsystems had been tested, they were integrated together to ensure they were compatible. These initial series of testing were completed by building the circuits on a breadboard. The majority of the testing was completed in the Senior Design Lab in an environment that simulates that which the completed Smart Mirror would be operated in. The results and learnings of these tests are also described in the sections below.

6.3.1 LED Lighting

The LED lighting on the Smart Mirror is a unique feature that the mirror will have integrated into its' design. The purpose of the lighting added to the mirror is to better illuminate the users face to log into their social media accounts to display feeds. A few different tests were run with the purpose of ensuring reliability and correct functionality of this feature.

To test the LED strip that was chosen for the Smart Mirror, a few components and devices are necessary. An N-Channel Power MOSFET was used in conjunction with the ATmega328P-AU microcontroller. Since the ATmega328 is the microcontroller which will be onboard the completed PCB, this is the most sensible option to use when prototyping. The remainder of this section goes into a more in-depth explanation of how this subsystem was tested.

6.3.1.1 Testing the LED strip

Before any modifications could be made to the LED strip, it needed to be tested for the most basic functionality of which it is capable of. Any modifications include, cutting the strip and soldering on more wires, or even attaching it to any part of the Smart Mirror frame. The LED strip which was purchased comes with no leads attached. Once the leads were soldered on, the LED strip was then plugged into a 12V power supply for its' first test. All the LEDs on the strip were powered on and were very bright as expected. However, since the lighting in the area where the Smart Mirror will typically be used will sometimes have enough or some lighting. Therefore, the LEDs will not need to be fully illuminated.

To solve the problem for these scenarios, the N-Channel Power MOSFET is introduced to this prototyping stage for the LED strip. The circuit which is created for the LED strip including the MOSFET is relatively small and simple. However, even with simple circuits mistakes can often be made. This prototyping sessions highlights mistakes. For the LED strip to have the maximum illumination capability, it must have access to 12 Volts with a substantial current source. The ATmega328 can only provide 5 Volts of output voltage which is not nearly enough, let alone the low current sourcing capabilities of the ATmega328. Hence, the MOSFET is used as a switch with the power to LED strip coming directly from the 12 Volt source.

A basic understanding of the Power MOSFET is as follows. The Gate acts as a switch for the Source and Drain pins of the MOSFET. For N-Channel, the Gate is voltage activated and virtually no current travels into either the Source or Drain from the Gate. So, when the circuit was first tested, the Drain pin of the MOSFET was connected directly to ground and the Source pin was connected to the negative lead of the LED strip. A resistor was used to connect the PWM control pin coming from the ATmega328 and the positive lead of the LED strip was connected to the power source. The step of connecting the ground from the ATmega328 and the ground from the 12 Volt power source was questioned. Since this was unsure of, the grounds were not tied together for the first test.

The LED came on as soon as it was powered and a program was written to slowly fade the LED Strip from zero brightness to full brightness. The LED strip did illuminate to the brightest level but would not resume to a zero brightness level. To troubleshoot this bug with the subsystem, one thing could only be changed at a time to accurately find the problem. The first thing to check was to be sure of whether or not the grounds needed to be tied together. Additional research was done and it was realized that the grounds did in fact need to be tied together to ensure that the reference for each side of the circuit were the same. The circuit was then tested again using the same exact MOSFET as before. The LEDs still would not shut off all the way. So, now the possibility of a bad MOSFET was in play since the circuit was not connected correctly to begin with.

New MOSFETS were ordered (a few additional ones this time for any potential mishaps) and the testing was resumed. This time, even more research was done to ensure that the MOSFET was connected to the correct places as it is specified in the datasheet. It was realized that the Drain and Source pins were not being utilized correctly. The Drain should have been connected to the negative lead of the LED strip and the Source to the ground of the circuit. With this rectification made to the circuit a second testing phase was conducted.

The circuit was carefully set up with the modified connections and this time with no resistor in between the PWM output of the ATmega328 and the Gate pin of the MOSFET. As mentioned above in this section, there is virtually no current flowing into or out of the Gate of the MOSFET, therefore no resistor is needed. This test worked successfully and the LEDs faded in and out! The LED strip faded all the way to zero brightness and all the way back to full brightness. Figure 16 is an image of the subsystem prototype.

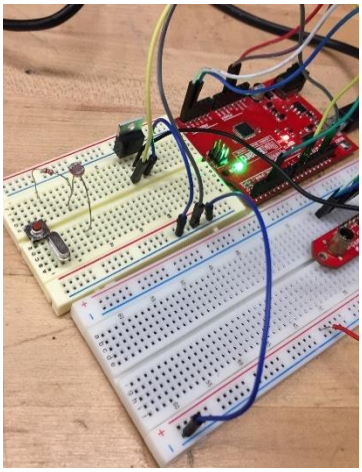


Figure 16 – LED Subsystem Breadboard Testing

6.3.2 Gesture Sensor

To verify the functionality of the ZX Gesture Sensor, a basic setup consisting of the ATMega328, gesture sensor, and personal computer were connected. The Arduino IDE was installed on the computer to permit programming of the ATmega. The Arduino IDE does not natively include the software library required to support the gesture sensor so the library was installed from the manufacturer's website.

Multiple examples sketches were uploaded to verify the functionality of the gesture sensor. The first test returned sample values from the sensor from register 0x0A, the register used to store Z distance readings. The data path flowed from the sensor's onboard register file, to the ATmega via I2C, to the FTDI module onboard the Arduino board via UART, and finally to the computer to appear in the Arduino IDE serial monitor. This method of data retrieval requires the ATmega to poll the sensor to request the data transfer.

For each Z distance reading, the data value proved to be accurate within ~1cm of the actual measured distance. Although the marketed range specifies a maximum detection range of only 10 inches, we found that accurate distances could be returned from an object roughly 24 inches away from the face of the gesture sensor.

After the initial Z distance verification tests were completed for the gesture sensor subsystem, the gesture sensing capabilities of the device were tested to ensure that correct readings were returned for the three supported gestures: left swipe, right swipe, up swipe. Utilizing the same software library provided by the manufacturer within the Arduino IDE, a sketch was uploaded which operated differently than the previously tested polling methods. Each time a gesture is detected, the gesture ID is stored to register 0x04 and the speed of the swipe stored to register 0x05. On change of these registers, register 0x01 is updated to assert whether a new gesture is available for retrieval.

The ATmega correctly ran the interrupt routine to request and retrieve the new gesture's data when the data available line signaled the microcontroller. In the full application of the project, the ATmega will process these gesture interrupts and send UART data messages to the Raspberry Pi. If this approach were not used, and the data was sent directly to the Raspberry Pi, the gesture interrupt routines would halt processing progress on other more important tasks, such as driving the display. The ATmega is capable of quickly processing the input while putting the less important tasks, such as taking the photo resistor readings, on hold momentarily until the next loop cycle reiterates.

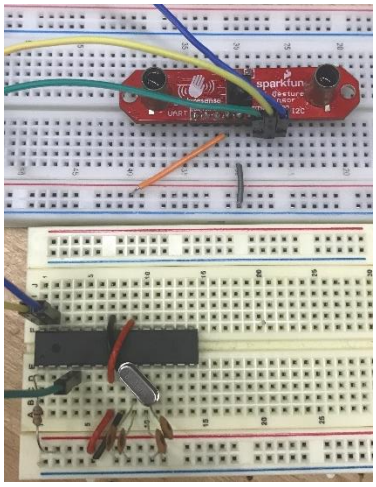


Figure 17 - The ZX Sensor relays gesture readings to ATmega328 via I2C using three (3) communication lines

Further testing resulted in mapping returned sensor data to physical distances. The ZX Sensor returns distance values in the form of unsigned integers in the range of 0 to 240 inclusive. These values do not map to a specific distance by default and must be converted within the ATmega software to a useable format with a standard unit of measurement.

After first selecting predefined physical distances, the ATmega was loaded with the program which interfaces with the sensor and prints Z distances to the serial terminal. An object was moved to each measurement increment away from the sensor and the returned value from the serial terminal was recorded. By executing three trials, an average was obtained, mapping the distance in inches to the return value of the sensor.

The results of this test show that the sensor's distance sensing is accurate between multiple trials and not dependent on unknown influences. At most, the returned values varied by ±4 between trials, resulting in a ~2% margin of error.

Table 15 - At predefined distances, the sensor value outputs were obtained between multiple trials

Physical Distance (inches)	Sensor Trial 1 (int)	Sensor Trial 2 (int)	Sensor Trial 3 (int)	Average (int)
0	0	0	0	0.0
2	0	0	0	0.0
5	10	8	9	9.0
8	24	25	24	24.3
10	39	40	39	39.3
12	54	55	52	53.7
15	78	79	80	79.0
18	101	109	105	105.0
20	118	120	119	119.0
22	135	141	136	137.3
25	152	160	159	157.0
28	212	220	216	212.3
30	214	220	222	217.3
32	240	240	240	240.0

Extrapolating the above data into a line graph allows a best-fit linear function to estimate the inputs and outputs of the exact function.

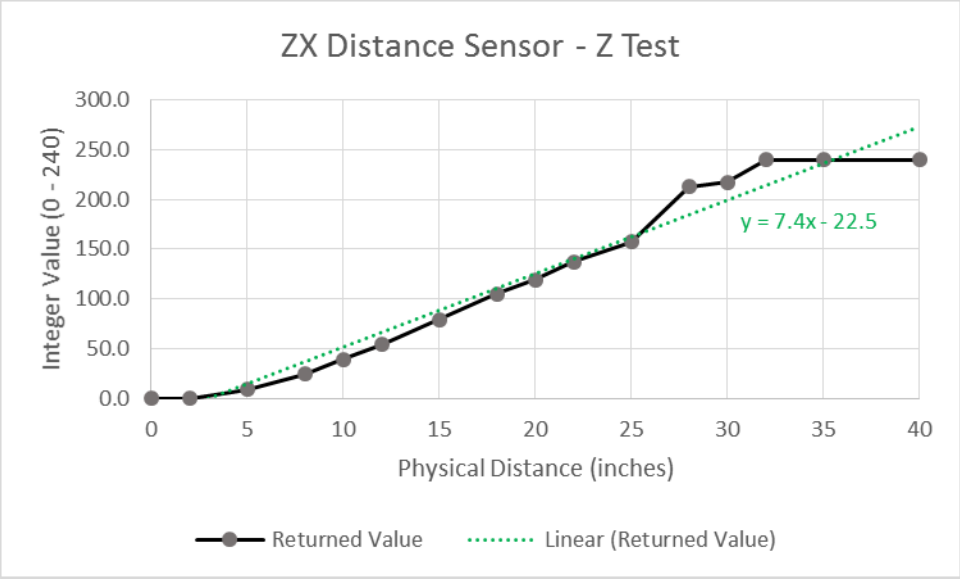


Figure 18 - ZX Gesture Sensor testing results in a function that maps the returned values of the sensor to real-world measurement units as inches.

Between five and twenty-five inches, the distance estimation is extremely accurate and follows a best fit linear function closely. Outside of the sensor's useful range, between 3

and 32 inches, the range estimation will be rounded to the base and maximum values permitted by the sensor. Based on the test data gathered, the ATmega will map the returned values of the gesture sensor as a linear piecewise function as shown in Figure 19.

$$Inches\ (int\ x) = \begin{cases} 0, & x \leq 10 \\ 7.4x - 22.5, & 10 < x < 240 \\ 32, & x \geq 240 \end{cases}$$

Figure 19 - A linear piecewise function will be programmed on the ATmega to convert the unsigned integer sensor values to inches.

6.3.3 Display

The screen chosen to prototype the smart mirror has been developed to work natively with the Raspberry Pi microcomputer. With a 7 inch diagonal display, the power consumption is expected to be limited compared with a full size monitor display. Prior to display testing, the Raspberry Pi had already passed tests by flashing the operating system image to the SD card and booting to the command line interface. In preparation for display testing, the distribution package list was updated using *sudo apt-get update* followed by *sudo apt-get dist-upgrade* to update all previously installed packages.

Testing the display was first completed by providing power via a 5V 3A, AC to DC converter plugged in to mains power. After connecting the DSI ribbon cable between the display and the Pi, the Pi was then powered from a computer port via a standard USB cable. The test worked as expected and the Raspberry Pi booted using the graphical user interface.

In the initial design of the system, in order to save power during periods of no activity, turning off the display by simply cutting supply power to the display appeared to be a feasible implementation for power savings. The Raspberry Pi would continue to run, and the display would power on and off similar to a computer monitor acting as a second display for a laptop. However, this method was not as simple as initially anticipated. In order to transfer data between the Raspberry Pi and the display, an I2C connection must be established and held. If the display loses power, the onboard register file's content is lost and the two devices no longer communicate.

An alternative method was found that would be a software implementation of controlling the backlight of the display. In the Raspberry Pi command prompt, manually piping a value to the backlight power control variable allows the display to be turned on and off. As the software continues to be developed, the node which receives incoming messages from the ATmega will process the packets and, depending on the contents, be capable of switching the display backlight off when the ATmega determines that no activity has occurred for the preset duration.

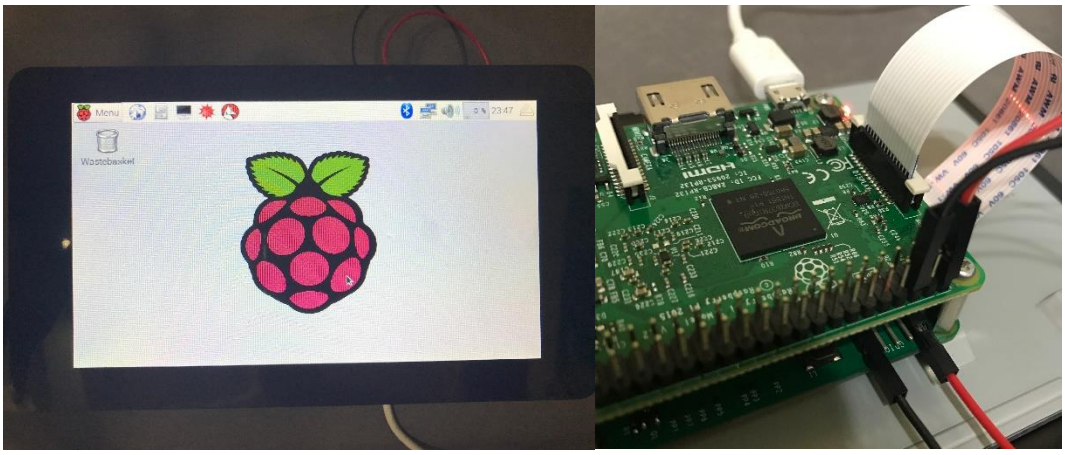


Figure 20 - A successful boot up sequence to the GUI. The display driver board is powered by the Raspberry Pi GPIO pins and communication passes via DSI ribbon cable

Partial to the anticipated 2A required to drive both devices simultaneously, the display and Raspberry Pi were found to be operable with a power supply delivering just 1A to the system. Under no load, the limited supply provided adequate power for basic navigation operations and file browsing. During high load applications later in development, such as the Apache server making data requests and face detection modules running image operations, power requirements are expected to increase. Because the manufacturer slightly overestimates the minimum power requirements of the devices, and the additional buffer included in the power system design, powering both devices using the custom designed power distribution board is anticipated to pose no issues.

6.3.4 Logic Level Converter

Prior to executing a full serial communication test between the ATmega and Raspberry Pi, ensuring that the logic level converter functions as expected is required to avoid applying excess voltage to the GPIO pins of the Pi. Specifics behind the theory of level converting can be found in section X-X, while this test solely focuses on verifying the functionality of the device.

A 5V reference voltage was applied to the high side of the logic level converter while a 3.3V reference voltage was applied to the low side of the logic level converter. Test cases included setting one of the channels to 5V and 0V voltages of the high side, and ensuring that the voltages were stepped on the low side of the channel to the corresponding voltage.

In the implementation of the logic level converter, the serial communication TX and Rx lines will be rapidly changing from high to low voltages. Although this test does not test the rapid switching, ensuring that sustained levels are properly converted simulates the same conditions the device will experience during normal use spread across a greater time interval.

The test confirmed that the converter functioned as expected and voltage overloads during serial communication will not occur during typical use cases.

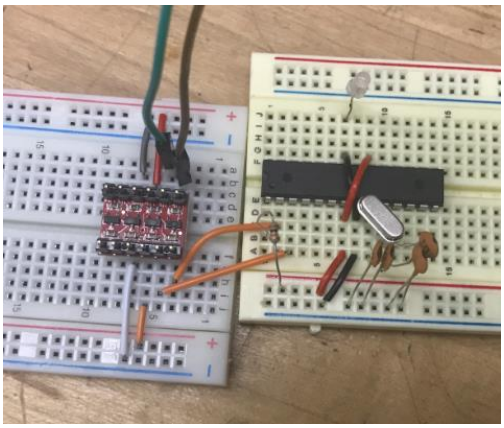


Figure 21 – Logic Level Converter Breadboard Test

6.3.5 Photocell

The photo resistor circuit's purpose is to determine the ambient light level in the location of the Smart Mirror. Based on the light level reading returned by the sensor and analyzed by the ATmega, the LEDs will be enabled to light to a specific maximum brightness should the room be dimly lit.

Testing for this circuit was completed using a serial enabled ATmega programmed to print the analog value returned by the photo resistor's voltage dividing circuit. The ATmega reads the voltage level between 0 and 5 volts and converts it to an integer value between 0 and 1023 inclusive. Depending on the software implementation, the values can be converted such that the lower end of the spectrum indicates relative darkness while the upper end indicates relative brightness, or vice versa. Since this project includes image operations for face recognition, and lesser values indicate lower intensity, for the purpose of this implementation and consistency sake, zero will be used to indicate full darkness while 1023 indicated full brightness.

During testing, rescaling was not required to remap low level brightness to the lower end of the analog spectrum. As shown in Table 16, lower light level environments returned readings which biased towards zero voltage.

While testing in various conditions, the following light level readings were obtained from the photocell. Unfortunately, since there is no method to measure the standard light intensity in a given environment without specialized equipment to return the lumens output, simple adjectives are required to describe the light level samples taken during the photo resistor tests.

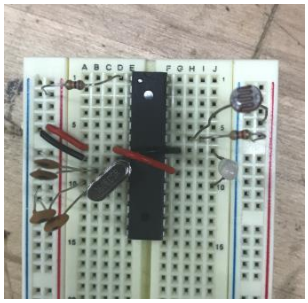


Figure 22 – Photocell Breadboard Test

Table 16 – Photocell Test

Environment	Photocell Value Range (0-1023)
Dark Windowless Room	005-100
Dimly Lit Room	100-400
Overhead Incandescent Lighting	400-600
Overcast Weather	400-500
Sunny Weather	900-1023
Flashlight on Sensor	1000-2023

Selecting a threshold to permit the lights to turn on or off will be completed based on the average use case for the location of the mirror. A user will typically require additional lighting when the sensor returns values between 0 and 400, so by sampling the average light level within a room and comparing to the threshold, the ATmega will enable the lighting and adjust the maximum brightness to compensate.

This test indicates that selecting the 4.7kΩ resistor properly scales the voltage division circuit to return a range between 0 and 5v for various light level conditions. Should an incorrect resistance value been utilized, the brightest light possible may have returned a value only half of the maximum 1023.

Overall, the photocell test proves that the device will function properly for determining the light level readings within the environment of the mirror. In the further development of the ATmega software, processing will be used to take the average values across a certain period of time to avoid a ping-pong effect of LED brightness. Additionally, in future implementation, to avoid a negative feedback loop, light level readings will be taken only during the startup procedure.

6.3.6 Serial Communication

During initial tests, serial communication was established between the ATmega328 and the Raspberry Pi. Using the concepts discussed in Section XX: Serial Communication, a two-wire UART implementation of serial communication was utilized to pass messages between the Raspberry Pi and the Arduino. By connecting the Tx pin of the microcontroller to the Rx pin of the Pi, and the Tx pin of the Pi to the Rx pin of the microcontroller, messages were generated by the Pi and transmitted to the microcontroller. The ATmega was programmed to check for serial data in the UART buffer during each repetition of the loop function. If serial data was available, the data would be read, retransmitted to the Pi, where the Pi would then print to screen any received UART messages. This test, nicknamed Bounce, was used to confirm that e ach device was capable of both transmitting and receiving messages with one another. In future development, the messages will contain useful information regarding the state of the system and be parsed for analysis to make decisions regarding which state should be entered next.

Testing serial communication capabilities were tested in three specific stages. Stage one of testing the serial communication consisted of verifying that the logic level converter produced the expected outputs for various inputs. Stage two consisted of verifying single direction communication between the ATmega and the Raspberry Pi, while stage three verified bidirectional UART communication between the two devices.

Prior to hardware setup, the embedded Linux OS running on the Pi required configuration to permit UART communication through the GPIO headers on the board. Because the Pi supports Bluetooth, a serial based communication method, the /dev/ttyAMA0 serial port which is normally reserved for GPIO has been assigned to the Bluetooth module. With two serial ports in total, one being occupied by the Bluetooth communication, the other port must be reassigned to act as a GPIO serial port rather than the console logging port. By stopping and disabling the serial-getty service and configuring the boot file, we can set up serial communication using the /dev/ttyS0 serial port. After rebooting the device, it is now possible to communicate with the Raspberry Pi via the UART Tx and Rx GPIO pins.

Stage two of serial communication testing ensured that the Raspberry Pi could accurately transmit a message to the ATmega via UART. By connecting the Raspberry Pi's Tx line to the channel one low input of the logic level converter, the converter translated the 3v input to the 5v Rx line to the ATmega. To test this functionality, a program was written in Python to connect to the serial terminal /dev/ttyS0 and transmit UART messages every five seconds. The ATmega was programmed to continuously read the UART buffer, copy the string, and forward it to the Arduino FTDI converter via the Tx line. The FTDI converter, which will not be included in the final design, allows the ATmega to communicate with a PC via USB port, so for debugging purposes, this method was used to verify that the ATmega was properly receiving the UART messages from the Raspberry Pi.

Stage three of serial communication testing ensured that the UART communication was capable of bidirectional operation by verifying that the ATmega could transmit a received message back to the Raspberry Pi. A simple Python program was used to both transmit and read the messages on the Raspberry Pi's serial port as illustrated in Figure X-X. While the bidirectional serial operation is a simple test to design and conduct, it will prove to be a valuable debugging tool in the future as the schematic diagrams are converted to a physical PCB. By running this test, two-way serial communication can be verified as functional.

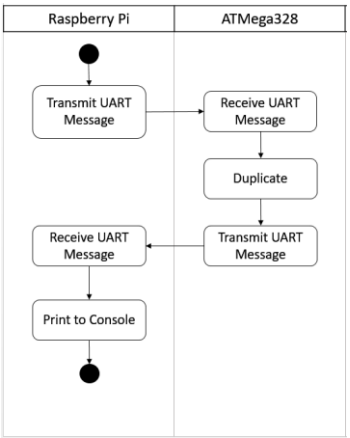


Figure 23 - A simple 'Bounceback' application used to verify UART communication between the Rapsberry Pi and ATmega will prove useful for both initial setup and final debugging.

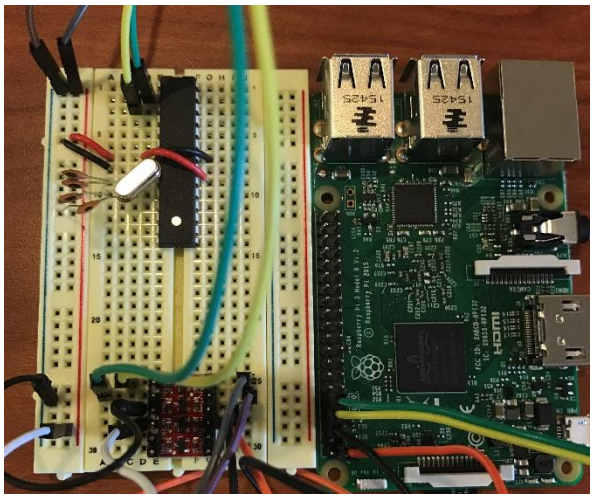


Figure 24 - Full serial communication testing using the ATmega328, Logic Level Converter, and Raspberry Pi

```
Received from the ATMega:'Hello from the Pi\r\n'
Sending a message (Pi to ATMega)
Received from the ATMega:'Hello from the Pi\r\n'
Sending a message (Pi to ATMega)
```

Figure 25 - Raspberry Pi remote terminal output during a 'bounce-back' UART message test.

6.3.7 Camera Testing

To ensure that the camera module is compatible with the Raspberry Pi and the overall project, the test plan consisted of first configuring the software on the Pi to accept command line inputs. Updating the packages for the Jessie release of embedded Linux was completed through the command line interface where the device would utilize the existing wireless connection to download the most up to date software. After updating the software, the configuration manager on the Raspberry Pi was used to enable the use of the camera module. By default, the camera setting is set to be disabled, so by enabling the setting and rebooting the device, the microcomputer is prepared to accept camera commands and interface with the module. With the Raspberry Pi powered down, a ribbon cable was connected from the camera module to the Pi to facilitate the serial transfer of data between the two devices.

Camera testing proved successful with the input of a command to the terminal. By specifying the command, the output, and the file with where to save the image, the camera board correctly captured an image and saved it to the Pi's memory. As shown below in Figure 27, the 8MP camera is capable of capturing incredible detail with respect to the small size and footprint. With considerations towards the camera's purpose in capturing images for face detection and recognition, the quality of the output is substantial and will pose no issues for the algorithm.

Understanding the camera's behavior in different light level settings will be important when determining the brightness of the LEDs positioned on the front of the frame. While

the LED lighting's purpose is to illuminate the user's face during mirror use, the alternative and more important purpose is to ensure that the camera module is capable of obtaining an accurate image of the person in front of the mirror. In low light level conditions, this would prove to be troublesome if the exposure level of the camera captures dark images.

In low light level conditions, the images returned by the camera were less than acceptable for facial recognition, supporting the decision to implement dynamic LED lighting within the project. Despite other products existing on the market to support these less than ideal conditions, the comparison in price and features did not outweigh the current camera module. Other devices supported the infrared spectrum provided infrared LEDs illuminated the space, however fail in regular lighting conditions. With less than adequate lighting, the images returned by the camera module were unfavorably dark and implementing a dual purpose feature such as lighting was a decision that will assist the project meet its final goals.

Overall, testing the camera module with the Raspberry Pi proved to pose no major pitfalls. Due to the Raspberry Pi's build in support of the camera module through the use of the camera serial interface, taking snapshots and saving the image to the Pi successfully tested the module's ability to support facial recognition capabilities.

```
pi@raspberrypi:~/Documents/SeniorDesign $ ls
cameraImageTest  cameraImageTest.jpg  FileBackups  serialTest.py
pi@raspberrypi:~/Documents/SeniorDesign $ raspistill -o test2.jpg
pi@raspberrypi:~/Documents/SeniorDesign $ raspistill -o test3.jpg
pi@raspberrypi:~/Documents/SeniorDesign $ raspistill -o test3.jpg
pi@raspberrypi:~/Documents/SeniorDesign $ raspistill -o test4.jpg
```

Figure 26 - Remote terminal output of the Raspberry Pi during image capture command testing

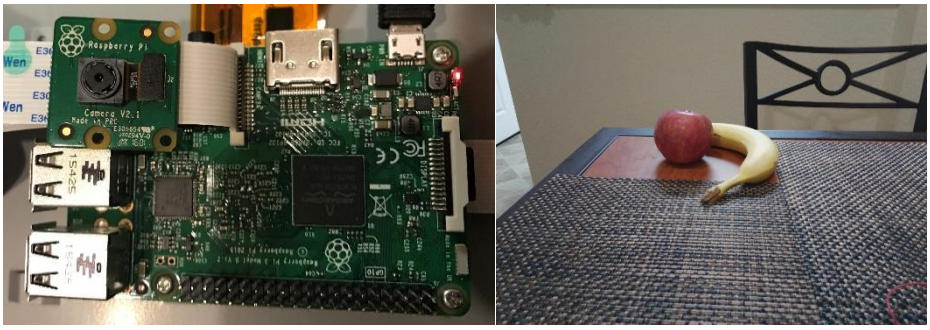


Figure 27 - The camera module, pictured with the Raspberry Pi top left, delivers quality capable of capturing sharp images for use in the facial recognition algorithm in a variety of light level conditions.

In the final implementation of the camera module, the module will be located on the top of the frame. Based on the location of the Raspberry Pi within the enclosure, there is a possibility that the module will require additional lengths of ribbon cable to allow the devices to mount in the correct location. Potential future tests include verification of the camera serial interface functionality over longer length lines to ensure that the signal propagation is not lost over the increased transmission distance. Online sources state that they have tested with up to 4m cable lengths and encountered no issues with the same configuration being used for this project, so extending the distance by less than an eighth of that distance is anticipated to pose no issue in the final implementation.

6.3.8 Mirror Display Combination

Testing the LCD display behind the one-way mirror glass required the setup of both the Raspberry Pi SD card flash as well as the configuration for use with the display. Since the concept of the mirror is based around the difference of black and white/colored light, the most effective way to verify that the principle worked was by starting the Raspberry Pi and viewing the outcome during the boot sequence.

As shown in Figure 28, the mirror acts as a reflective surface in areas where the display emits black pixel light and also where the back surface is bare. Events where this test may have failed include utilizing a mirror with tinting applied too lightly or too heavily. If either event occurred, the display output would not have been visible through the mirror or the effect of the reflective surface would be compromised by the ability to view the components located behind it in the frame enclosure.

This test also brought forth an issue to be addressed during the final assembly of the mirror. If the backside of the mirror is illuminated with any form of lighting, the mirror becomes pellucid in an undesirable fashion. During the construction of the final product, ensuring that the enclosure is closed will enable a seamless transition between the reflective surface and the image projected by the display.

Overall the combination of the LCD Display with the selected one-way mirror glass will meet the requirements for the project and be included in the final design and assembly.

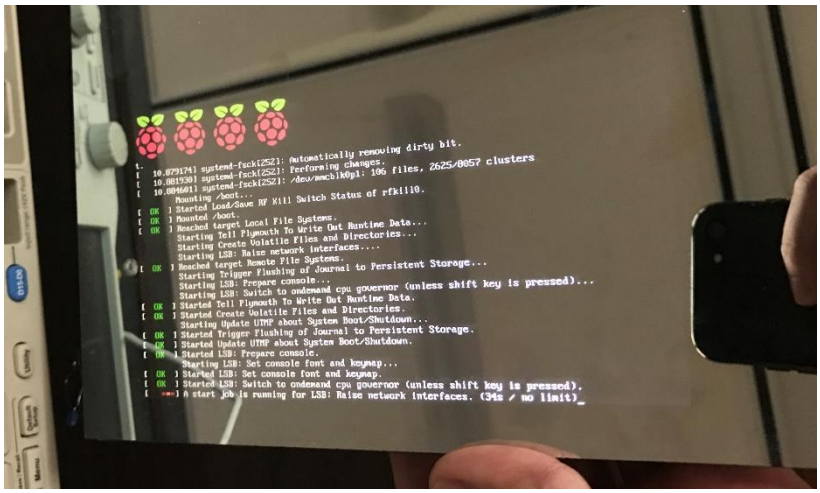


Figure 28 – Display and Mirror Reflectivity Test

6.3.9 ATmega328

The ATmega328P-AU microcontroller was chosen over various microcontrollers due to many reasons explained in the research sections above. Each of the subsystems within the Smart Mirror will be tested individually in order to ensure that they are fully functional. Along with individual tests, each of the subsystems of the Smart Mirror will be tested together to check for any faults. The system as a whole must function smoothly and soundly.

The ATmega328P-AU has an internal clock that can be utilized for certain applications. Some of the benefits of this internal clock is that there are no extra components needed on the printed circuit board. Another advantage of the internal clock is the fact that is has a

very low power usage. However, the internal clock's frequency range is limited. To alleviate the issue of a small range of frequencies, an external clock will be tested in our subsystem and full system tests.

There are various setups that can be configured depending on the applications that the microcontroller will be used for. Due to the fact that the Smart Mirror will be using UART Serial Communication, it will need to have a clock with a higher frequency than what the internal clock is capable of producing. The next few parts of this section will cover the various tests and configurations that were considered when designing the surrounding circuits for the microcontroller.

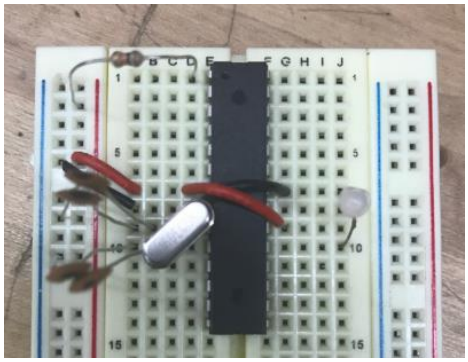


Figure 29 – ATmega328P-AU Breadboard Test

6.3.9.1 Bootloading ATmega328P-AU

The ATmega328P-AU which was purchased for the purpose of prototyping is a simple yet powerful microcontroller which boasts a maximum clock speed of 20.0 MHz and lower power consumption rating than other microcontrollers of the same class. This is a low power microcontroller that can be used for a multitude of applications. The versatility of it makes it simple to use and program as well. The following sections will provide a more in depth look at the steps taken to prepare the microcontroller for prototyping. The following will also provide explanation as to why the specific package was chosen for prototyping compared to the other options available on the market.

6.3.9.1.1 Package of ATmega328

The ATmega328 comes in various packages and choosing the one specific to a projects needs can sometimes be difficult. One of the more standard packages which is seen on the Arduino microcontroller is the 23 pin DIP (Dual In-Line Package) as shown in Figure 30. This package is easy to snap onto a breadboard and begin prototyping right away.

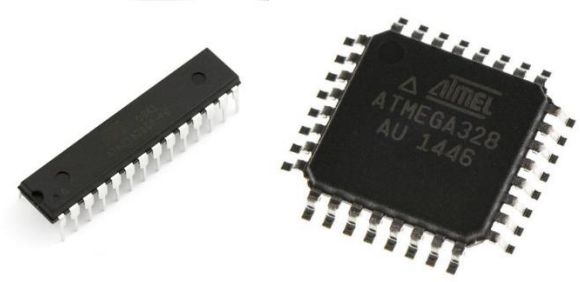


Figure 30 – ATmega328 DIP vs TQFP packaging

The next type of package is the 32 pin TQFP (Thin Quad Flat Package) and is shown in Figure 30. This package type is much lower profile and all around smaller than the 28 pin DIP package. Most likely, this will be the package chosen when selecting parts for the final PCB design.

The last package is the MLF (Micro Lead Frame) package and is the smallest of the packages. This package was not purchased or even considered for prototyping do to the fact that there are no leads which stick outside of the package like the other ones. As seen in Figure 30, this package has leads, but they are meant more for a machine to solder them onto PCB and other components.

The TQFP was purchased and used as the primary prototyping package since it will be the one most likely to be used on the final PCB.

6.3.9.1.2 Bootloading the ATmega328P-AU

The ATmega328P-AU (TQFP) which was purchased did not have the Arduino IDE pre-bootloaded. The Arduino IDE is the program used to flash the microcontrollers with various instructions for the purpose of testing all of the subsystems for the Smart Mirror. There are ATmega328P-AU (TQFP) on the market which come already bootloaded with Arduino but they are very costly as well. So, due to cost and the willingness to learn more about the process of bootloading as well as the functionalities of the microcontroller itself, it was decided that an ATmega328P-AU would be bootloaded manually.

Since this package is not one which can be snapped into a breadboard like the Dual In-line Package, it is necessary to obtain a breakout board to which the microcontroller is soldered too. This breakout board can then be snapped into a breadboard and prototyping/bootloading can commence. The breakout board used for this application is shown in Figure 31. Bootloading the ATmega328 also requires a clock. The selection of the clock configuration is discussed in detail in section 6.2.9. All connections were made to the ATmega328P-AU for an attempt at bootloading Arduino to the ATmega328P-AU. Many reference were made to the ATmega328 datasheet to make sure power, ground and communication cables were connected to the correct pins on the microcontroller.

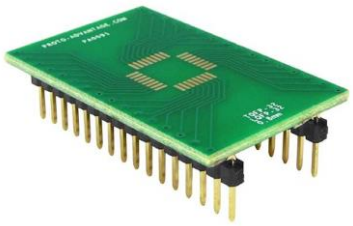


Figure 31 – Breadboard Breakout Board used for ATmega SMD Package

An Arduino UNO was used to bootload the ATmega with Arduino. The communication is important to make sure that the data is accurately translated to the ATmega328 for a successful bootloading process to take place. Unfortunately, the bootloading process has thus far failed. An error comes up saying that there is an invalid device signature,

essentially specifying that the attached device cannot be identified. There have been multiple attempts at correcting the issue at hand, but for the time being the backup plan will be exploited for prototyping. Testing and troubleshooting will continue in parallel to main prototyping activities.

6.3.9.1.3 Bootloaded 28-pin DIP ATmega328

The 28-pin DIP ATmega328 was also purchased in case the ATmega328P-AU did not function as hoped. The 28-pin DIP ATmega328 functions the same as the other package except for a couple less Analog-to-Digital converter pins. Since, the prototyping procedures for this project do not require all of the pins on the microcontroller to be occupied, this option will be adequate.

Since this option comes bootloaded with Arduino, none of the bootloading procedures explained above are necessary. This is more of a plug-and-play solution than anything else, making prototyping a seamless and speedy process. Prototypes of the various subsystems for the Smart Mirror were completed and tested successfully using this method.

6.3.10 Mounting Frame

There are several factors to be taken into consideration when building a frame. Namely; types of wood to be used, the way in which the frame is constructed, and the materials used to keep the joints of such a frame together.

6.3.10.1 Softwood

Softwood is typically used for simple projects. These types of woods include Pine, spruce, fir and cedar. They are typically very soft to handle. They dent easily and can easily be damaged in the process. These woods are harvested from conifer trees. Typically, they are cheaper than hard woods because conifer trees grow faster and their pliability make them easier to harvest. Typically, these softer woods are better at absorbing and releasing moisture. These are the most common types of woods used in home projects. Pine softwood was the ideal choice used in this project.

6.3.10.2 Hardwood

Hardwoods come from deciduous trees – the type of tree that loses its leaves in the winter – and take much longer to mature. They come in various types of woods such as oak, maple, walnut, hickory, and mahogany. These types of woods are not easily dented – as their name implies. These types of woods are typically used in fine furniture and woodworking. They are more difficult to find than softwoods and usually require the user to go to a specialty woodworking shop or lumberyard.

6.3.10.3 Softwood Classifications of Lumber

A quality of wood must then be chosen after the hardness of said wood has been chosen. There are several different types of softwood classifications that are used when dealing with lumber. These include (but are not limited to): Common Yard Lumber, Select Yard Lumber, Structural Lumber and Shop/Factory Lumber. These all have different uses and wood qualities – of which are expounded upon below.

6.3.10.4 Common Yard Lumber

Yard lumber has several different classifications that are chosen based on visual inspection of the wood. There is No. 1 Common, No. 2 Common, and No. 3 Common. These all have separate uses based on what the customer is searching for. No. 1 Common Yard Lumber is

considered the highest quality yard lumber. It is designated by very few, small knots in the grain of the lumber. This classification of wood is typically used for at-home DIY projects. No. 2 Common Yard Lumber has larger – and more frequent—knots. It is typically used in general woodworking projects. No. 3 Common Yard Lumber has even larger knots than No. 2 Lumber. It is considered tarnished or blemished and it typically suited for fencing, boxes or crates. This project would call for No. 1 Common Yard Lumber.

6.3.10.5 Lumber used in this project

The lumber chosen for this project is the softwood Pine with classification No. 1 Common Yard Lumber. This wood was considered ideal for this project because it is an inexpensive softwood that is easy to cut, and manipulate. Without putting undue stress on the frame it will expand and contract based on moisture in the environment. This is ideal for home-use because the end-user may have varying degrees of moisture in their home environment.

6.3.10.6 Choosing the Frame Joint

In order to effectively create a squared frame that will hold up with time a frame joint must be carefully considered. There are several different frame joints that can be chosen. For this reason, we will only focus on frame joints that are ideal for frames using softwood.

The most common type of joint used in woodworking is the Basic Butt Joint as seen in

Figure 32. It is easily created using two cut pieces of wood and aligning them at a ninety-degree angle. This method of creating a joint requires the use of a saw, a tape measure, wood glue, screws and a nail gun. This is the most commonly implemented, as it is the simplest. It has a long drying period because the wood must set before any other application can be accomplished. Another common type of joint used in woodworking is the Pocket Hole Joint as seen in

Figure 33. It is, ultimately, the joint that is implemented in this project. It requires the use of a Pocket Hole Jig, screws, clamps, a saw, a nail gun, wood glue and a tape measure. It is a very strong and stable joint. It can experience significant pressure before breaking (and, typically, the wood will splinter before the joint gives). This joint will not blemish the face of the frame; one of the most attractive aspects of this particular joint.

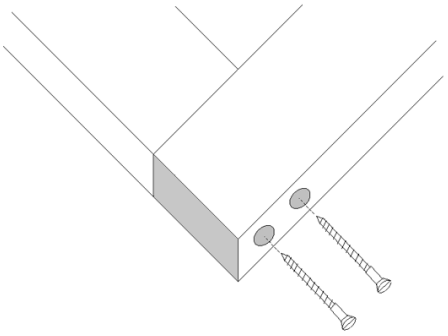


Figure 32 – Basic Butt Joint

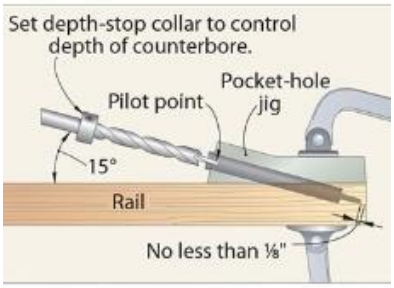


Figure 33 – Pocket Hole Jig Joint

6.3.11 Assembling the Frame

Using a soft Pine made of No. 1 Common Yard Lumber, the techniques involved in creating a Pocket Hole Jig Joint, and the Pythagorean Theorem the frame was assembled.

$$A^2 + B^2 = C^2$$

let A = 14 in (the width of the frame) and B = 16 in (the length of the frame)

Thusly, the "square" of the frame would be 21.26 inches in diagonal.

This is denoted as the "square" of the frame because it is the most stable set of measurements for a rectangular or square object. Once the frame size has been determined it is ideal to square the extension of the frame. This extension of the frame is used to make the frame a free-standing mirror. It also creates a convenient way to hide unsightly wires or electrical components.

6.3.11.1 Choosing the mirror.

There are several different types of mirrors to choose from. There need for this project is to have a mirror that allows light from both sides. That means a typical silver-backed mirror is out of the question.

a) Plane mirrors are a simple one-way mirror that has a singular side covered in metal. These metals are typically brass, copper, or another reflective metal. These metals are typically backed by a thin piece of glass that prevents tarnishing.
b) Two-way mirrors are used for police interrogation rooms and secure areas. They have film coating which makes it possible to see into light rooms.
c) Silvered mirrors are the most common of mirrors. They typically have the highest degree of reflective properties and are used in several different applications; such as furniture or home décor.

Two-way mirrors are ideal for the needs of this project. It would allow enough light from one side to allow a display to send smart information to the user. Ideally, it would allow the user to have an external light on during usage of the mirror.

The mirror decided on for this project has the dimensions of 12 inches in width by14 inches by length by 1\4 in depth. The depth of this particular choice of glass perfectly fits in the mirror frame. The two-way mirror sits flush against the frame and allows plenty of room for hardware to be stored.

6.3.12 Power Supply

The power supply circuit was tested by assembling all components together on a breadboard. In Figure 30, the chip on the green breakout board is the 5V regulator. The chip in the TO-220 package is the 3.3V regulator. From left to right the capacitors are valued as 680uF, 220uF, and two 1uF. The black, vertical component is a Schottky diode, and the horizontal component with two orange stripes is a 33uH inductor. A DC coaxial power jack was used as the input port with a 12V, 4.8A, AC to DC converter providing the input power.

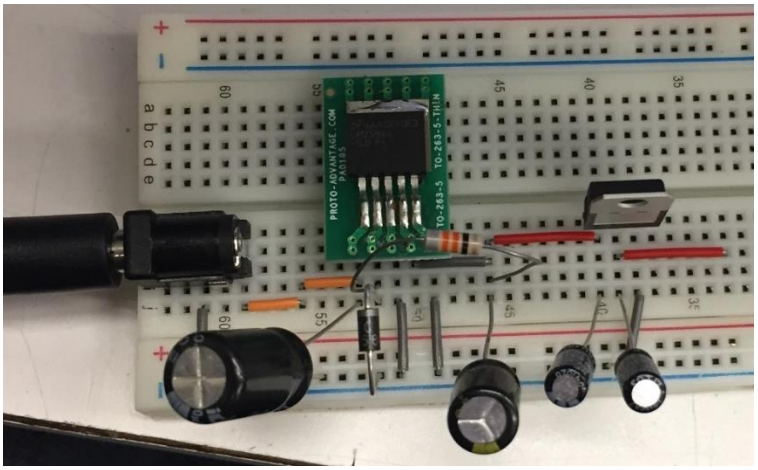


Figure 34 - Power Supply Breadboard Test

To test the power supply, the circuit for the LM2596 5V switching regulator was assembled first. This circuit included the first two capacitors, the Schottky diode, and the inductor. Once assembled, the output voltage was checked using an Innova 3320 digital multimeter. The output voltage was recorded at 5V even, with no fluctuations. This met expectations, so the testing could continue.

The next step was assembling the circuit for the 3.3V regulator, which included the last two capacitors. After assembling this next circuit, the output voltages of both regulators were then tested using the digital multimeter. The output of the linear regulator was 3.38V and the output of the switching regulator was 5V. These values were acceptable and the testing was continued.

The next test to complete for the power supply circuit was the ability to power the Raspberry Pi. The Raspberry Pi requires 5V and 2A for operation when the display monitor and camera module are operating as well. The Raspberry Pi was chosen as the first component to check with the power supply because its power requirements are much higher than all the other subsystems. To connect the power supply circuit to the Raspberry Pi a USB connection was used. The Raspberry Pi can also be powered using the GPIOs but there is no circuit protection like what is provided on the Micro USB port circuit. For that reason, the Micro USB port was used to power the Raspberry Pi. The USB connector on the Pi is of the Micro USB variety. For this project a Micro USB connector was also chosen due to its size on the planned PCB board. Micro USB male to Micro USB male cables are not readily available for purchase, nor are they cheap, so a standard USB 2.0 to Micro USB cable was used with a USB 2.0 to Micro USB adapter attached to the standard USB 2.0 side. SparkFun's Micro USB connector module was used on the breadboard to provide a port for the power supply, and the 5V rail was connected to its VCC pin. When the circuit was tested, the Raspberry Pi was originally not able to be powered on. The current was measured leaving the switching regulator as less than 2A, meaning the Raspberry Pi was not getting a strong enough current. It was quickly deduced that the source of this issue was the inductor. When the inductor was purchased the current rating was unknown. It was believed the current rating was not large enough to handle 2A. After this realization, a new inductor was purchased with a 3A current rating.

After the inductor was replaced an attempt to power the Raspberry Pi was made again. Still, the Raspberry Pi was not being powered on. The voltage was measured at multiple points to determine if a loss was occurring anywhere: at the output of the switching regulator, the voltage rail on the breadboard, the Vcc header on the Micro USB module, and the Vcc pin of the USB cable. It was recorded that while the Raspberry Pi was disconnected the voltage at all these points was 5.01V, but when the Raspberry Pi was connected the voltage dropped to 4.3V-4.6V, meaning not enough voltage was being supplied once a load was connected. The source of this issue was determined to be the supporting circuit of the regulator. The capacitors chosen were not rated high enough to provide 5V once a load was connected. The datasheet was then referenced and new components that meet all necessary parameters were selected. This included a new input and output capacitor, as well as a faster Schottky diode.

The next test to be run with the power supply circuit was powering the ATmega328, another key component to the project. The ATmega328 was assembled on a breadboard with all associated supporting components. The ATmega328 chip was first powered with help of an Arduino UNO board and a code was run which would blink an LED diode. After this base case was run the Arduino UNO board was disconnected and the power supply circuit was used to power the chip at the same pins. When the power supply was connected the LED diode began blinking like expected and the test was marked as passed.

The next test was to see if the circuit could power the ATmega328 and logic level converter circuit. This step was done next in order to check the functionality of the 3.3V linear regulator. The ATmega328 is powered from the 5V rail, and the logic level converter circuit uses the 3.3V rail and the 5V rail as reference voltages. The load currents from both are small, in the mA range, and vary based on usage. The Raspberry Pi was powered separately, not with the power supply, in order to protect it. Before testing the ability to power the ATmega328 chip directly, an Arduino UNO board was tested first as it contains circuit protection and no parts were at risk. With the assurance the Arduino UNO board could be powered, the ATmega328 and Raspberry Pi were powered, and reference voltages applied to the logic level converter. The Raspberry Pi display screen was connected in order to view messages sent by the ATmega328. A simple program was then run to ensure messages could be sent between the two devices. This test was passed as readings taken by the ATmega328 were seen on the Raspberry Pi display screen.

The ATmega328 and Raspberry Pi are the main components of the project, so after confirming both could be powered, the rest of the subsystems were tested. The first of these modules was the gesture sensor. The gesture sensor was connected to the correct data pins of the ATmega 328 via header cables. The Vcc and GND pins of the gesture sensor were then connected to the 5V and ground rail of the power supply circuit. A program was run which could read gestures and the sensor was able to do so, meaning the power supply passed this test.

The next component to be powered by the circuit was the LED strips. First the LEDs were connected to the 12V rail to see that they could be powered on by the voltage and current provided by the AC to DC converter. Then the LED PWM circuit was connected to the ATmega328 and power supply circuit. A program was run which pulsed the LEDs on and off, which they successfully were able to do. The gesture sensor was then integrated and a program was run which turned the LEDs on with a right swipe and off with a left swipe.

The LEDs behaved as expected, proving the power supply could power these 3 devices at the same time.

A final test was then run which would prove the power supply could power the ATmega328, gesture sensor, LED strips, LLC. These devices were connected to the appropriate voltage rails of the power supply and the Raspberry Pi was powered separately. A program was run similar to the program in the previous tests, except the readings of the ATmega328 were also sent to the Raspberry Pi and displayed. This test successfully went was expected.

7 Project Software

The following sections outline the software design architecture for all related components of the Smart Mirror. Both the ATmega and Raspberry Pi will require various developmental stages throughout the software implementation lifecycle based on the chosen architectures. Any program related coding is referenced within the following section and will be described through a series of text description, standard software diagrams, and use case scenarios. While this section addresses the software design, final test procedures may be referenced in Section 9.

7.1 Software Overview

The software overview is used to illustrate the scope of this architecture. There are several different architectures that are useful for different architectures. In order to understand the full scope of the project, and to be able to implement it, a full understanding of the different types of computer architectures must be had. Then, once a full understanding of the types of software architectures is met, a choice can be made. This project implements a Service Oriented Architecture with SOA services and the interactions between the internet and the interface are implemented using a ReSTful, stateless architecture.

The software components for the Smart Mirror are divided between the ATmega and the Raspberry Pi. The ATmega will be responsible for preprocessing the sensor data and relaying any important events to the Raspberry Pi. The Pi will act as the main processing unit, running the open source Magic Mirror framework to be improved upon. The Pi will be responsible for interfacing with the outside network to obtain basic data for the feeds which will be pushed to the LCD display. Both the ATmega and Raspberry Pi will work in unison to create a complete system which meets all requirements of the project.

Figure 35 describes the software implementation used to navigate the decision flowchart. The culmination of both the ATmega and Raspberry Pi programming will be required to fully realize the intended functionality.

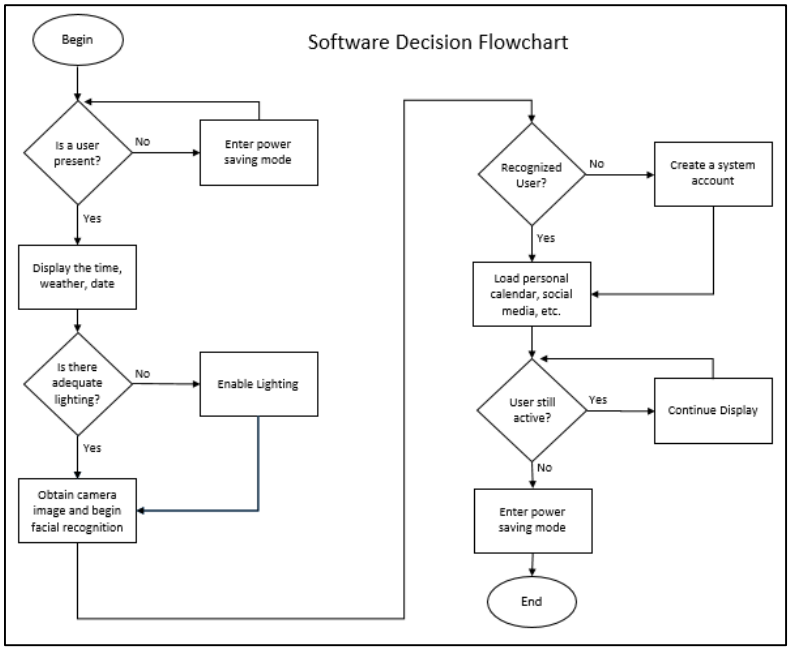


Figure 35 - The operational software of both the ATmega and Raspberry Pi will follow a decision flowchart

7.1.1 Software architectures

There are several different options available when designing software architectures. These include (but are not limited to) Blackboard, Client-server, component-based, data-centric, monolithic, pipes and filters, rule-based or service oriented architecture. All of these architectures serve different purposes and would be equally served for this project. Below are the comparisons between the architectures best suited for this project.

7.1.1.1 Client-server architectures

Client-server architectures are used for partitioning tasks or workloads between a server provider and a service requester. These are thusly named server and client respectively. These server-client models can be used over a Local Area Network (LAN) or an internet connection. The server serves the client the resources requested of it in a one-way a-symbiotic connection. The client does not share any information or resources with the server. A shared resource may be any item on the server's storage disks. This is why the server is considered a service. It is servicing the needs of the client. Typically, the client-server connection is applied via a response-request messaging system. The client has no concern for the performance of the server. It only concerns itself with the service being rendered. Using this response-message protocol over the application layer in the TCP/IP protocol stack; a formal exchange can be made by (and from) the client. This formal conversation is facilitated by APIs and other abstraction layers. Such abstraction layers are not immune to malicious attack. They can be brought to their knees via a Denial of Service attack in which the malicious program or individual repeatedly bombards the server with request-response messages; preventing any such client from querying the server.

7.1.1.2 Pipelines and Sockets

Pipelines are considered to be a linked chain of elements that process data in such a way that the end of one link is the beginning of the next link in the chain. Typically, it is linear. One directional. They are often referred to as data streams. They may be fully bidirectional via a backchannel it its communication channels. Usually, they follow a stricter one directional acyclic graphing schematic. The lack of cycles gives pipelines their name. Typically, these pipeline-socket architectures are utilized by multitasking operating systems. Using scheduling and task-handling operations, these pipelines are optimized. All other operations cease once a read/write operation is performed in order to allow time for the data to be retrieved or sent while being unmolested by errant processes. This prevents deadlocking as the errant process would just wait for the CPU to be free. In order to make efficient use of the CPU, pipeline buffers are used. These allow the CPU to complete a read/write task without halting all other processes. These waiting processes would just wait in the queue. These buffers are usually utilized using system calls for read/write operations.

7.1.1.3 Service Oriented Architecture

This is an expounded-upon version of client-server architecture. It uses services to provide components via a communication protocol over a network. These principles allow the architecture to be free of dependencies on other technologies or products. It is considered to be a discrete module of functionality that allows independent updates and remote access. A service-oriented architecture is useful software architecture – allowing the programmer to build a many modules architecture that does not depend on any of the other modules. This sort of architecture is considered to be a strong foundation for a redundant system. It embodies the core principles of Object-Oriented Programming; encapsulation, abstraction, inheritance, and polymorphism. As such, this architecture is usually written in object-oriented languages such as Java. This architecture is ideal for communicating over a network without requiring human interaction. A service-oriented architecture has several core values; Business value, strategic goals, intrinsic inter-operability, shared services, flexibility, and evolutionary refinement. It is an ideal architecture for stability, redundancy and independence.

7.1.1.4 Representation State Transfer (REST)

A ReSTful architecture is one which provides interop capabilities between nodes on the internet. These available ReSTful resources require requesting systems to access and/or manipulate existing textual representations of resources using stateless operations. These stateless operations can be predefined as in the case of WSDL or SOAP, or they can have a much more generic usage. The response from the web resource can be in HTML, JSON or XML. These quick responses using stateless protocols allow for fast performance, reliability, expandability, and reuse by working on the fly. This system is not without its faults. It experiences limitations based on the stateless protocol, the cache, and the client-server. It is a fantastic way to get data from web resources.

7.1.1.5 Building the architecture

The architecture decided upon for this project was the Service Oriented Architecture. This modified, modular client-server architecture was considered ideal when dealing with so many moving parts. This allows separate modules for each section; facial recognition, news feed, time/date/weather, hardware handling. These sets of redundancies allow each module to function independently and in an isolated manner. This is ideal when considering the

application of such a project. The user can disable the malfunctioning modules without harming the other functionality. This is also ideal for a user that wishes to have a simpler mirror. They may choose to use only the time and date functionality (but nothing else). They may wish to have all the bells and whistles. It is perfectly configurable for the user's needs.

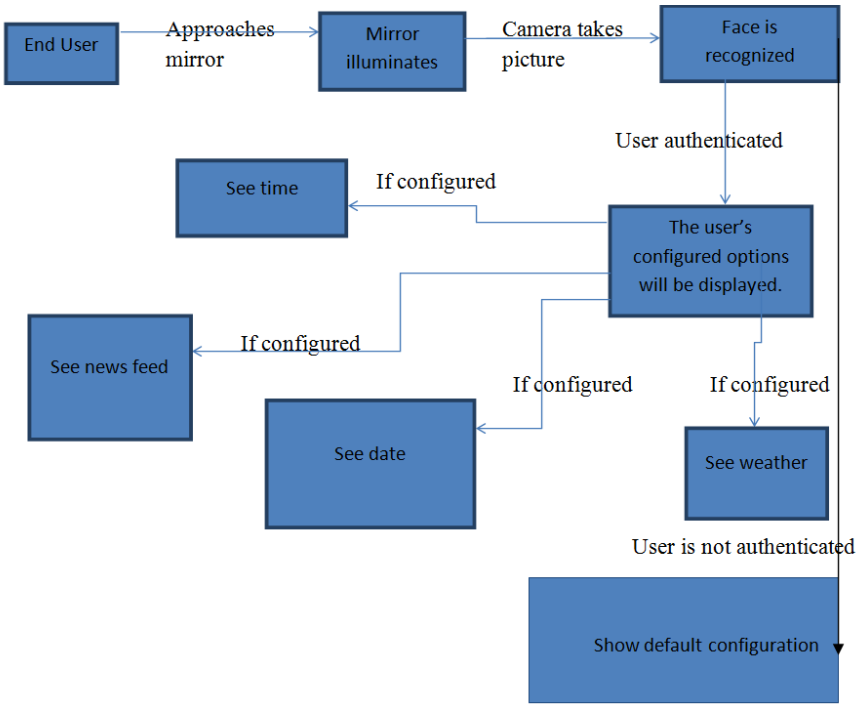


Figure 36 - Activity Diagram

This activity diagram gives a basic overview of how the user shall interact with the system. The user should be able to walk up to the mirror and the mirror should light up with minimal interaction. The Smart Mirror should then take a fully illuminated photo of the user. This image shall be sent to the facial recognition module processing on the Raspberry Pi. The facial recognition module sends an indicator to the modular JavaScript architecture on the Raspberry Pi. If the user is an authenticated user with proper privileges, then that user's configuration settings are displayed. If the user is not authenticated, then a default configuration of settings shall be displayed.

These configured settings can be changed in a configuration file in the architecture. These settings include (but are not limited to) clock, weather, newsfeed, and calendar. These options allow the user to choose which modules they want to have displayed. This also allows for a certain amount of control over issues. For example, if the newsfeed module began giving the user issues (or if the news were too shocking for the user) they may decide to disable the module. This can be disabled without affecting the functionality of the infrastructure, server or the other modules.

7.1.1.6 Context Diagram

The context of this architecture is such that the central motivator of all things in this environment is the Smart Mirror Infrastructure. It validates users, checks the weather, time, date and newsfeed of users, and queries the Apache server. These queries will be done by

using a ReSTful architecture. All components revolve around the Smart Mirror. The modules, user and Apache Webserver all rely on the Smart Mirror in order to function. They interact on a basic level with the Smart Mirror.

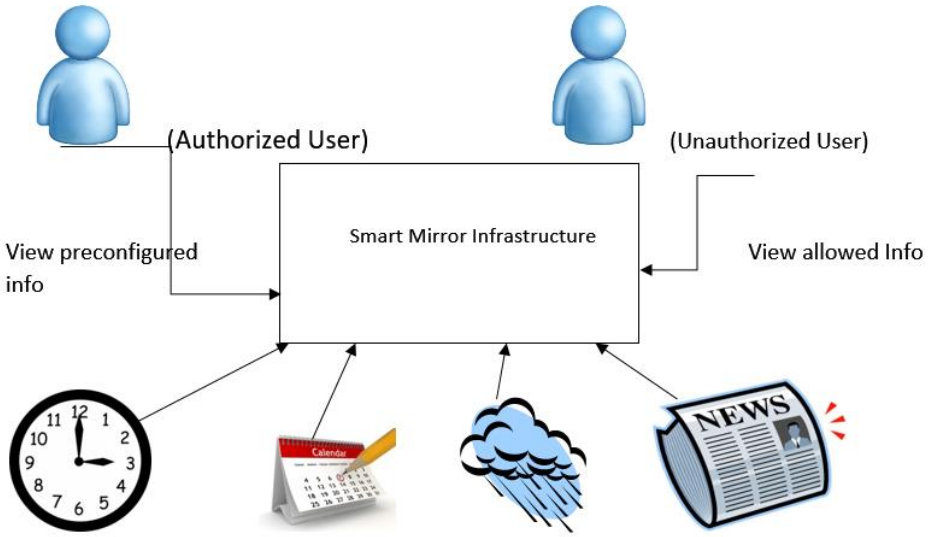


Figure 37 - Context Diagram

7.1.1.7 UML Use-Case Diagrams

A use-case diagram is primarily used to establish user requirements. There are two basic use-cases for the Smart Mirror in question. One, authorized user approaches (seen in Figure X). Two, an unauthorized user approaches (seen in Figure X). These cases in question are used to keep the mirror private. The main user can configure the mirror however they choose and not worry about their personal space being violated. Every software architecture design begins at the user story. These use-cases illustrate the user story for this mirror.

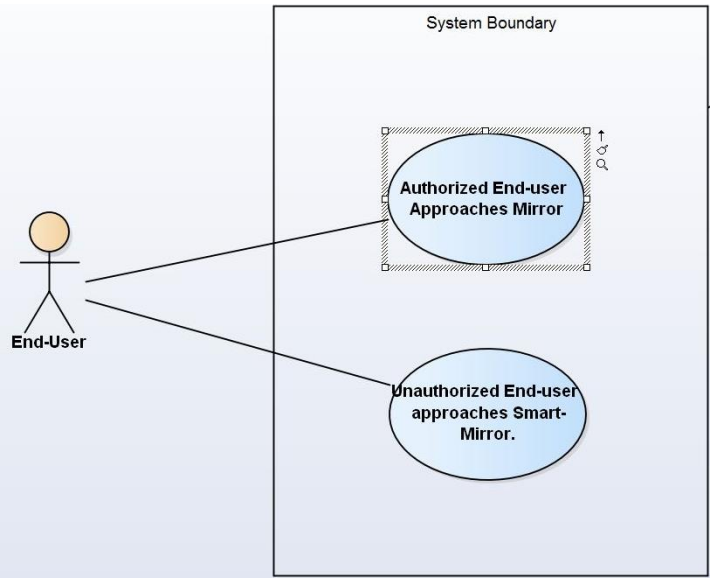


Figure 38 – Primary Use-Cases

Use-Case 1: Authorized End-User Approaches Smart-Mirror Scenario:

1. End-user approaches Smart-Mirror.
2. Smart-Mirror illuminates End-User.
3. Camera-Module captures photo of illuminated End-User.
4. Photo is analyzed in Facial-Recognition module.
5. End-user is confirmed as Authorized End-User.
6. Smart-Mirror displays configured information specific to End-User.

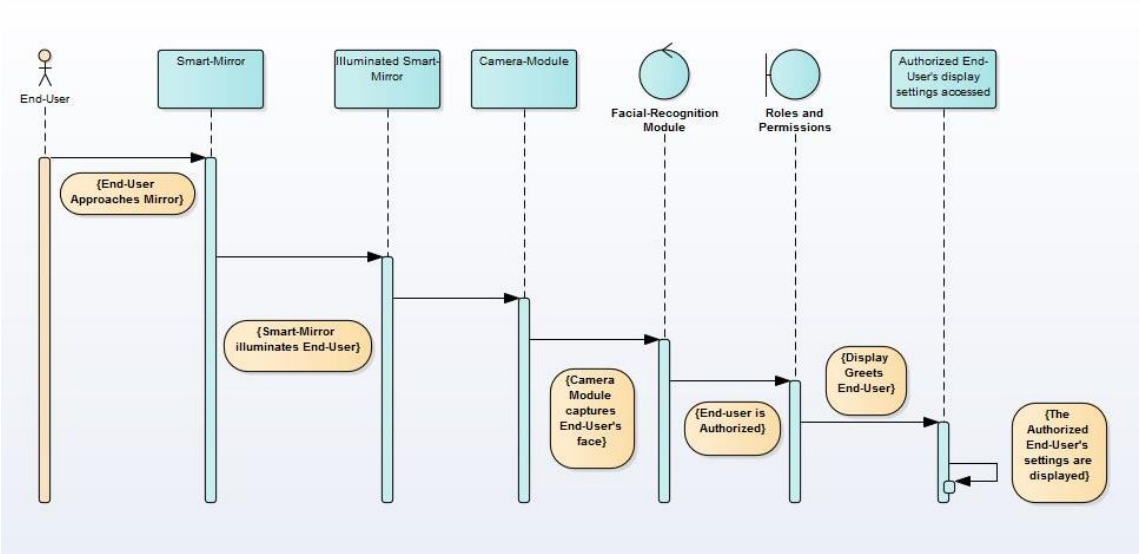


Figure 39 – Authorized User Use Case Diagram

The ideal use-case for this architecture revolves around authorized users. The end-user (ideally, the owner of the smart mirror) will configure the facial recognition module to recognize their face. This aforementioned facial recognition module will be used as the gateway to the user's configuration settings.

Use-Case 2: Unauthorized End-User Approaches Smart-Mirror Scenario:

1. End-User approaches Smart-Mirror.
2. Smart-Mirror illuminates End-User.
3. Camera Module captures photo of illuminated End-User.
4. Photo is analyzed in Facial-Recognition module.
5. End-User is confirmed as Unauthorized End-User.
6. Smart-Mirror displays the Time and Date.

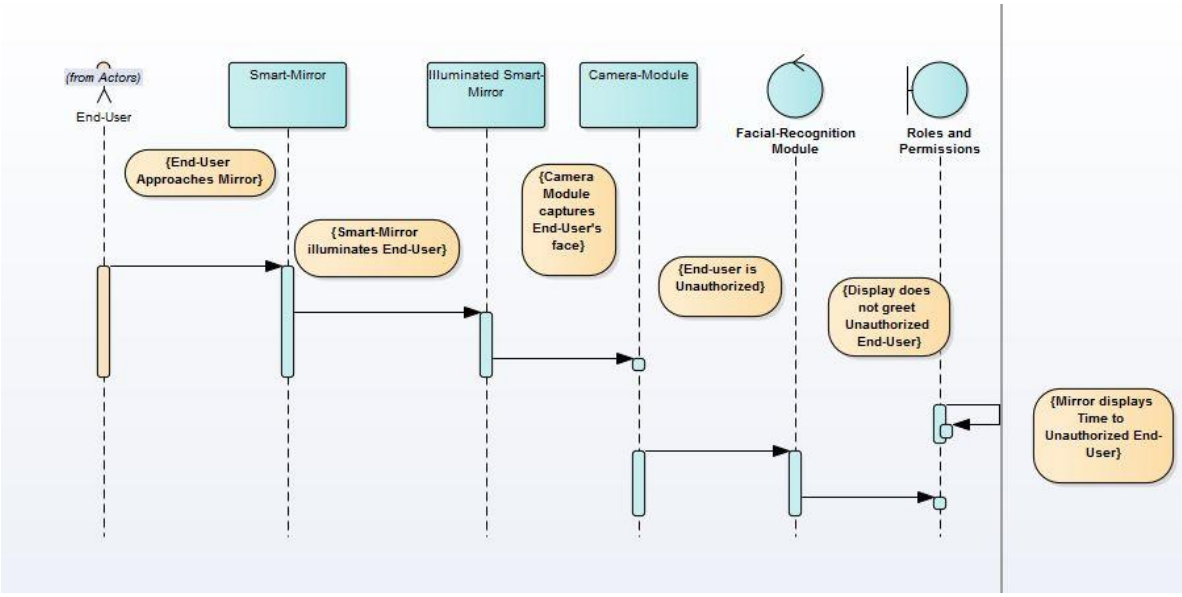


Figure 40 – Unauthorized User Use Case Diagram

7.1.1.8 Component Diagram

This component diagram illustrates the relationship between the client and the server. The Raspberry Pi takes place of the client and the Apache Server is the server. The Raspberry Pi services the hardware interrupts being sent by the interface of the Smart Mirror and forwards those requests to the modules. Using a ReSTful, stateless interaction from the modules, the Apache Server will receive (and service) a series of ReST calls from the modules. The Apache Server forwards that ReSTful, stateless requests to the respective webpages on the internet.

The user interaction is a combination of physical and configurable interactions. The user may interact with the mirror using a series of gestures or the user may interact with the mirror using a configuration file that stores all the users (both unauthorized and authorized) settings.

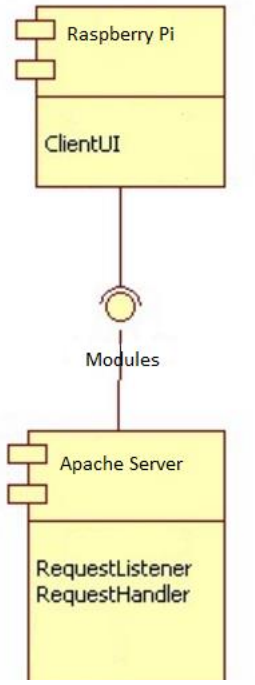


Figure 41 – Component Diagram

7.1.1.9 UML Class Diagram

This class diagram is a simplification of a web-based architecture. This framework is oriented using Cascading Style Sheets and Hyper Text Markup Language coding standards. This allows a simpler depiction of such architecture. If a full depiction of such architecture

were to be established, then there would be several pages of class relationships between Hyper Text Markup Language, Cascading Style Sheets and JavaScript code. It is unnecessary to get such an idea across. The standard idea of web-based development includes the idea that Hyper Text Markup Language is used to lay out the structure of the webpage, the CSS is used to determine how a page appears, and JavaScript executes the logic. JavaScript is intended to manipulate the existing HTML and CSS scripts.

The Cascading Style Sheets used in this architecture are reusable and they are housed in a central location. This allows each distinct module to access the Style Sheets without redundancy and without wasting memory space. This UML diagram also does not indicate the future modules of FacialRecognition and RolesAndPermissions.

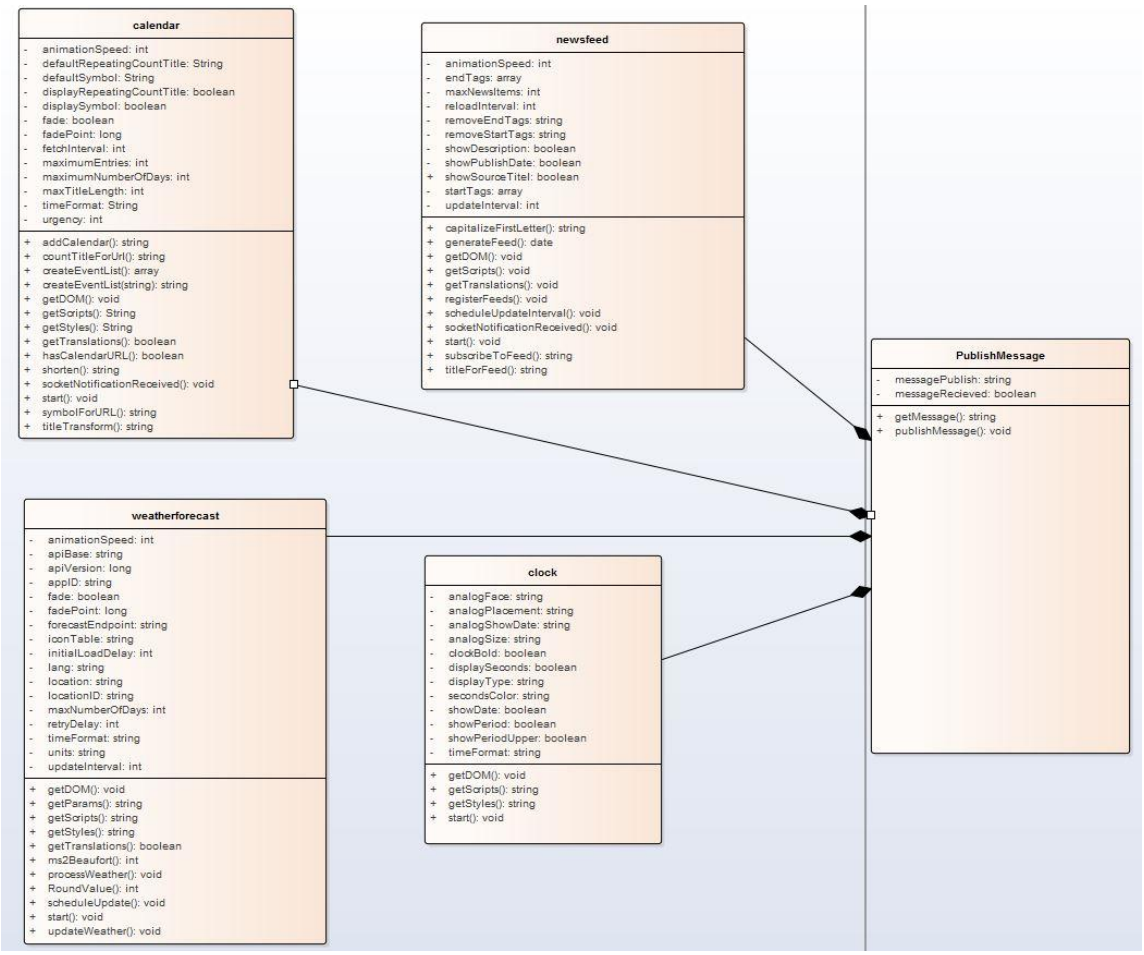


Figure 42 – Class Diagram

7.1.2 Coding Conventions

There are several types of coding conventions that will be implemented for this project. They include CSS, HTML, python, and JavaScript coding conventions. A coding convention typically illustrates the way in which a language will be implemented and maintained. Coding conventions identify and explain recommended programming styles, methods and practices for implementation. Software structural quality, white spaces,

programming principles, rules of thumb, indentation, declarations and comments must all be followed in order to create good coding habits. Google Style Sheets are typically the end-all be-all of coding conventions. Most developers attempt to follow Google's standards as closely as possible.

7.1.2.1 HTML/CSS coding conventions

Typical stylistic rules to follow while programming in HTML or CSS include; indent by two spaces at a time, use only lowercase, and removing trailing white spaces. General metadata rules include; use UTF-8 character encoding with no byte order mark, mark TODOs and action items with the TODO keyword, and use comments effectively to explain code.

HTML specific rules include; Use HTML5, only use valid HTML if possible, use HTML for its intended purpose, provide alternative multimedia contents, separate structure, presentation and behavior, do not use entity references, omit optional tags, omit type attributes. HTML formatting rules include; indent for every block, list, and table element and indent every such child element, when quoting attribute values, use double quotes.

CSS style rules include; use valid CSS where possible, use meaningful/generic ID and class names, use short ID and class names, avoid qualifying ID and class names with type selectors, use shorthand whenever possible, omit unit specification of "0" values, omit leading "0"s, use three-character hexadecimal notation, prefix selectors with an application-specific prefix, separate words in ID and class names with hyphens, do not use user agent detection or CSS 'hacks'.

CSS formatting rules include; alphabetic declarations, indentations of all block content, use semicolons after all declarations, use a space after a property name's colon, separate selectors and declarations via new lines, separate rules by new lines, use single quotes for attribute selectors and property values. Most importantly, be consistent. A coding convention is worthless unless it is consistently followed.

7.1.2.2 JavaScript coding conventions

JavaScript coding conventions include; all lowercase file names, use UTF-8 source file encoding, source file structure should have: license, JSDoc, module statement, require statement and implementation, the file implementation follows all dependency declarations and may consist of module declarations.

Formatting styles of JavaScript include; braces are used for all control structures, no line-break before, or after, opening a brace, no line-break before, or after, closing a brace, if blocks are empty they may be concise, object and array literals are optionally block-like, class literals are indented as blocks, the body of the function expression is indented two spaces more than the preceding line, switch statements are indented two spaces, one statement per line, semicolons are required after every statement, column limit is 80 characters, line-wrapping is acceptable, white spaces are specific for both horizontal and vertical spacing, function arguments are put on same line as function name, it is recommended to group all parenthesis, comments are to document how code functions, declare types as needed, use trailing commas for array literals, use trailing commas for object literals, and many, many more. As with all other coding standards, *consistency is key*.

7.1.2.3 Python coding conventions

Python language rules include; run pylint over your code, use imports for packages and modules only, import each module using the full pathname location of the module, exceptions are allowed but must be used carefully, avoid global variables, local/nested/inner classes and functions are fine, simple cases are acceptable, use default iterators and operators for types that support them, use generators as needed, one-liner lambda functions are acceptable, conditional expression one-liners are also acceptable, default argument values are acceptable in most cases, properties for accessing or setting data where you would normally have used simple accessor or setters, use 'implicit' false if possible, lexical scoping is acceptable, use function and method decorators when needed, do not rely on built-in types' atomicity for threading, avoid power features if possible.

Python style rules include; do not terminate lines with semi-colons or use them to put several commands on a single line, max line length is 80 characters, use parentheses sparingly, indent code blocks with four spaces, use two blank lines between top-level definitions and one between methods, follow typographic rules for spaces involving punctuation, most files do not need to start with a shebang line, use comments for module, function method and in-line style, classes need to explicitly inherit from other classes (includes nested classes), explicitly close files or sockets after use, use TODO for temporary code, imports should be on individual lines, use a single statement per line, access control is trivial if using public variables, use underscores between words in names. As with all other coding conventions, it is useless unless programmers are *consistent.*

7.2 Raspberry Pi software

The existing software available on the Raspberry Pi is numerous. There is an existing Linux based operating system that allows for commercial-off-the-shelf immediate applications. The existing Raspberry Pi software includes Raspbian, and an Apache Server.

7.2.1 Raspbian

Initially released in June of 2012, Raspbian is a Debian based Linux Operating System that is easily flashed to the Raspberry Pi module. It allows consumers to easily do many things. These things include (but are not limited to) configuring the Wi-Fi chip, configuring the Bluetooth chip, and configuring the internet settings of the Raspberry Pi. This Operating System is the officially released OS for the Raspberry Pi. It is officially provided and supported by the Raspberry Pi Foundation. This iteration of the Linux Operating System is updated and maintained on a separate branch of the GitHub Linux tree. The desktop environment used is called PIXEL.

7.2.2 The Apache Server

One of the existing off the shelf items available for use on the Raspberry Pi 3 is an Apache server. This is an amazing item because it enables us to use an existing, stable, application without having to worry about building one. This open source software is maintained by an open community of developers. This apache server has some inherent functionality that is useful. Its modules include, but are not limited to, Secure Sockets Layer, Proxy module, Transport Layer Security support, custom log files, and filtering. The versatility of such a

server allows for extensive applications. One such application is a LAMP server (Linux, apache, mysql, PHP). This stack allows a versatile webserver on a Raspberry Pi.

There are several possible uses of an Apache server. It has the capability to support Perl, Python, Tcl, and PHP. Though, for this project only the PHP interface was exercised. Apache also allows for URL rewriting (which is also used in this project), external extension module, and ModSecurity. Apache also implements a variety of MultiProcessing Modules (MPM). These modules allow for Apache to run in different modes such as hybrid (thread + process), process-based or event-hybrid modes. This allows Apache to better react to the needs of the infrastructure.

Apache also implements Event MPM which is specifically designed to deliver static pages effectively. It is as comparably fast as the existing event-based web servers (including Apache's event-based server), though it still underperforms nginx.

7.2.3 MySQL

MySQL is an open sourced relational database management system. This database uses Structured Query Language to request data from its stored tables. It is considered to be a central component of the LAMP open sourced web application software stack. LAMP is an acronym for Linux, Apache, MySQL. MYSQL is written in C or C++. It is very simple and easy to get MySQL installed on Linux because it is a simple repository request from the application cache defaulted for many Debian based Operating Systems.

MySQL is good for simple web based applications and has a lighter version of the application called MySQL Lite. This is, in particular, useful for embedded applications. It requires very little drive space and has some feature limitations – though these limitations will not hinder the usefulness to this project. This still allows for usability for this project and responsiveness, while not using a significant portion of the space on the SD card.

7.3 ATmega Software

The ATmega328, flashed with the Arduino open source platform, will be responsible for handling the hardware inputs and outputs for the mirror system. By having a dedicated system perform the arduous task of continuously sampling the photo resistor and gesture sensor, controlling the LED brightness, and relaying important messages, processing power on the Raspberry Pi can be allocated towards the heavy lifting tasks such as facial recognition, display updates, and server management.

The operational software for the ATmega328 can be divided into five (5) main components: libraries, global variables, setup, loop, and supporting functions. Organizing the software running on the ATmega328 in such a way allows for the initialization as well as continuous processing of inputs and outputs.

Within the Setup function, commonly, pins are declared as inputs or outputs, serial communication is initialized, and various operations which require single execution during the life of the code are added to the function. When the board is powered on, the Setup function will run only once to complete these operations. If the chip loses power or is reset, the software will once again run the setup function a single time. Upon completion, the microcontroller will proceed to execute the loop stage of the code.

Within the Loop function, the main operations of the microcontroller are evaluated for execution. The loop function runs continuously for the life of the device until the microcontroller is either reset or the power source is disconnected. Operations existing within the loop function are typically related to analyzing the current state of inputs and evaluating the data to determine the outputs required by the microcontroller.

To begin, the Arduino platform must import the correct libraries which will be necessary to simplify operations later in the program execution. Currently, Wire.h and ZX_Sensor.h support key operations within the later functions.

Within the project's Setup function, the initialization of serial communication will occur to facilitate the transfer of data between the microcontroller and Raspberry Pi. Additionally, software setup for the gesture sensor will be necessary.

Within the project's Loop function, the ATmega328 will be managing numerous processes to analyze the inputs of coming from the photocell and the gesture sensor. For each loop execution, a reading will be obtained from the photocell. If the level is below the predefined threshold,

During testing, it became clear that simply basing the LED status off of the raw photocell readings could lead to a ping-pong effect during periods where the readings were within close range to the threshold value. In order to reduce this effect of quick on-off fluctuations, a supporting function is added to average a predefined number of photocell readings over a period of time. Each time a reading is taken, the value is saved to an array within the supporting function. When enough values are gathered to make an accurate estimation of the average light intensity in the time period, the average value is returned by the supporting function, where the value is then processed to determine if additional lighting is required in the environment.

To further improve the dynamic lighting of the system, rather than implementing a fade-to-off and fade-to-on approach, the average intensity calculations returned by the supporting function will be used to adjust the maximum brightness permitted. Since the brightness of the LEDs can be represented by a numerical pulse width modulation value, the system will be capable of mapping the average light level to an acceptable maximum average voltage applied to the MOSFETs responsible for dimming the LEDs through the use of an additional supporting function.

```
// #include ApplicableLibraries
// Global Variable Declarations
// Supporting Function Declarations

void setup() {
  // Setup runs once
}

void loop() {
  // Loop runs infinitely
}

// Supporting Functions Defined Here
```

Figure 43 - Arduino Platform Software Structure

Gesture Sensor support will be provided by the ZX_Sensor library released by Adafruit with the development of the gesture sensor.

Table 17 - Hardware/Software Pin Relationships

ATmega328 Pin Assignments				
Physical Pin	Software Pin	Type	Purpose	Function
4	2	Digital	Gesture Sensor Inturrupt	Input
28	A5	Analog	Gesture Sensor I2C Clock	Input
27	A4	Analog	Gesture Sensor I2C Data	Input/Output
23	A0	Analog	Photoresistor Value	Input
3	1	Digital	UART Transmit	Output
2	0	Digital	UART Receive	Input
11	5	Digital	LED PWM_1	Output
12	6	Digital	LED PWM_2	Output

The above methodology assumes that the ATmega software will be written using a procedural method. The Arduino software utilizes a compiler based on C and C++. The Arduino language is specific to the brand and many of the libraries that are written to support the hardware are written using C++. There are certain abstractions that are added to the language which make it simple to use for enthusiasts, however, more experienced programmers can utilize the object oriented methodology to compile software.

An object oriented software design will allow classes of object to be created to encapsulate the variables and methods. By approaching the software design in this manner, the program flow begins to step away from normally implemented procedural execution and moves toward the object oriented approach in which different objects interact with one another. By encapsulating each one in this way, we begin to see interaction between the device classes rather than the loop method needing to manage the interactions with continuous checking statements or comparisons. Each device class will be responsible for not only managing itself, but also understanding when to interact with the other device classes.

Overall, a hybridized method of programming the ATmega328 will be used to combine the procedural programming techniques to regularly gather sensor data while the object oriented methodology will be used to invoke new instances of objects and take action to achieve the desired outputs.

The following activity diagram illustrates the steps taken by the ATmega to process the user input. When the ATmega receives a gesture interrupt, the GestureSensor class object will read the gesture and signal the SleepHandler class object to disable the sleep mode. The SleepHandler ensures that the MessageHandler signals the Raspberry Pi to start the various functions required for operation such as enabling the LCD backlight and face recognition module. The PhotoSensor object will take light level readings and calculate if additional lighting is required. As the ATmega loops through the routine, it will check if the user is still present in front of the mirror by obtaining the distance. If the distance is out of range of where a person would normally be standing using the mirror, the SleepHandler class then puts the system into a sleep mode by notifying the Raspberry Pi to halt facial recognition and disable the LCD backlight.

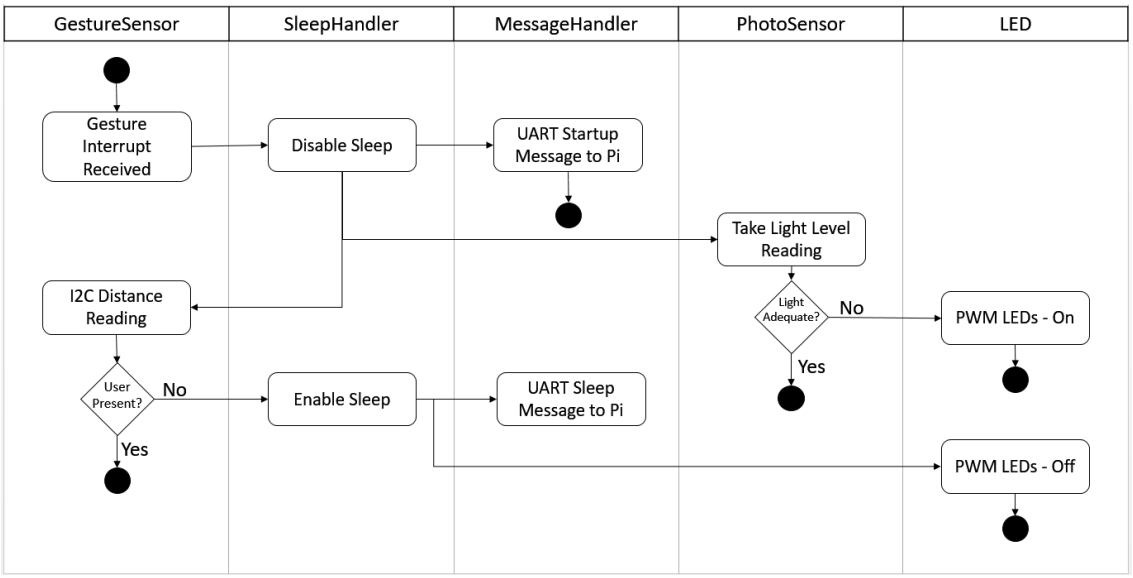


Figure 44 – ATmega Activity Diagram

7.3.1 Specific UART Message Design

Utilizing serial communication UART messages have been described in various sections within this document, however, specifics as to the format and function of the messages have yet to be described in detail. Table 18 will be used as a reference during software implementation to standardize the messages which will be used between the ATmega and Pi.

The newline escape sequence will be used as the last transmission byte indicating the termination of the message. During message parsing on both devices, the standard character will aid in separating multiple messages that may accumulate within the UART buffer of each device. Post processing, the message will be cleared from the internal buffer to ensure parsing in the message a second time does not occur.

Table 18 - The mirror will utilize a set of custom messages standardized within the project for UART communication between the ATmega and Raspberry Pi.

Message String	**Direction**	**Function**
"Sleep\n"	ATmega to Pi	Activity has not been detected. Turn off the backlight and limit external data fetching
"Wake\n"		Activity has been detected. Turn on the backlight, begin facial recognition, fetch external data
"Right\n"		A gesture has been detected in a specific direction. Change the display to show the next module.
"Up\n"		
"Left\n"		
"Running\n"	Pi to ATmega	Raspberry Pi startup sequence has been completed and is ready to begin accepting further UART messages
"Verified\n"		Face detection has recognized the user. Flash the LEDs to confirm.
"VFailed\n"		Verification has failed using face detection; the user was not recognized. Flash the LEDs to notify.

7.4 Facial Recognition

Facial Recognition on the system will be used to identify the user who is in front of the mirror. Software used for this purpose can be broken down into three main categories: Verification, Watchlist, and Identification. Verification methodology is used to test a claim made by the system to verify that the user is who they claim to be based on a pre-established relationship within a database. Identification methodology, the focus of the facial recognition software for this project, is based around taking a sample image from the user, comparing it to the database of known faces, and finding the correct match.

Facial recognition is executed in two steps: detection and identification. Before attempting to match a user's face to the set of known images the database, an algorithm must be used to locate and identify the presence of a face within the input image.

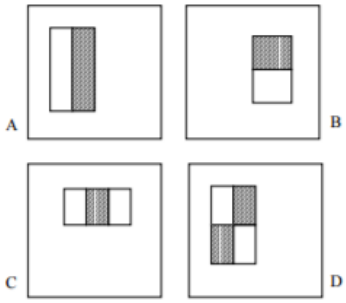


Figure 45 - Sample classifiers are used to identify faces by convolving with the input image.

The Adaboost method for facial recognition is hinged around building a team of classifiers whose combined efforts can correctly identify the presence of a face, even though alone, the classifier may only be correct 50%-70% of the time. This method of boosting creates a team of experts who complement one another and reach an accuracy of upwards of 97% correct identification. For example, if expert one can correctly identify face one, and expert two can correctly identify face two, their combined efforts will result in an algorithm that can identify both of the faces in the set of two images.

The algorithm must be trained using sets of known faces and known non-faces to determine the error rate for each expert classifier. The input to Eigenanalysis is a set of N face images of various users unfolded into a series of vertical vectors held in a matrix. When the mean face is calculated from this dataset, we can then calculate Eigenvectors for each face by subtracting the mean from each face. This leads to a set of images and weights for each user in the databases. If these Eigenfaces were recombined based on the weight they are assigned for each user, the original image of the user would be recreated. For facial recognition, however, after roughly 50 recombination, there would exist adequate difference in which 1000 different users could be differentiated against one another.

These concepts reduce the brute force method of comparing single pixels to pixels for numerous users and overall increases the speed and limits the redundancy for facial recognition. Most importantly, the size of the data produced is much less than the brute force face comparison method which is important for embedded devices.

The system will support facial recognition through the development of an additional module add-on supported by the Magic Mirror open source software. By complying with a specific format of json configuration files, the base software of the Smart Mirror will be able to interact with the additional module to correctly call the supporting software used to detect the presence of a face and analyze the identity of the face.

The language of choice used to implement the facial detection module will be written using Python. Languages to support face recognition are commonly implemented with OpenCV C++ or Python and while extensive library support currently exists for both languages, along with the Raspberry Pi's capability of compiling and executing both languages, selecting the development language is largely dependent on the support for general purpose input output pins as well as support for the Camera Serial Interface.

On the Raspberry Pi, OpenCV requires roughly 5 hours for compilation. Despite the time constraints, utilizing the OpenCV libraries will greatly enhance the accuracy of the face

detection and recognition module. Currently, all desired implementations of Eigenfaces, Fisherfaces, and Histograms are supported by OpenCV. Examples are currently released for C++, however, the basic concepts will require converting the Python to ensure runability on the Raspberry Pi.

Due to the relatively high processing power required to scan and detect faces in a video stream, the facial detection module will be triggered by user input, such as a swipe with the gesture sensor, where a series of still images will be taken by the camera. The module's software analysis will then scan each of the images taken within the set until a face is correctly identified using the aforementioned methods. By comparing the face with a database of known user images, the system will exit the stage of facial detection and enter the facial recognition stage. Once the module has identified the current user, the smart mirror base software will be capable of loading user-specific data from the social media feeds of the user. Inter-module communication or nested module implementation may need to be considered to correctly pass identification and authentication data to each service.

Development procedures for the Facial recognition algorithm will be implemented in a six stage process verifying that each stage functions as expected before working forward. By building the software from the ground level basics and up, the complex processing required to identify faces will exist on a strong substructure of code.

Because the facial recognition procedure will not be continuously running, a procedure first will be established to kick off the image capture and algorithm. When the ATmega receives information from the gesture sensor that activity has been detected, the ATmega will notify the Raspberry Pi to begin startup sequences, one of which will be facial recognition.

The second step in facial recognition development will be using Python to obtain an image from the camera board, converting the image to greyscale, and saving the greyscale image to the filesystem. This basic operation will be completed numerous times during each startup sequence and ensuring that the image can quickly and accurately be converted and saved will establish the groundwork for the following facial recognition and detection.

Once images can be captured, moving towards detecting faces within the images will be developed. Potential algorithms include Adaboost as previously mentioned. OpenCV libraries include face detection functions through the use of Haar cascades through importing xml configurations.

The following steps will be completed in the development of the face recognition logic using Python and OpenCV.

Table 19 – Smart Mirror Face Recognition Development Stages

Smart Mirror Face Recognition Development Stages		
Step	Stage Title	Stage Description
1.	Startup Sequence	Start facial recognition when the RPi receives startup message from the Arduino
2.	Capture Image	Capture an image, convert to greyscale, and store to filesystem
3.	Detect Face	Detect a face from the stored greyscale image
4.	Database Creation	Create a database of positive and negative face examples to compare against
5.	Face Recognition	Correctly train classifiers to recognize and return the identity of the input image
6.	Algorithm Comparison	Implement and compare the performance of EigenAnalysis, Fisher Faces, and Histograms

The supporting Python programs will be separated into a minimum of three separate files to clearly distinguish the functionality between each subcomponent. For example, ImageCapture.py, FaceDetection.py, and FaceRecognition.py. Separating the complete program in this manner will permit debugging and verification of inputs and outputs separately.

8 Project Prototype Construction and Coding

The following sections describe the steps taken towards the development of the Smart Mirror Prototype. The first sections include the bill of materials as well the schematics for each subsystem and how they were designed. Once the schematics are finalized, a PCB layout will be created and sent to a vendor for manufacturing. The section will also include a coding plan for the software moving forward.

8.1 Bill of Materials

The following component map is used to outline the current prototype's required materials. For each labeled component in Figure 46, a corresponding description may be found in Table 20.

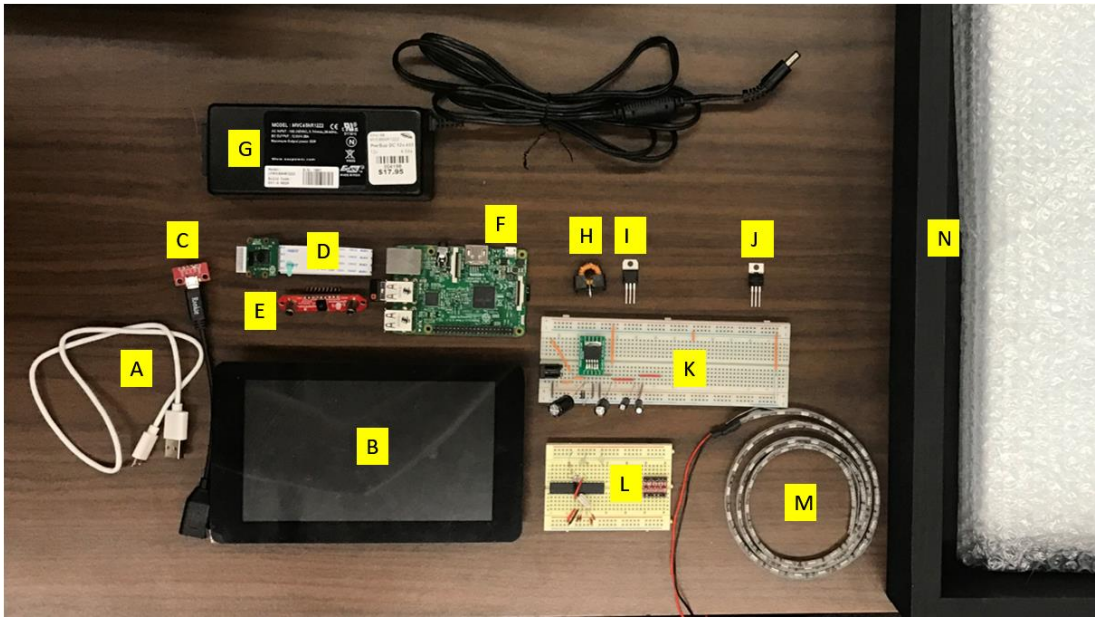


Figure 46 – Component Map

Table 20 – Component Map Key

Label	Component Description
A	USB to MicroUSB Cable
B	7” LCD Display
C	MicroUSB Breadboard Breakout & Female USB Socket
D	Camera Module v2
E	ZX Gesture Sensor
F	Raspberry Pi Model 3B & MicroSD card
G	12V 4A AC to DC Converter
H	PE-5404NL Inductor
I	LD1117 3.3V Linear Regulator
J	IRLB8721PbF N-Channel MOSFET
K	Breadboard Assembly #1: - DC Coaxial Power Connector - LM2596 5V Switching Regulator - Schottky Diode - 680 uF Capacitor - 330 uF Capacitor - Two (2) 1 uF Capacitor
L	Breadboard Assembly #2: - ATmega328 - 16MHz Crystal Oscillator - Four (4) 10pF Ceramic Capacitors - Logic Level Converter - Photocell - 4.7kΩ Resistor
M	12V White LED Strip
N	Two-way Mirror and Assembled Frame

8.2 Integrated Schematics

The electronic design software, Eagle, was used for this project because it offers both schematic and PCB design capabilities. The circuitry for this project was designed in pieces and then combined into one full schematic. Each individual subsystem was designed by the engineer responsible, and once all circuits were completed, they were combined into one project file and interconnected. The following sections break down the design of each subsystem and show their respective schematics as well as the complete version. Once the

full schematic was completed, rigorous amounts of prototyping was done to validate each of the systems. The completed design of the schematic is also very useful to the Computer Engineers working in the group. This assists them in understanding how the code will interface with the hardware.

8.2.1 Power Supply

The power supply circuit was designed while keeping efficiency in mind. In order to provide power to all components of the project a 12V, 5V, and 3.3V rail needs to be provided. One way to reduce wasted power is decrease the difference between the input and output voltages of the regulators. With this in mind, the circuit was designed so that the voltage decreases from large to small as you go across the schematic. It is more efficient to have the input of the 3.3V regulator be 5V rather than the 12V input. The following sections will go in depth on the supporting circuit required by each regulator.

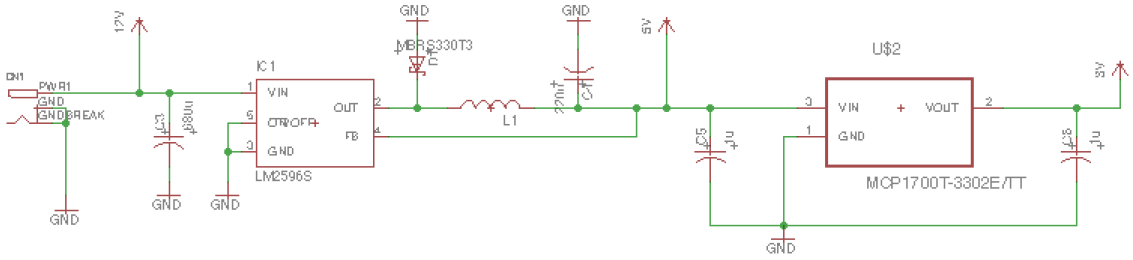


Figure 47 - Power Supply Schematic

8.2.1.1 DC Coaxial Power Connection and 5V regulator

Figure 1 shows the schematic design for the voltage input and 5V switching voltage regulator LM2596. Input voltage of 12V is provided through the use of a DC coaxial power connection. Pin one of the coaxial power connection is the input voltage and connected to the input of the LM2596. Pins 2 and 3 of the coaxial power connection or tied to ground. Pin 1 of the LM2596 is the input voltage pin. This pin is also connected to a 660uF bypass capacitor to avoid large voltage transients. As specified by the datasheet, this capacitor should have a high RMS current rating, and be aluminum or tantalum. Pins 5 and 3 are tied to ground. Pin 2 is the output pin. A low electrolytic or tantalum capacitor with a low ESR should be used as the output capacitor to filter the output and provide feedback stability. A diode is connected to the output to provide the inductor with a path to ground when the switching regulator is off. A Schottky diode is best due to its fast switching speed and low voltage dropout. A 33uH inductor is also connected to the output as recommended by the datasheet. Pin 4 is the last pin and is the feedback pin, which is connected to the node after the output inductor.

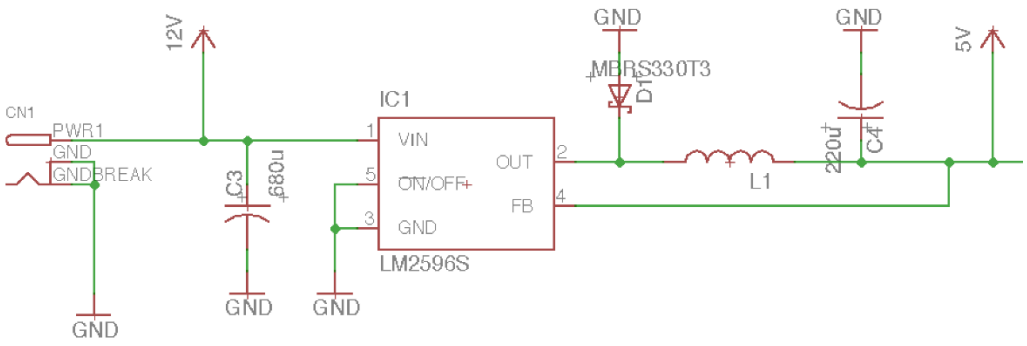


Figure 48 - 5V Regulator Circuit and DC Coaxial Power Connection

8.2.1.2 3V Regulator and Supporting Circuit

The 3V regulator used in the power supply circuit is Microchip's MCP1700T-3302 linear regulator. The supporting circuit for this chip can be seen in Figure 49.

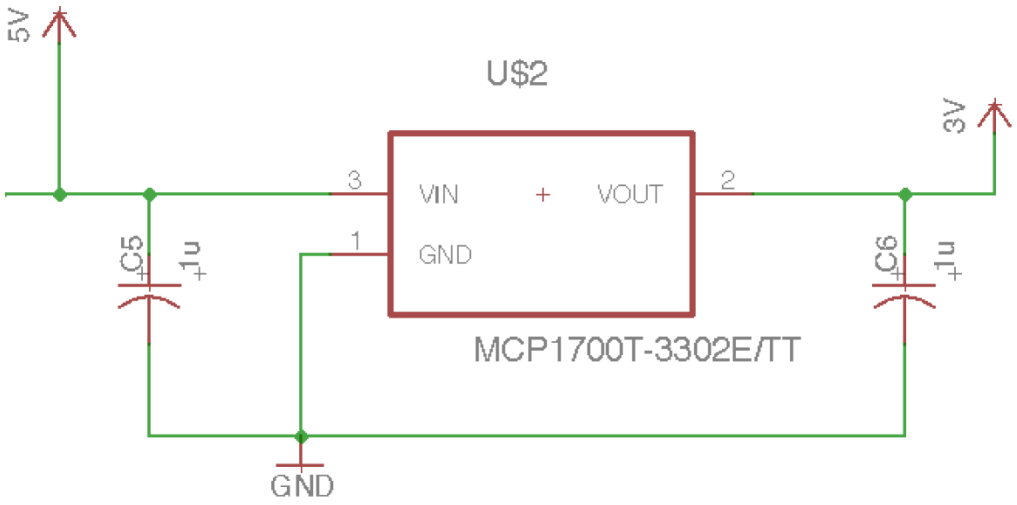


Figure 49 - 3.3V Regulator Supporting Circuit

The supporting circuit for the MCP1700 is very simple. Pin 3 is connected to the input voltage. The 5V rail provides the input voltage in order to reduce power wasted. Pin 3 is also connected to a bypass capacitor of 1uF that is connected to ground. Pin 1 is connected directly to ground. Pin 2 is the output voltage of 3.3V and is also connected to a capacitor of 1uF that is also connected to ground.

8.2.2 ATmega328P-AU Schematic

The schematic for the microcontroller used for the Smart Mirror, the ATmega328P-AU, is shown in Figure 50 below.

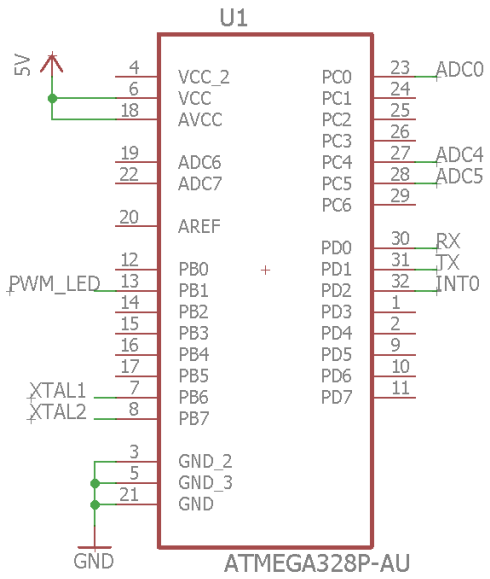


Figure 50 – ATmega328P-AU Schematic

First of all, to power the microcontroller the grounds of the ATmega need to be connected together and properly grounded. It is important that the all the grounds of the ATmega actually get connected together when design the PCB to inhibit noise from entering the chip. On the ATmega328P-AU there are three VCC pins. One is specifically for the analog pinouts of the microcontroller. It is recommended from the datasheet to connect this to 5 Volts even if those functionalities are not being used. So, for the purpose of staying thorough in this project as well as avoiding any potential mishaps once the PCB is manufactured this pin will be connected to a 5 Volt supply. Now there are two VCC pins left on the microcontroller. Again for the same purpose of circumventing future issues with the PCB, both of these will be connected to a 5 Volt power supply.

There are three ports on the ATmega328P-AU, all of which will be utilized. All ports are bi-directional input/output ports that are capable of sourcing and sinking current depending on the application. Port B specifically is used for the external clock configuration. The input and output to the internal amplifier are located at PB6 and PB7, respectively. PB1 has been selected for the output of the PWM signal to be sent out to the MOSFET that controls the power sent to the LED strip on the front of the Smart Mirror.

Port C is 7 bits and contains some analog to digital converters as well. The photocell used for the ambient light detection of the Smart Mirror needs to be connected to an analog to digital converter. The input pin PC0 is perfect for this type of input in order to create a smooth working connection from the photocell circuit to the microcontroller. Another two analog connections that are necessary for this project are the analog input connections from the gesture sensor. The gesture sensor will be using I2C communication to the microcontroller. This includes two connections; the I2C clock and I2C data pins. Both of these should be connected to an analog pin on the microcontroller.

Next, Port D will be discussed and how its pinouts interface with the other circuits involved in this project. Port D is an 8-bit port which mostly contains digital inputs and outputs for various applications. One which will be used for the gesture sensor as well is PD2 as an

interrupt pin. This is a placed on a digital pin as not to be putting a constant signal into or out of the sensor to reduce power usage and to prolong its' longevity. Also located on Port D are the transmit (TX) and receive (RX) pins. These are used for UART communication to the microcomputer being used for the Smart Mirror. The transmit and receive pins on the microcontroller are programmed as output and input pins, respectively, regardless of the program flashed to the microcontroller.

The microcontroller is left with a few unused pins. Unused pins can, in theory, pick up external noise or even noise from the power supply or other components nearby on the PCB. It is important to either program some set level to these pins or enable the internal pull-up resistor. If the pin is not configured correctly, it could pull small amounts of current. However, these small amounts can add up quickly especially if it is happening during periods of sleep or low power usage modes of the microcontroller. The best option to pursue will be to make sure the pins have their internal pull-up resistors enabled. Another helpful part of the complete schematic is pin assignments. Table 21 shows the assignments of each of the pins of the microcontroller on the custom PCB.

Table 21 - ATmega328 Pin Assignments

ATmega328 Pin Assignments					
Physical Pin	**Software Pin**	**Name**	**Function**	**Used for:**	**Description:**
6		VCC		5V	Power supply to microcontroller
18		AVCC		5V	Power supply to microcontroller
13	6	PB1	Output	PWM_LED	PWM control for LEDs
7		PB6	Input	XTAL1	Internal Clock I/O
8		PB7	Output	XTAL2	Internal Clock I/O
3		GND_2		Ground	Ground connection
5		GND_3		Ground	Ground connection
21		GND		Ground	Ground connection
23	A0	PC0	Input	ADC0	Input for Photocell
27	A4	PC4	Input/Output	ADC4	Gesture Sensor Control
28	A5	PC5	Input	ADC5	Gesture Sensor Control
30	0	PD0	Input	RX	Receiving port from Pi
31	1	PD1	Output	TX	Transmitting port from Pi
32	2	PD2	Input	INT0	Interrupt for Gesture Sensor

8.2.3 Logic Level Converter

In order for the ATmega328 and Raspberry Pi 3 to communicate with each other, a logic level converter circuit is needed. The ATmega328 outputs a 5 volt signal and can only

receive 5 volt signals, whereas the Raspberry Pi sends 3 volt signals and only reads 3 volt signals. The two devices communicate through their receiver and transmitter pins so each signal will need to be either boosted or reduced depending on the direction. To convert these signals the open source circuit used on the SparkFun Logic Level Converter Module was implemented. The circuit features a N-channel MOSFET used to convert the voltages as explained in the Relevant Technologies section. For the circuit to function, reference voltages must be provided. These references should be set to whatever voltage the user wants on each side of the circuit. For this project 5V and 3.3V are the reference voltages. The power supply circuit supplies the 5 and 3.3 voltages to the logic level converter circuit. The circuit shown in Figure 51 is the circuit between the ATmega's RX pin and the Raspberry Pi's TX pin. Another identical circuit is used between the ATmega's TX pin and the Raspberry Pi's RX pin.

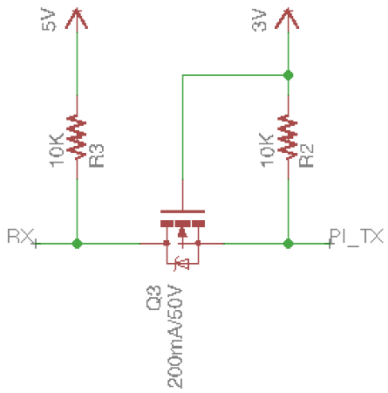


Figure 51 - Logic Level Converter Circuit

8.2.4 Photocell Connection Schematic

The schematic for the photocell is shown in Figure 52. A JST connector is used to interface the circuit on the custom PCB to the physical photocell. This is done to have the ability to route the photocell to a place where the ambient light can be detected then sent to the microcontroller. Once the ambient lighting conditions are measured by the photocell, the program tells the LEDs to either get brighter or dim depending on the conditions. If the lighting is poor in the area where the Smart Mirror is located, the LEDs will get brighter and vice versa.

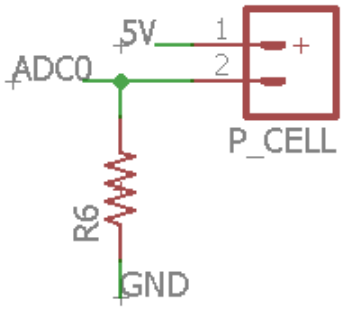


Figure 52 - Photocell Schematic

8.2.5 Micro USB port

In order to power the Raspberry Pi, a micro USB cable will be used. The PCB will need a micro USB connector in order to provide this power. Standard USB has 5 connections, voltage bus, two data lines, an identification line, and a ground. This connection between the two boards is not for transmitting data, so only the voltage and ground pins are used. The 5V rail provided by the power supply is connected to Pin 1, and Pin 5 is tied to ground.

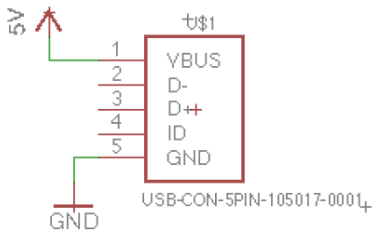


Figure 53 - Micro USB Port

8.2.6 Gesture Sensor Connection

The gesture sensor is connected to the PCB using a five-pin JST connection. This type of connection is durable and strong, ensuring the gesture sensor does not become disconnected while the mirror is being moved around. Pin 1 is connected to the 5V rail, and Pin 2 connected to ground. The gesture sensor talks the ATmega328 using I2C. Pin 3 of the connector is the Data ready line, Pin 4 is the I2C clock line, and Pin 5 is the I2C data line.

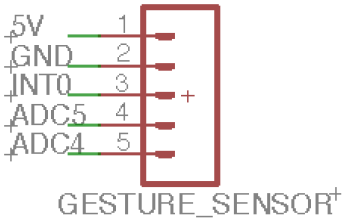


Figure 54 - Gesture Sensor Connector

8.2.7 LED Strip

In order to test the LED strip, an N-Channel Power MOSFET was used in conjunction with the microcontroller. A schematic of the circuit used to test the LED is shown in Figure 55. The pin labeled ‘PWM_LED’ goes to the ‘PB1’ output pin of the ATmega328P-AU microcontroller. This output is then sent to the Gate of the MOSFET. The positive end of the connection to the LED will be connected to a 12 V power source. The negative end of the LED will then go to the Drain pin of the MOSFET. The Source of the MOSFET is connected to ground. When the microcontroller sends out the PWM signal to the Gate of the MOSFET, it completes the circuit from the LED’s negative side to the grounded side (Source) of the MOSFET. Therefore, giving the user the ability to turn the LED on and off or raise/lower the brightness with ease.

A JST connector is used to connect the leads of the LED to the PCB. This is to maintain flexibility when mounting the LED strips to the Smart Mirror. There needs to be enough wire length to be able to attach the LED strips and keep the PCB in a concealed place behind the Smart Mirror.

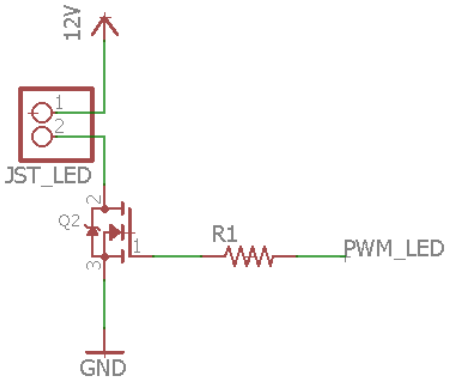


Figure 55 - LED Schematic

8.2.8 Photocell Circuit Schematic

Figure 56 shows the schematic for the photocell circuit. It should be noted that this circuit is not to be placed on the PCB board. This is because this circuit will need to be on the outside of the mirror frame in order to accurately measure light level, while the PCB will be inside the frame. It has yet to be determined whether the circuit will be built on a form of protoboard, or if a separate PCB will be made. This circuit is designed the same way it was tested, using a 4.7k Ohm resistor. The circuit will require three connections to the PCB. The node between the photocell and resistor will be connected to an analog pin of the ATmega328 to measure the voltage difference. Then the ground and 5V nodes will also need to be connected the respective rails.

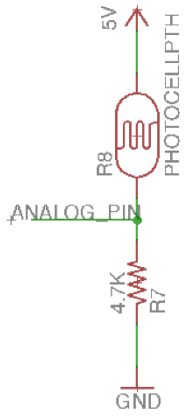


Figure 56 - Photocell Schematic

8.2.9 Full Schematic

After the schematics for each subsystem and component were designed, they were all combined into one full schematic. When putting this schematic together, care was taken to ensure all busses and nets were connected to the correct components. The power supply was integrated first in order to provide the necessary power rails. Then one by one, the other components were added in. Each component requires a connection to a power rail, so it was pertinent to ensure they were all labeled correctly. It was also important to make sure that the pins of the ATmega328 were tied to all the correct nets of the other subsystems.

During this portion of the design process, time was also taken to decide what types of packages and connections were used for each component. When making these decisions it is important to consider a few factors such as size, angle, and direction.

With a complete schematic in place, steps can be taken to design the layout of the PCB. The software used to design the schematic, Eagle, provides the necessary tools to transfer the schematic to board layout, making it easy for the user.

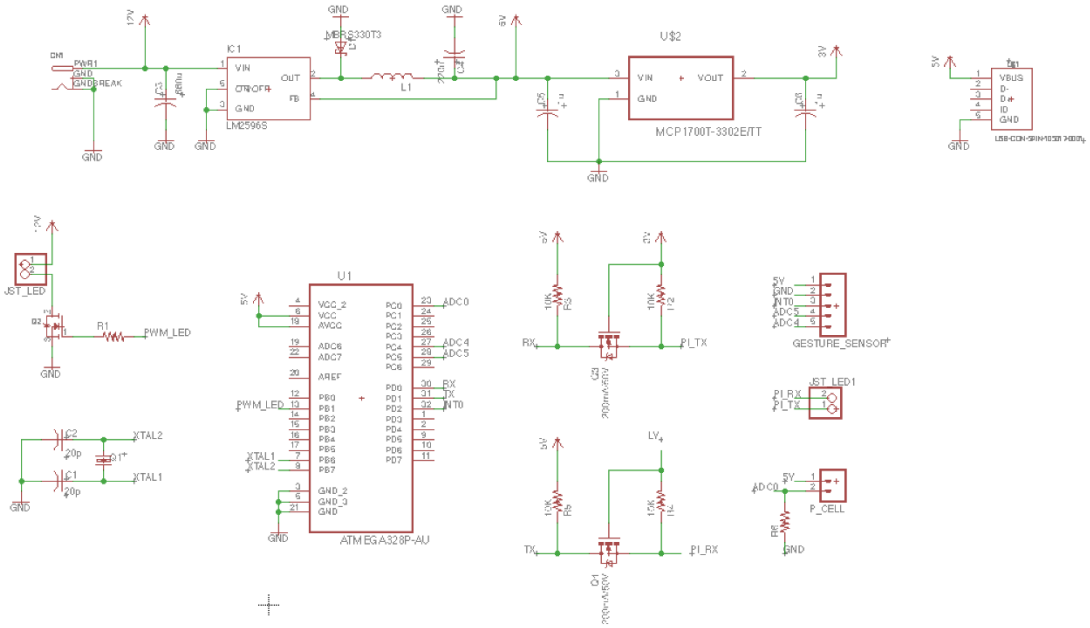


Figure 57 - Full Schematic

8.3 PCB Vendor and Assembly

A key requirement of Senior Design is designing a PCB. The ECE program currently does not offer any required courses in PCB design so this step of the project is a major learning point. Various methods can be used when deciding how to design a custom PCB. There are many different software packages that have been developed over the years to help with designing and creating a schematic that will easily translate to a PCB.

The Eagle software that was used for schematic designing, will also be used for PCB designing. Eagle software makes it easy for the user to go from schematic design to PCB

design and is the main reason this program was chosen. With only little prior experience of working with PCB boards from various internships, much of the PCB design techniques will be learned from the Internet.

In order to save on costs, only one PCB will be designed. This will feature the full power supply circuit including voltage regulators, the ATmega328 microcontroller, the LED PWM control circuit, as well as the logic level converter circuit. There will also be various ports mounted to the PCB including the coaxial power connector, a Micro USB port to connect to the Raspberry Pi in order to provide it power, a two pin port for the LED strips, a two pin port for serial communication between the two devices, a five pin port for the gesture sensor, and a two pin port for the photocell circuit.

Our group has selected OSH Park as our PCB vendor. OSH Park is a community that takes multiple users PCB designs and prints them all on the same panel. This means users split the cost of getting a panel printed which leads to budget friendly prices. OSH Park's website advertises $5 per square inch for two layer boards and the price includes three copies of the board. Getting three copies is very beneficial for security in case one board is damaged during testing

8.4 Final Coding Plan

The final coding plan will consist of the development of all three subcomponents of the software architecture in tandem: the main framework, the facial recognition software, and the ATmega software. Predefined tests in Section 9 will ensure that integration of the multiple components interact seamlessly and effortlessly as each feature is developed.

With two programmers contributing towards the same product code, GitHub will be utilized to organize all progress throughout the software development cycle during the spring semester. A project repository will house the separate component software structures and allow multiple contributions from both contributing parties. This method will also ensure regular progress monitoring to hold accountability for meeting the project milestones and deadlines.

The shared implementation assignments between both computer engineering team members are to both be implemented on the Raspberry Pi. To avoid compatibility issues between a simulated Linux environment and the Raspberry Pi's Linux release, both team members will each be using a separate board device to develop the product with. Using the two separate devices for development will also ensure consistent program output is produced over the course of the semester with little to no hindrance created when a test is desired. During the development lifecycle, notes regarding system configurations, installations, and any other dependencies will be taken to ensure recreation is possible should complete system failure occur. Following the completion of the code, the two device implementations will be merged to one system image in which the final software will reside.

At a point two thirds from the end of the semester, a majority of the software will have completed development and passed the tests defined in Section 9. The remainder of the semester will be used to further debug any integration issues between the modules and

components of the software architecture and ensure that all development test cases pass the evaluation.

To complete the software coding plan, tests will be completed with the final system hardware to account for any unforeseen data skew due to the electrical circuit implementations. Applying to only the ATmega software section, voltage readouts for the sensors have the possibility of slightly varying from breadboard tests. If there is significant difference and code corrections are possible, this final step in the coding plan will be to correct for any hardware differences.

Should time permit, documentation and tutorial guidelines will be created and published in the spirit of utilizing open source software. While the full system will be described in detail for the final presentation of the project, the usability of the system may not necessarily exist as a straight forward or self-explanatory process. By creating an installation guide and software user manual, in the future, additional hobbyists may contribute towards a system which enhances the technology developed in this senior design project.

8.4.1 Roles and Permissions Module

Roles and permissions are labels that are stored in a MySQL database. This database is stored on the Raspberry Pi and is solely responsible for storing the roles of each group and the permissions allowed for each group. Ideally, the database will be accessed via a webpage by a super user. This super user will be used to access multiple different tables; those of which include role_id and perm_id. These tables will illustrate the roles and permissions, respectively, of each of the users enabled. These tables will be queried and accessed using a PHP webpage located in the RolesAndPermissions module of the Smart Mirror file system. These tables will be queried to have the configuration settings of each user. Once the user in question has been authenticated, the table's output will be fed to the local config.js file to configure the Smart Mirror interface. Otherwise, if the user were to be unauthenticated, the default configuration will be used.

9 Prototype Testing Plan

The following sections will describe the various tests that will be completed once the PCB board is manufactured and the prototype is built. The hardware tests will be done in a logical order, starting with the power supply circuit. Once its ensured the power supply circuit is functioning, tests with other subsystems can begin on the PCB.

Post PCB development, the software will require additional testing to ensure correct connections between the various subsystems. Verifications for both sensor data and serial communication will be conducted will be used to ensure that the final product is capable of delivering and meeting each of the required specifications defined from the start of the project.

The creation of a hardware and software test procedure during the planning stages of the project will allow for a streamlined development process during the spring semester. By laying out each of the desired tests and expected results, team efforts can be focused on the final implementation, test, and debugging process. Due to the accelerated nature of the system development, planning these details early in the designing phase will prove to be a valuable method to verify the intended functionality during the final half of implementation. The following tests will also help ensure project requirements and specifications are on track to completion.

9.1 Hardware Test Environment

All hardware testing will take place in an environment similar to the environment the mirror would be operated in. This means indoors in a dry, clean room. The effects of weather are irrelevant for this project so no tests with water or wind will be needed. The testing temperature should be room temperature to simulate use in a user's house. Most testing will be conducted in the Senior Design Lab, room 456 in Engineering 1. Due to schedules and availability, some testing will be completed at group member's homes as well, but the environment will still match the conditions described above.

9.2 Hardware Specific Testing

Hardware testing will begin by testing the components and subsystems individually. Once a subsystem is tested and fully functional, it will be integrated with other subsystems to make sure all parts are compatible. Hardware specific tests will be conducted on the completed system to ensure each component and subsystem are in working order. Once all subsystems have been tested and integrated together, tests will be run with the full prototype.

Once the designed PCB is received from the vendor, hardware specific testing will begin to ensure the board functions as expected. A series of tests will be done starting first with the individually subsystems. Once the subsystems are determined to be satisfactory, tests will then be run with the whole system working together. If any bugs occur during the testing process the design will need to be reviewed. A breadboard test will be done again to simulate the bug. If the issue is present during the breadboard test then it can be concluded as a design issue and revisions will need to be made. If the bug is not present on

the breadboard simulation then the next step is to troubleshoot the PCB board to determine if there are any errors in the layout, or if the vendor made an error in manufacturing of the board. If that's the case, the vendor will need to be contacted to correct the issue. The following sections describe the test that will need to be run for each subsystem.

9.2.1 Power Supply Circuit

Test Name	Power System Test
Purpose	To ensure the power supply system provides a 12V, 5V and 3.3V rail for all components.
Test Materials	1. Power supply circuit on PCB 2. AC to DC converter cable 3. Raspberry Pi 4. Micro USB to Mirco USB cable 5. Innova Digital Multimeter
Prerequisites	1. Ensure the AC to DC converter is outputting 12V using the digital multimeter
Procedure	1. Connect the AC to DC converter to a standard wall outlet 2. Connect AC to DC converter to PCB 3. Measure voltage at the 12V pin of LED strips connector 4. Measure output of the 5V switching regulator using the multimeter 5. Measure output of 3.3V linear regulator using the multimeter 6. Connect the Raspberry Pi to PCB using Micro USB cable 7. Observe if Raspberry Pi is on
Expected Results	Regulators should output listed voltages. The Raspberry Pi should turn on, meaning it is receiving enough current.

9.2.2 ATmega

Test Name	ATmega328P-AU Test
Purpose	To ensure power and functionality of the microcontroller that is to be mounted on the PCB.
Test Materials	1. Power supply to the ATmega328P-AU 2. External Clock Circuit 3. Innova Digital Multimeter
Prerequisites	1. Ensure all connections are secure and in their respective locations to the microcontroller

	2. Ensure all grounds are connected to avoid burning up a chip
Procedure	1. Connect the external clock circuit in a Full Swing Crystal Oscillator configuration with respective capacitors 2. If there is any, erase all previous memory on the ATmega328P-AU 3. Power the ATmega328P-AU and check that the oscillator is producing an acceptable waveform 4. Program one of the inputs to blink an LED to test that the MCU does in fact work
Expected Results	ATmega328P-AU should power on and the oscillator should produce an acceptable waveform which the MCU can use. Any program flashed to the MCU should run smoothly and with no problems.

9.2.3 Logic Level Converter Circuit

Test Name	Logic Level Converter Test
Purpose	To ensure the logic level converter circuit will allow the ATmega328 and Raspberry Pi to communicate
Test Materials	1. PCB 2. AC to DC converter cable 3. Raspberry Pi 4. Micro USB to Mirco USB cable 5. Jumper wires 6. Innova Digital Multimeter
Prerequisites	1. Power supply provides a 5V and 3.3V rail
Procedure	1. Power up PCB 2. Connect Micro USB cable to Raspberry Pi to power on 3. Connect jumper wires to the TX and RX pins of the PCB and Raspberry Pi. 4. Measure the reference voltages of the logic level converter circuit 5. Run program that has the two devices communicating
Expected Results	The reference voltages is 5V on the ATmega328 side and 3V on the Raspberry Pi side. The devices can be able to communicate with each other

9.2.4 LED Strips

Test Name	LED Strip Test
Purpose	To ensure LEDs can turn all the way off and on via PWM
Test Materials	1. PCB 2. AC to DC converter cable 3. LED Strips 4. LED Strips connector cable
Prerequisites	1. Power supply provides a 12V rail 2. ATmega328 is functioning
Procedure	1. Power up PCB 2. Connect LED strips to proper connector on PCB 3. Run PWM program on ATmega328
Expected Results	The LED strips should slowly get brighter till all the way on, the slowly dim till all the way off

9.2.5 Gesture Sensor

Test Name	Gesture Sensor Test
Purpose	To ensure gesture sensor can function with PCB board
Test Materials	1. PCB 2. AC to DC converter cable 3. LED Strips and connector 4. Gesture Sensor and connector
Prerequisites	1. Power supply provides a 5V rail 2. ATmega328 is functioning 3. LED Strips are functioning
Procedure	1. Power up PCB 2. Connect LED strips and gesture sensor to respective connectors on PCB 3. Run program where LEDs turn on when sensor detects someone in front of it 4. Run program that turns LEDs off and on with left and right swipe
Expected Results	The LEDs should come on when someone is in front of sensor. LEDs should turn off with left swipe, on with right swipe.

9.2.6 Photocell

Test Name	Photocell Circuit Test
Purpose	To ensure the photocell circuit functions with the PCB
Test Materials	1. PCB 2. AC to DC converter cable 3. LED Strips and connector 4. Photocell circuit and connector
Prerequisites	1. Power supply provides a 12V rail 2. ATmega328 is functioning 3. LED Strips are functioning
Procedure	1. Power up PCB 2. Connect LED strips and photocell circuit to respective connectors on PCB 3. Run program where LEDs will come on when it is dark, and off when it is light. 4. Turn room lights on and off
Expected Results	When room lights are off, LEDs should be on. When room lights are on, LEDs should be off.

9.2.7 Display Visibility

Test Name	Display Visibility Test
Purpose	To ensure the display screen is visible while illuminated behind the mirror.
Test Materials	1. PCB 2. AC to DC converter cable 3. Raspberry Pi 4. Micro USB to Mirco USB cable 5. Raspberry Pi 7” touchscreen display 6. LED strips
Prerequisites	1. Power supply can power Raspberry Pi 2. LED strips are functioning
Procedure	1. Power up PCB 2. Connect Micro USB cable to Raspberry Pi to power on 3. Connect LEDs to PCB board and display to Raspberry Pi 4. Run program on Raspberry Pi to show on display white text with a black background 5. Place display against backside of mirror 6. Observe display visibility from other side of mirror

	7. Place lit LEDs on sides of mirror and observe display visibility
Expected Results	The display screen should be visible through the two-way mirror, even with the LEDs turned on.

9.2.8 Hardware Full Integration Test

Test Name	Hardware Full Integration Test
Purpose	To ensure all hardware components of the project will function together
Test Materials	1. PCB 2. AC to DC converter cable 3. Raspberry Pi 4. Micro USB to Mirco USB cable 5. Jumper wires 6. LED strips 7. Gesture Sensor 8. Photocell circuit 9. Raspberry Pi 7” display 10. Raspberry Pi camera
Prerequisites	1. All components pass all previous tests
Procedure	1. Power up PCB 2. Connect Micro USB cable to Raspberry Pi to power on 3. Connect LEDs, gesture sensor, photocell circuit, and TX/RX connections from Raspberry Pi to the PCB board. 4. Connect 7” display, camera module, and TX/RX connections from PCB to Raspberry Pi 5. Run a program which does the following: • Turn on LEDs when someone approaches sensor in low light, turns on display screen, and takes picture. • Turn on display screen when someone approaches sensor in good light but not LEDs, and takes picture. • Turns off all modules when no one is in front of sensor

Expected Results	The prototype should function as the program suggests. When no one is in front of mirror, modules are off. If someone is in front of sensor in low lightings all modules including LEDs are on. If Someone is in front of sensor in good lighting, all modules except LEDs are on.

9.3 Software Test Environment

Software specific tests will be conducted on the completed system in parallel with the hardware tests to verify that the architecture is stable and permitted to interact with the hardware. If possible, software tests may be initially completed on a full computer system before transferring to the native environment in which they were designed to run on. The test environment will vary between predetermined locations with different network connectivity.

9.4 Software Specific Testing

Software specific tests will be used to ensure that the architecture functions, responds, and delivers the expected output. By completing tests for each of the major software components, project specifications and objectives will have a defined set of tests and proofs for completion. Although each of following tests will be conducted in its entirety, additional tests may be required as the need arises. In such cases, test procedures and results will be appended to the documentation for review and added to the final testing plan.

9.4.1 Wi-Fi Test

Test Name	Wi-Fi Wireless Connection Test
Purpose	To ensure the Raspberry Pi can access the network
Test Materials	1. PCB 2. AC to DC converter cable 3. Raspberry Pi
Prerequisites	1. Power supply provides a 5V rail 2. Raspberry Pi SD Card is flashed and running an OS image
Procedure	1. Power up Raspberry Pi 2. Configure /etc/networks/ to reference wpa_supplicant.config file 3. Configure wpa_supplicant.config to include the SSID and PSK of the desired network 4. Use ifconfig and ipconfig to verify connection to the wireless router. From a PC, navigate to 192.168.1.1 and verify from the router's perspective the Pi has been connected 5. From a command prompt, *ping* a known website, such as google.com to verify that the Pi is able to wirelessly access the internet

Expected Results	The Raspberry Pi has been assigned an IP address and is connected to the wireless router. Multiple TCP/IP packet responses from the website are received.

9.4.2 Face Detection

Test Name	Face Detection
Purpose	Determine if a person's face is present in an image
Test Materials	1. PCB Power supply 2. Raspberry Pi 3. Camera Module
Prerequisites	1. Power supply provides a 5V rail 2. Raspberry Pi SD Card is flashed and running an OS image 3. Python program has been written to obtain a camera image and search for the presence of a face
Procedure	1. Power up Raspberry Pi 2. Obtain an image from the camera module using *raspistill –o testImage.jpg* 3. Begin the Python program and pass in the the image as a command line argument using *python faceDetection.py testImage.jpg*
Expected Results	The program will return two images – the original image with a green box outlining the detected face, and an image which has been cropped to the dimensions of the face.

9.4.3 Face Recognition

Test Name	Face Recognition
Purpose	Determine if a person's face is authorized
Test Materials	1. PCB Power supply 2. Raspberry Pi 3. Camera Module
Prerequisites	1. Power supply provides a 5V rail 2. Raspberry Pi SD Card is flashed and running an OS image 3. Face detection has been implemented correctly 4. A populated database of authorized face images and non-face images
Procedure	1. Power up Raspberry Pi 2. Obtain an image from the camera module using *raspistill –o testImage.jpg*

	3. Begin the Python program and pass in the the image as a command line argument using *python faceDetection.py testImage.jpg* 4. Pass the face cropped image to the Face Recognition Module 5. Run the program to compare the input image to the database of users using one of the discussed algorithms
Expected Results	The program will return the name of the person who has been authorized, or will return a non-authorized string.

9.4.4 Framework Related Tests

The following tests verify the functionality of the smart mirror display framework. These tests are related to the requests made to the outside network as well as verification that the display updates with the required modules.

9.4.4.1 Clock Module Shown as Analog on Display

Test Name	Clock Module Shown as Analog on Display
Purpose	To test whether the End-User is able to configure the time in a manner they choose.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "Clock" module section.
	5. Create a section similar to:
	a. Config:
	{
	dataType: analog
	analogSize: 200px
	analogFace: simple
	secondsColor: #888888
	analogPlacement: bottom
	}
	6. Go to the Chromium Browser.
	7. dataType is configurable to use an analog or digital clock format, simply use the keywords **analog** or **digital.**

	8. analogSize defaults to 200px and allows the user to configure what size of an analog interface is viewable on the display. 9. analogFace has a default configuration of **simple**, but it has other options by using keywords **none** or **face-##** (01-12). 10. secondsColor defaults to #888888 but is configurable any HTML RGB color. 11. analogPlacement defaults to bottom, but is configurable to **top**, **right**, **bottom**, or **left.** 12. analogShowDate defaults to top, but is configurable using keywords **false**, **top**, or **bottom** 13. View the change made to webpage http://localhost:8080/
Expected Results	The Clock module should be viewed as an analog clock on webpage http://localhost:8080/

9.4.4.2 The Time is Viewable in Digital Format

Test Name	Clock Module Shown as Digital Format on Display
Purpose	To test whether the End-User is able to configure the time in a manner they choose.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "Clock" module section.
	5. Create a section similar to:
	a. Config:
	{
	dataType: ditigal
	timeFormat: *config.timeFormat*
	showPeriod: true
	showPeriodUpper: false
	clockBold: false
	}
	6. timeFormat has the possible values of 12 or 24. This allows the user to have military time or am/pm time.

	7. showPeriod defaults to true and allows the user to configure it using the keywords **true** or **false.** 8. showPeriodUpper defaults to false and allows the user to configure whether they want am/pm to be in capitalized letters by using keywords **true** and **false.** 9. clockBold defaults to true and allows the user to bold the minutes of the digital clock, and it is configurable using **true** or **false**. 10. Go to the Chromium Browser. 11. View the change made to webpage http://localhost:8080/
Expected Results	The Clock module should be viewed as an analog clock on webpage http://localhost:8080/

9.4.4.3 The Current Weather Module Viewable on Display

Test Name	Current Weather module viewable on Display
Purpose	To test whether the End-User is able to configure the Current Weather to be viewable on the display.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the “currentweather” module section.
	5. Create a section similar to:
	a. Config:
	{
	location: ‘’
	locationID:’’
	appid:’’
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The Current Weather for End-user’s area should be viewed as an analog clock on webpage http://localhost:8080/

9.4.4.4 Current Weather not viewable on Display

Test Name	Current Weather not viewable on Display
Purpose	To test whether the End-User is able to disable the Current Weather module.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "currentweather" module section.
	5. Comment out the section:
	a. Config:
	{
	location: ''
	locationID:''
	appid:''
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The Current Weather module should not be viewed on webpage http://localhost:8080/

9.4.4.5 Weather Forecast module shows on Display

Test Name	Weather Forecast module shows on Display
Purpose	To test whether the End-User is able to configure the Weather Forecast module.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "weatherforecast" module section.
	5. Create a section similar to:
	a. Config:
	{
	location: ''
	locationID: ''
	appid: ''
	maxNumberOfDays:
	updateInterval:
	}
	6. Default for maxNumberOfDays is 7.
	7. Default update Interval is 10 minutes.
	8. Go to the Chromium Browser.
	9. View the change made to webpage http://localhost:8080/
	b. There should be a default of 7 days' data
	c. It should update every 10 minutes.

Expected Results	The Weather Forecast module should be viewable on webpage http://localhost:8080/

9.4.4.6 Current Weather Module Not Shown on Display

Test Name	Current Weather Module Not Shown on Display
Purpose	To test whether the End-User is able to disable the Current Weather Module.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/
Procedure	1. Go to the directory MagicMirror/config/ 2. Open config.js in Notepad. 3. View the default configuration of the config.js file. 4. Go to the "weatherforecast" module section. 5. Comment out the section: d. Config: { location: '' locationID: ''

	appid: ‘’ maxNumberOfDays: updateInterval: } 6. Go to the Chromium Browser. 7. View the change made to webpage http://localhost:8080/
Expected Results	The weather forecast module should not be viewable on webpage http://localhost:8080/

9.4.4.7 Newsfeed Module Shows on Display

Test Name	Newsfeed Module Shows on Display
Purpose	To test whether the End-User is able to enable the newsfeed module to their particular newsfeed.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the “newsfeed” module section.
	5. Create a section similar to:
	e. Config:
	{
	feeds: [
	{ //this is feed #1
	title:
	url:
	showSourceTitle:
	showPublishDate:
	showDescription:
	reloadInterval:
	updateInterval:
	maxNewsItems:
	},
	{//this is feed #2
	title:
	url:
	showSourceTitle:

	showPublishDate: showDescription: reloadInterval: updateInterval: maxNewsItems: } } 6. Title is the name of the newsfeed. 7. URL is the site that you wish to scrape news from. 8. maxNewsItems is the number of items viewable at any given time, and the default is 0. For the purposes of functionality, change this to 5. 9. showSourceTitle, showPublishDate, showDescription are Boolean values. 10. reloadInterval will fetch headlines from the URL and has a default value of 5 minutes. updateInterval will update the newsfeed on the display with the next headline every 10 seconds. 11. Go to the Chromium Browser. 12. View the change made to webpage http://localhost:8080/ f. The user should be able to view the feeds stored in this file g. The End-User may be able to have a single feed; or multiple feeds. h. Using default values, there should be 5 headlines to cycle through. i. Using default values, the headlines should be fetched every 5 minutes. j. Using default values, the headline on display should be changed every 10 seconds.
Expected Results	The Newsfeed module should be viewed on webpage http://localhost:8080/

9.4.4.8 Newsfeed module Not Shown on Display

Test Name	Newsfeed Module Not Shown on Display
Purpose	To test whether the End-User is able to disable the newsfeed module.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi)

	3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "newsfeed" module section.
	5. Comment out the section:
	k. Config:
	{
	feeds: [
	{ //this is feed #1
	title:
	url:
	showSourceTitle:
	showPublishDate:
	showDescription:
	reloadInterval:
	updateInterval:
	maxNewsItems:
	}
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The newsfeed module changes should be viewable on webpage http://localhost:8080/

9.4.4.9 Date shows on Display

Test Name	Date shows on Display
Purpose	To test whether the End-User is able to configure the date to be visible on the display.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/
Procedure	1. Go to the directory MagicMirror/config/ 2. Open config.js in Notepad. 3. View the default configuration of the config.js file. 4. Go to the "Clock" module section.

	5. Create a section similar to:
	l. Config:
	{
	dataType: analog
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The date changes should be viewable on webpage http://localhost: 8080/

9.4.4.10 Date Does Not Show on the Display

Test Name	Date does not show on Display
Purpose	To test whether the End-User is able to configure the time in a manner they choose.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "Clock" module section.
	5. Create a section similar to:
	m. Config:
	{
	showDate:true
	analogShowDate: top
	}
	6. analogShowDate defaults to **top** but can be configured to be **false**, **top**, or **bottom** and is used to display analog time and the date.
	7. Go to the Chromium Browser.
	8. View the change made to webpage http://localhost:8080/

Expected Results	The date changes should be viewable on webpage http://localhost: 8080/

9.4.4.11 Roles and permissions module allows for an authorized user.

Test Name	Roles and permission module allows for an authorized user.
Purpose	To test whether the End-User is able to enable the authorized user module.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "rolesandpermissions" module section.
	5. Create a section similar to:
	n. Config:
	{
	authUser:true
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The Smart Mirror shows an authorized user their configuration (else, it shows the default configuration)

9.4.4.12 Roles and Permissions module allows for unauthorized users.

Test Name	Roles and Permissions module allows for unauthorized users.
Purpose	To test whether the End-User is able to allow for unauthorized users.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "Clock" module section.
	5. Create a section similar to:
	o. Config:
	{
	unauthUser:true
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	The Smart Mirror shows the main user's configuration (with no validation done through roles or permissions)

9.4.4.13 Facial Recognition module enabled

Test Name	Facial Recognition Module enabled
Purpose	To test whether the End-User is able to allow authenticate authorized users.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the "facialrecognition" module section.
	5. Create a section similar to:
	p. Config:
	{
	facialRecog:true
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	Facial recognition module should begin when a user is detected

9.4.4.14 Facial Recognition module disabled

Test Name	Roles and Permissions module allows for unauthorized users.
Purpose	To test whether the End-User is able to allow for unauthorized users.
Test Materials	1. Raspberry Pi 2. Smart Mirror Display 3. Smart Mirror Power Supply
Prerequisites	1. Plug in the smart mirror. 2. Log into Raspbian (the Operating System being used on Raspberry Pi) 3. Open up Chromium (the default browser for Raspbian) 4. Go to http://localhost:8080/

Procedure	1. Go to the directory MagicMirror/config/
	2. Open config.js in Notepad.
	3. View the default configuration of the config.js file.
	4. Go to the “facialrecognition” module section.
	5. Create a section similar to:
	q. Config:
	{
	facialRecog: false
	}
	6. Go to the Chromium Browser.
	7. View the change made to webpage http://localhost:8080/

Expected Results	Facial recognition module should end when a user is no longer detected

10 Administrative Topics

The following sections will describe various administrative aspects of the project. This includes a description of the team members and their respective roles and responsibilities. A section for project milestones, decided at the beginning of the semester, and a section for the team's budget and purchases can be found here as well.

10.1 Team Description and Delegations

The Smart Mirror team consists of two electrical engineering and two computer engineering students. By incorporating two different areas of engineering, the coursework taught by each major can be combined to contribute towards the goals of the project. This is commonly seen within the workplace, obtaining various employees of different backgrounds to complement the team, to form a well-rounded set of field expertise.

Katlin Joachim, a computer engineering student, has previous experience in software construction and implementation. Through two years of in-field experience she has gathered knowledge of building use-case scenarios, Class diagrams, extensive test plans and functional programming. Her background in software development will support the software architecture on the Raspberry Pi and, through her knowledge of programming languages; she will create the authentication functionality to support multiple users.

Austin Keller, an electrical engineer, has experience in circuitry design as well as component research and selection. Through an internship at VoxxHirchmann, he has learned many skills beneficial to this project. These skills include reviewing schematics for errors, finding components to fulfill requirements, and creating test plans and environments. These skills will be beneficial during the part selection process of the project, as well as determining the best tests for all components. The experience in working with schematics will help to design the schematic for the PCB as well as reviewing it for any discrepancies.

Reid Neureuther, a computer engineering student, has obtained previous experience prior to senior design with robotic systems and the integration of both microcontrollers and microcomputers. Through the extracurricular experiences available at the University of Central Florida, he has taken opportunities to lead multi-disciplined teams through the various workflows required to design robotic system controllers and telemetry devices with embedded Linux. His background in embedded technology will help support the project's initial design and follow through with logic hardware support. Reid's professional experience includes three internships at two corporations. He spent two years working with Siemens Energy in Orlando, FL, starting in an IT position working with Product Lifecycle Management. After one year, he transferred to the Siemens Wind sector to design and create a database system to manage the wind farm project statistics. His current employment at General Dynamics has allowed him to experience the software development processes outside of an academic environment and become familiar with integration and testing procedures.

Daniel Yoder, an electrical engineering has spent the last four years studying at the University of Central Florida. Pursuing a degree in engineering is something he has been passionate about since he was a young child. He has reached and surpassed many of the

goals set forth by himself, including obtaining a variety of internships and co-ops during his time in college. In his first work experience, heavy amounts of team-building and leadership skills were obtained and sharpened. Later work experiences led to more hand-on experiences as he progressed through the more upper level engineering courses at UCF. These courses along with their accompanying lab sections taught him an abundance of information on the way electronic devices and how microcontrollers work. His profound experience with electronics and team-building will assist the team in the development of the project, and more specifically, many of the hardware aspects of the design.

Delegating each team member to a specific set of tasks will ensure that the responsibilities expected from each person are well defined and traceable.

Table 22 - Each team member is delegated a specific set of responsibilities within the project

Computer Engineering	Electrical Engineering
Katlin Joachim: • Microcomputer Operational Software • Network Data Feed • Physical Mirror Design	Austin Keller: • Power System Design • Power Distribution Design • PCB Design
Reid Neureuther: • Facial Recognition • Microcontroller Operational Software • Hardware Sensor Input Processing	Daniel Yoder: • PCB Design • Packaging Selection • Display and LED Lighting

10.2 Milestones

Due to time constraints presented by semester dates, this project needed to be broken down into sets of milestones; they are, as follows:

Table 23 - Milestones

No.	Task	Status
Senior Design I		
1.	Research chipsets • Research and compare different chipsets for the PCB layout design	Completed
2.	Purchase mirror materials and build frame • Purchase Two-Way mirror	Completed

	• Purchase wood, screw, and nails. • Build frame and dry fit mirror. • Install hardware for mirror and display modules.	
3.	Research and purchase microcontroller • Establish key requirements • Research microcontrollers • Compare and contrast microcontrollers • Determine which microcontroller meets specifications • Purchase microcontroller for project	Completed
4.	Research and purchase lighting • Establish key requirements • Research LEDs • Compare and contrast LEDs • Determine which LEDs meets specifications • Purchase LED module	Completed
5.	Research and purchase display • Establish key requirements • Research displays • Compare and contrast displays • Determine which displays meets specifications • Purchase the display module	Completed
6.	Research and purchase Wi-Fi module. • Establish key requirements • Research Wi-Fi Module • Compare and contrast Wi-Fi Module • Determine which Wi-Fi Module meets specifications • Purchase Wi-Fi Module	Completed
7.	AC/DC Converter • Establish key requirements • Research AC/DC converter components • Compare and contrast components • Determine an AC/DC converter design that meets specifications • Create AC/DC Converter design	Completed
8.	Research and Design PCB Layout • Establish key requirements • Research PCB Layout components • Compare and contrast PCB Layout Components	Completed

	• Determine which PCB Layout components and PCB Layout production company meets specifications • Design PCB Layout and prepare to send design to manufacturer	
9.	Research and Design Facial Recognition module • Establish key requirements • Research Facial Recognition modules • Compare and contrast Facial Recognition techniques • Determine which technique meets specifications • Design and implement Facial Recognition module	Completed
10.	Research and Design News/Media Feed module • Establish key requirements • Research news feed/media feed scraping/api techniques • Compare and contrast scraping/api techniques • Determine which implementation meets specifications	Completed
11.	Research and design Wake on User Detection • Establish key requirements • Research Proximity Sensors • Compare and contrast Proximity Sensors • Determine which Proximity Sensor meets specifications • Purchase and implement Proximity Sensor	Completed
Senior Design II		
1.	Build Prototype	Future
2.	Testing and Redesign	Future
3.	Finalize Prototype	Future
4.	Peer Presentation	Future
5.	Final Report	Future
6.	Final Presentation	Future

10.3 Budget

As mentioned in one of the beginning sections of this report, this project was fully funded by the students that designed, and prototyped all aspects of this project. At this point, no sponsors have been a part of the Smart Mirror project. With that being said, budgeting was an important part of the project throughout the first semester considering college is enough of a financial burden on a student. During the first semester of design, components listed in section 8.1 were ordered and tested for functionality. Namely, all power distribution components, sensor components, and microcomputer and microcontroller chips with supporting hardware are all in possession of the team's inventory. Some of these

components purchased will not be used for the final product and were purchased solely for the purpose of prototyping. This was an aspect that was slightly looked over in the initial planning stages of the project. However, once the budget was finalized there was no turning back. As a team, a great deal of effort was put forth to use any components at hand from previous labs and classes taken at the university. Any penny saved was worth it since many of these cheaper components can add up if certain ones are burned up or are the incorrect one. Special care was taken when handling and prototyping many of the components due to their static electric fragility.

The University of Central Florida provided its students with all power supplies, function generators, oscilloscopes, and multimeters. These are all state-of-the-art equipment available to the student at no extra cost. The availability of these tools saves thousands of dollars for these projects which is a nice plus when it comes to prototyping and building.

Many of the parts purchased for this project were relatively affordable. Nevertheless, there were cases, especially towards the end of the semester, when components were damaged while testing and would need to order a spare because the original spares were all used or damaged as well. This would, in turn, cause the team to have to pay a little more for shipping than originally intended to get the component delivered in a timely manner. For this reason, an additional item was added to the budget, called the Project Management Cost.

The Project Management Cost was added on to the budget in an effort to add some wiggle room for cases like the ones described above. Twenty percent of the total cost (before the Project Management Cost) was taken and declared as the Project Management Cost. This was agreed all team members as a fair amount to allocate to this item on the budget.

So, the following table provides a summary of the original budget as well as what has been purchased thus far. The remainder of the budget will be utilized during the second semester of Senior Design. The maximum limits of the budget will most likely not be touched since one of the last big costs of the project is the custom PCB. Some of the components purchased for initial prototyping will be used in the final and complete working prototype such as the display, two-way mirror, frame, and some power supply components.

BUDGET for Senior Design		MATERIALS		FIXED COST	BUDGET	ACTUAL	UNDER/OVER
PART DESCRIPTION	VENDOR	UNITS	$/UNIT				
Two-way Mirror		1	$ 150.00		$ 150.00	$ 68.43	$ (81.57)
PCB		1	$ 150.00		$ 150.00		$ (150.00)
Microcomputer		1	$ 50.00		$ 50.00	$ 35.70	$ (14.30)
LEDs		2	$ 30.00		$ 60.00	$ 28.50	$ (31.50)
Camera Module		1	$ 50.00		$ 50.00	$ 25.74	$ (24.26)
Display		1	$ 40.00		$ 40.00	$ 68.99	$ 28.99
Framing/Enclosure		1	$ 40.00		$ 40.00	$ 47.18	$ 7.18
Project Management Cost - 20%				$ 108.00	$ 108.00	$ 97.40	$ (10.60)
					$ -		$ -
					$ -		$ -
					$ -		$ -
					$ -		$ -
TOTAL					$ 648.00	$ 371.94	

Figure 58 - Budget

At the current stage of design, all components have been ordered, save the PCB and supporting hardware such as the connectors for the peripherals. All other components which were purchased for testing in the first stage of development will be utilized in the final design and assembly in the following semester. Compared to the initial estimate of roughly $600 for the total cost of the mirror, the current sum of $272 allots for an additional $338 of expenditures for PCB manufacturing and unforeseen expenses during the second stage of project assembly in the spring.

11 Project Summary and Conclusion

Over the course of the current Fall semester, the team has successfully designed a complete Smart Mirror system prepared for implementation in the Spring semester of 2017. By predefining the project specifications and objectives, the design phase of the Smart Mirror has continued to move forwards through component comparison and selection. As each subsystem design was completed, prototype testing ensured that the various selections were adequate for implementation. Along the way, the team ensured that each milestone was moving towards completion in a timely manner such that the full design would meet the required deadline. During the following semester, the software will be fully developed to support the requirements and PCB manufacturing will ensure the hardware reaches a state comparable to a finished product. Each of the multiple subsystems defined within the Smart Mirror will exist as a complete, finished, system.

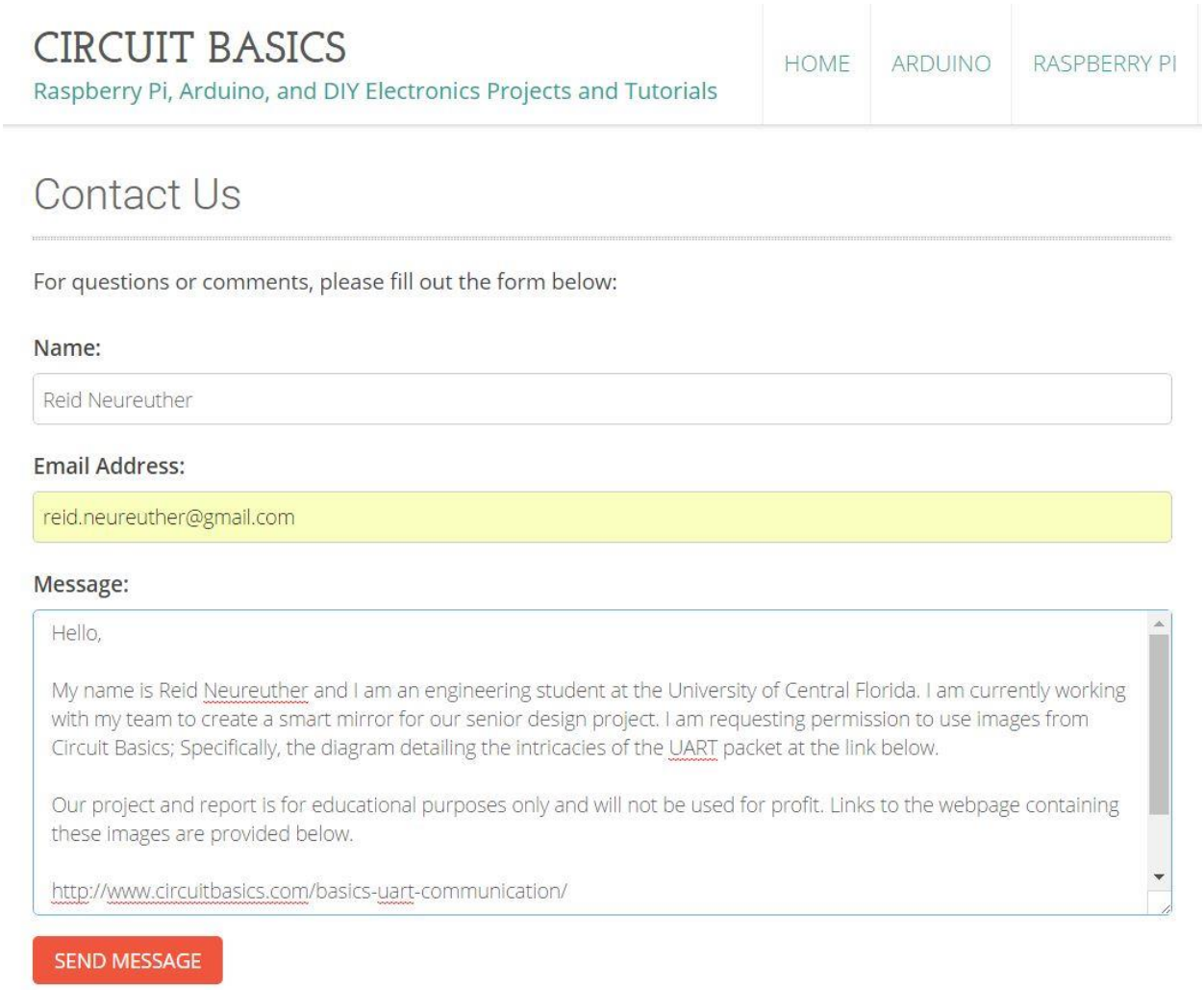
This project idea has given the team an opportunity to learn about a mix of hardware engineering, electrical engineering and software engineering. Thus far, it has allowed all team members to exercise their existing knowledge of their respective fields and expand on those areas. The electrical engineers have grown in their understanding of PCB layouts, circuit diagram concepts and electronics. The computer engineers have had the chance to exercise their understanding of embedded programming and software programming. This project will inevitably provide a great illustration of the team's technical skills and abilities.

Overall, the lessons learned during the semester will transfer to both the following build semester as well as post-graduation full-time engineering positions. Each of the team members has been provided an opportunity to practice real-world engineering skills. Between technical management, budget allocation and tracking, feature trade-off decisions, and meeting required deadlines, the Senior Design course has acted as a valuable transitional stage between the academic and professional environment.

12 Appendices

12.1 Appendix A – Copyright Permissions

The following email chains provide the team with the permission to use some of the figures obtained in this report. However, many of the figures and tables used throughout this report were created by the students on this team for the Smart Mirror project.



CIRCUIT BASICS

Raspberry Pi, Arduino, and DIY Electronics Projects and Tutorials

HOME ARDUINO RASPBERRY PI

Contact Us

For questions or comments, please fill out the form below:

Name:

Reid Neureuther

Email Address:

reid.neureuther@gmail.com

Message:

Hello,

My name is Reid Neureuther and I am an engineering student at the University of Central Florida. I am currently working with my team to create a smart mirror for our senior design project. I am requesting permission to use images from Circuit Basics; Specifically, the diagram detailing the intricacies of the UART packet at the link below.

Our project and report is for educational purposes only and will not be used for profit. Links to the webpage containing these images are provided below.

http://www.circuitbasics.com/basics-uart-communication/

SEND MESSAGE

Austin Keller <austink95@gmail.com> 8:31 PM (21 hours ago)

to direct

Hello,
My name is Austin Keller and I am an engineering student at the University of Central Florida. I am currently working with my team to create a smart mirror for our senior design project. I am requesting permission to use images and information from Application Note AN97055. This includes the image "Figure 2. Bi-directional level shifter circuit connects two different voltage sections of an I C-bus system". Our project and report is for educational purposes only and will not be used for profit. Links to the webpages containing these images are provided below

https://cdn-shop.adafruit.com/datasheets/an97055.pdf

Thank You,
Austin Keller

Sparkfun:

Photos: Please feel free to use our product photos in your project documentation or reports. If you would like to use a photo for a commercial venture, please contact us first at partnerships@sparkfun.com. You can also find SparkFun photos on our Flickr page.

TI:

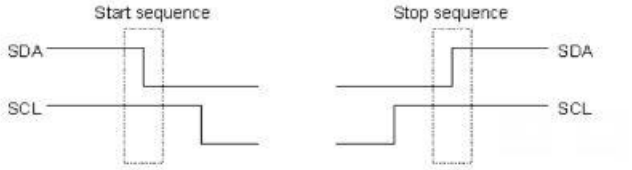
TI grants permission to download, print copies, store downloaded files on a computer and reference this information in your documents only for your personal and non-commercial use. But remember, TI retains its copyright in all of this information. This means that you may not further display, reproduce, or distribute this information without permission from Texas Instruments. This also means you may not, without our permission, "mirror" this information on your own server, or modify or re-use this information on another system.

Hello,

My name is Reid Neureuther and I am an engineering student at the University of Central Florida. I am currently working with my team to create a smart mirror for our senior design project. I am requesting permission to use images from Robot-Electronics; Specifically, the start sequence and stop sequence diagrams under the I2C Physical Protocol heading:

The I2C Physical Protocol

When the master (your controller) wishes to talk to a slave (our CMPS03 for example) it begins by issu
stop sequence are special in that these are the only places where the SDA (data line) is allowed to ch
beginning and end of a transaction with the slave device.



Our project and report is for educational purposes only and will not be used for profit. Links to the webpage containing these images are provided below.

http://www.robot-electronics.co.uk/i2c-tutorial

Best Regards,
Reid Neureuther
Computer Engineering | University of Central Florida
reid.neureuther@gmail.com
(931) 249-3557

Sales 4:20 AM (13 hours ago)

to me

Hello Reid,

Our project and report is for educational purposes only and will not be used for profit.
Yes, the images may be used as above.

Best Regards,
Gerry.
sales@robot-electronics.co.uk

12.2 Appendix C – List of Tables

12.3 Appendix D – List of Figures

12.4 Appendix E – Sources Cited

@adafruit. "Adafruit DotStar Digital LED Strip - White 60 LED - Per Meter." Adafruit Industries Blog RSS. N.p., n.d. Web. 01 Dec. 2016.

@adafruit. "Cool White LED Weatherproof Flexi-Strip 60 LED - (1 M)." Adafruit Industries Blog RSS. N.p., n.d. Web. 01 Dec. 2016.

@adafruit. "Pi Foundation Display - 7" Touchscreen Display for Raspberry Pi." Adafruit Industries Blog RSS. N.p., n.d. Web. 01 Dec. 2016.

“5050 SMD LED.” 5050 SMD LED (n.d.): 1-11. Wayjun. Web.

Barr, Michael. "Introduction to Pulse Width Modulation." Embedded. N.p., 21 Aug. 2001. Web. 01 Dec. 2016.

“Basics of UART Communication.” Circuit Basics. N.p., 13 Feb. 2016. Web. 01 Dec. 2016.

“Driving LEDs - Choosing Between Analog and Digital Topologies.” Driving LEDs Choosing Between Analog Toplogies | DigiKey. N.p., n.d. Web. 01 Dec. 2016.

Durr, O., and Y. Pauchard. "Deep Learning on a Raspberry Pi for Real Time Face Recognition." ResearchGate. Zurich University of Applied Sciences, n.d. Web.

Geitgey, Adam. "Machine Learning Is Fun! Part 4: Modern Face Recognition with Deep Learning." Medium. N.p., 27 Sept. 2016. Web. 01 Dec. 2016.

"Google HTML/CSS Style Guide." Google HTML/CSS Style Guide. Google Docs, n.d. Web. 1 Dec. 2016. <https://google.github.io/styleguide/htmlcssguide.xml#Protocol>.

"Google JavaScript Style Guide." Google JavaScript Style Guide. Google Docs, n.d. Web. 01 Dec. 2016. <https://google.github.io/styleguide/jsguide.html>

"Google Python Style Guide." Google Python Style Guide. Google Docs, n.d. Web. 01 Dec. 2016. <https://google.github.io/styleguide/pyguide.html>

Guo, Guodong, and Hong-Jiang Zhang. "Boosting for Fast Face Recognition."

Hanzra, Bikramjot. "Face Recognition Using Python and OpenCV." Face Recognition Using Python and OpenCV. Hanzra Tech, 3 Feb. 2015. Web. 01 Dec. 2016.

Http://pctechmag.com/author/ebatambuze/. "LCD Vs LED, Which One Is Better?" PC Tech Magazine. N.p., 2014. Web. 01 Dec. 2016.

International Rectifier. IRLB8721PbF (n.d.): n. pag. Web.

Jansen, A.; Bosch, J. (2005). "Software Architecture as a Set of Architectural Design Decisions". 5th Working IEEE/IFIP Conference on Software Architecture (WICSA'05)

Jim. "RS-232 vs. TTL Serial Communication - SparkFun Electronics." RS-232 vs. TTL Serial Communication - SparkFun Electronics. Sparkfun, 23 Nov. 2010. Web. 01 Dec. 2016.

Keeping, Steven. "Understanding the Advantages and Disadvantages of Linear Regulators." Understanding Advantages Linear Regulators. Electronic Products, 05 Aug. 2012. Web. 30 Sept. 2016.

Krishna, Gpoi, and A. Srinivasulu. "Face Detection System on Adaboost Algorithm Using Haar Classifiers." International Journal of Modern Engineering Research (IJMER) 2.5 (n.d.): 3556-560. Ijmer. Web.

Kun, Jeremy. "Eigenfaces, for Facial Recognition." Math Programming. N.p., 16 Aug. 2013. Web. 01 Dec. 2016.

“Logic Signal Voltage Levels.” Logic Gates - Electronics Textbook. All About Circuits, n.d. Web. 01 Dec. 2016.

McComb, Gordon. "Using Passive Infrared Detection." Using Passive Infrared Detection. Robotics Universe, n.d. Web. 01 Dec. 2016.

Microchip, “Low Quiescent Current LDO,” MCP1700 datasheet, 2005 [Revised Jun. 2016].

“Microcontroller Clock—Crystal, Resonator, RC Oscillator, or Silicon Oscillator?” Microcontroller Clock—Crystal, Resonator, RC Oscillator, or Silicon Oscillator? - Application Note - Maxim. N.p., n.d. Web. 01 Dec. 2016.

“Millicandela to Lumens Calculator.” Millicandela (mcd) to Lumens (lm) Conversion Calculator. N.p., n.d. Web. 01 Dec. 2016.

NSL-5532. THIS ONE Luna Optoelectronics | Sensors, Transducers | DigiKey. N.p., n.d. Web. 01 Dec. 2016.

Olson, Tim. "What's The Difference Between Regulated & Unregulated Power Supplies?" What's *The Difference Between Regulated & Unregulated Power Supplies?* APG, 09 Apr. 2015. Web. 11 Sept. 2016.

“Orlando Computer Recycling, Disposal, and Data Destruction by TBF Computing, INC.” Orlando Computer Recycling, Disposal, and Data Destruction by TBF Computing, INC.N.p., n.d. Web. 01 Dec. 2016.

“PDV-P8001.” Luna Optoelectronics | Sensors, Transducers | DigiKey. N.p., n.d. Web. 01 Dec. 2016.

Perry, D. E.; Wolf, A. L. (1992). "Foundations for the study of software architecture" (PDF). ACM SIGSOFT Software Engineering Notes. 17 (4): 40. doi:10.1145/141874.141884

Philips Semiconductors, Appl. Note 97055

“RC Oscillator Circuit - The RC Oscillator Tutorial.” Basic Electronics Tutorials. N.p., 19 Apr. 2016. Web. 01 Dec. 2016.

RuralGuru, Member #537977, Member #386229, Member #340822, GraysonR, and Fezder. "Mini Photocell." SEN-09088 - SparkFun Electronics. N.p., n.d. Web. 01 Dec. 2016.

Skill Level: Beginner, and Nate | June 19, 2008 | 38 Comments. "Beginning Embedded Electronics - 3 - SparkFun Electronics." Beginning Embedded Electronics - 3 - SparkFun Electronics. N.p., n.d. Web. 01 Dec. 2016.

Steve. "Standard Density (30 LEDs/M) LED Flex Strips." Standard Density LED Flex Strips. N.p., n.d. Web. 01 Dec. 2016.

“SuperSonic 13.3-Inch 1080p LED Widescreen HDTV HDMI AC/DC Compatible.” Amazon. Amazon, n.d. Web. 01 Dec. 2016.

Texas Instruments, “SIMPLE SWITCHER Power Converter 150-kHz 3-A Step-Down Voltage Regulator,” LM2596 datasheet, Nov. 1999 [Revised Sept. 2002].

Tony, DiCola. "Embedded Linux Board Comparison." Overview | Embedded Linux Board Comparison | Adafruit Learning System. Adafruit, n.d. Web. 01 Dec. 2016.

“Ultrasonic Sensing.” Sensors - Ultrasonic Sensing. Rockwell Automation, n.d. Web. 01 Dec. 2016.

“Using the I2C Bus.” Robot Electronics. N.p., n.d. Web. 01 Dec. 2016.

Viola, Paul, and Michael Jones. "Rapid Object Detection Using a Boosted Cascade of Simple Features." Accepted Conference on Computer Vision and Pattern Recognition (2001): n. pag. Web.

“ZX Distance and Gesture Sensor.” SparkFun Electronics. SparkFun Electronics, n.d. Web. 01 Dec. 2016.